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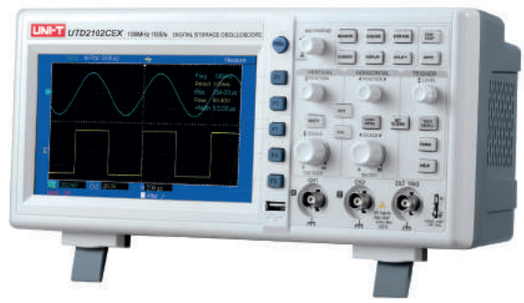

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Projects supervised by members of the Department of Metallurgy and Materials Engineering

FOREWORD

On behalf of the staff of the Faculty of Engineering, I welcome you to the 29th edition of the engineering undergraduate final year projects exhibition. This year 97 undergraduate projects will be on display within the various Faculty labs, allowing the general public, as well as our industrial partners, alumni and prospective students the opportunity to appreciate the work that our students have developed over the past year.

I invite you to read carefully through the introductory pages of this brochure, where you will find information on the courses that are offered by the Faculty, on the major facilities of the Faculty, on the ongoing externally funded and postgraduate projects, as well as on staff members of the Faculty. The brochure also contains one-page summaries of each of the undergraduate projects that are on display during the exhibition, explaining the project objectives, the approach and methods taken, and the results obtained. There is also useful information in the form of adverts from a good number of industrial sponsors of the exhibition, without whom this event would not be possible.

I take this opportunity to thank all the Faculty members for their contribution to the Faculty and specifically the members of the Faculty's Public Relations and Outreach committee for the organisation of this year's exhibition and the collation of the information for this booklet. I believe you will find it highly informative.

Andrew Sammut

Dean, Faculty of Engineering

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The University of Malta offers two engineering degrees, each with 4 years duration. The first two years of both degrees provide the basic scientific background required for advanced studies in the two degrees. In these two years, all subjects are compulsory. In the third and fourth year you will be able to choose subjects according to your interests. When you apply for the Engineering degree, you will be asked to choose ONE:

Bachelor of Engineering (Honours) in Electrical and Electronic Engineering

This degree covers the generation, distribution, application and control of electrical energy. Electrical and electronic engineers can apply their scientific knowledge in the fields of transport, space technology, biomedical technology, control, robotics and automation, communications and machine vision. Optional subjects include microcontrollers, advanced electronic and power circuit design, electrical and renewable energy, advanced drives, signal processing, image processing, control systems and artificial intelligence.

Bachelor of Engineering (Honours) in Mechanical Engineering

This degree covers the design, development and improvement of mechanical components and systems that make our world and lives function. Mechanical engineers can apply their scientific knowledge in the fields of bioengineering, robotics, the production of sustainable and clean energy, access to clean water, aerospace, nano-manufacturing and nano-materials. If you follow this degree, then you will be asked to choose one of three streams namely:

1. Applied Mechanics and Thermofluids Engineering
2. Applied Materials in Engineering
3. Industrial and Manufacturing Engineering

ENTRY REQUIREMENTS

Applicants must satisfy the General Entry Requirements for admission, namely, the Matriculation Certificate and Secondary Education Certificate passes at Grade 5 or better in Maltese, English Language and Mathematics.

Applicants must also satisfy the following Special Course Requirements:

- passes at Advanced Matriculation Level at Grade C or better in Pure Mathematics and in Physics.

Applicants in possession of passes in the Secondary Education Certificate Examination at Grade 5 or better in Maltese and English Language, and of either the MCAST-BTEC Higher National Diploma in an area deemed by the Board to be relevant to the Course, or the MCAST Diploma in Industrial Electronics, may also be admitted into the course.

If applicants are graduates of a university or have other qualifications considered to be sufficient, they may be exempted by the University Admissions Board, on the advice of the Faculty Admissions Committee, from the whole or part of these special course requirements.

The admission requirements are applicable for courses commencing in October 2018.

POSTGRADUATE COURSES

Master of Science in Building Services Engineering

This programme is aimed at consolidating engineering professionals in the area of building services. It focuses on the various systems that compliment building design and function. Areas of study cover basic conversion processes, fire safety engineering in buildings, characterisation of HVAC science and technologies, electrical services, low voltage systems, the novel internet of things paradigm, sustainability in building services practice and certification methods. Case studies encouraging an integrated approach towards building services projects will be sought during various instances of the programme.

ENTRY REQUIREMENTS

The degree of Bachelor of Engineering (Honours) from the University of Malta or from any other higher education institution recognized by Senate, obtained with at least Second Class (Honours). In exceptional cases the Admissions Board, on the recommendation of the Faculty Board, may admit into the Course applicants not in possession of the qualification listed above, provided that it is satisfied that such applicants are in possession of other relevant academic or professional qualifications and experience that together are deemed to be comparable to the level of a first cycle degree. The admission of such applicants may be made conditional on the results of an interview.

Master of Science in Maritime Engineering

The programme allows students to build on and integrate prior knowledge and understanding of their engineering discipline at an advanced level to solve a substantial range of practical engineering problems, through individual or group case studies or projects with a specific direction towards the maritime field of study and industry. The programme covers a wide range of engineering disciplines from ship fundamentals, resistance and propulsion and their systems, hydrodynamics, computational fluid dynamics, oceanography, materials for the marine environment, maritime structures, renewable energy generation and water treatment. Furthermore, essential topics covering economic, environmental, ethical, legal, managerial and social issues are also covered.

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a) the degree of Bachelor of Engineering (Honours) from the University of Malta, or from any other higher education institution recognized by Senate, obtained with at least Second Class (Honours); or

b) the degree of Bachelor of Science (Honours) from the University of Malta, or from any other higher education institution recognized by Senate and obtained with at least Second Class (Honours) in an area of study deemed relevant by the Faculty Board; or

c) any other Honours degree in a relevant area which the Faculty Board deems comparable to the qualifications indicated in (a) or (b).

In exceptional cases the Admissions Board, on the recommendation of the Faculty Board, may admit into the Course applicants not in possession of a qualification listed above, provided that it is satisfied that such applicants are in possession of other relevant academic or professional qualifications and experience that together are deemed to be comparable to the level of a first degree. The admission of such applicants may be made conditional on the results of an interview.

Master of Science in Electrical Engineering by Research

Some subject areas covered in this programme include: Electrical Drives; Electrical Machine Design; Electric Transportation; Control and Grid Integration of Renewable Energy Sources; Energy Storage; Building Services; Electrical Power Systems; Power Electronics; Smart Grids; Microgrids; Power Quality and EMC; Electrical Energy Efficiency; Signal, Image and Biomedical Signal Processing; Computer Vision; Distributed Computational Intelligence; Machine Learning; Automatic Control; Adaptive and Intelligent Control; Robot Control; Spatio-temporal System Modelling; Swarm Robotics; Human-machine Interface Design, Analysis and Evaluation; Aircraft Flight Trajectory; Prediction/Management; Autonomous Navigation Systems; Analogue/Digital Signal Processing; Air/Road Traffic Management; Intelligent Transportation Systems; Biomedical Electronics and Industrial Electronics and Precision Instrumentation.

ENTRY REQUIREMENTS

a) a Bachelor of Engineering (Honours) degree with at least Second Class (Honours); or

b)a Bachelor of Science (Honours) degree with at least Second Class (Honours) in appropriate subjects as approved by the Faculty Board; or

c) a Bachelor degree with a Third Class (Honours) in Engineering or in a relevant area of study together with other qualifications, including relevant experience following the first cycle degree; or

d) equivalent qualifications approved by Senate on the recommendation of the Faculty Board.

Admission of applicants under (c) and (d) shall be made conditional on the results of an interview and in such cases the Faculty Board may require applicants to successfully complete a preparatory programme.

Master of Science in Mechanical Engineering by Research

Some subject areas covered in this programme include: Applied Mechanics and Biomechanics; Robotics; Strength, Stability and Integrity of the Structures; Applied Multiphysics Modelling; Composite Structures; Mechanics of Welding; Environmental Engineering; Offshore Renewable Energy; Solar Energy, Aerodynamics and Wind Energy; Airconditioning Systems; Heat Transfer in Electrical Machines; Internal Combustion Engines; Naval Architecture; Laser Material Processing; Surface Engineering for corrosion and wear resistance; Nanomaterial Modelling; Biomaterials; Tribology; Tribo-corrosion; Functional Coatings; Diffusion Treatments; Austempered Ductile Iron (ADI); Product Design and Development; Design of Biomedical and Assistive Devices; Artificial Hand Design and Development; Rapid Prototyping; Tooling and Manufacturing (RPTM) using Fused Deposition Modelling (FDM) and Electron Beam Melting (EBM); Polymer Processing (Injection Moulding and Thermoforming); Lean and Agile Manufacturing; Micro and Nano Manufacturing; Sustainable Manufacturing; and Industrial Automation.

ENTRY REQUIREMENTS

a) a Bachelor of Engineering (Honours) degree with at least Second Class (Honours); or

b) a Bachelor of Science (Honours) degree with at least Second Class (Honours) in appropriate subjects as approved by the Faculty Board; or

c) a Bachelor degree with a Third Class (Honours) in Engineering or in a relevant area of study together with other qualifications, including relevant experience following the first cycle degree; or

d) equivalent qualifications approved by Senate on the recommendation of the Faculty Board.

Admission of applicants under (c) and (d) shall be made conditional on the results of an interview and in such cases the Faculty Board may require applicants to successfully complete a preparatory programme.

Master of Science in Integrated Product Development

The Course is built on two fundamental pillars of Product and Process Engineering, and Business. The programme blends these topics together and even allows the student an element of specialisation or focus in any one of these two pillars within the programme itself. This Course is intended to fortify skills and to maximise performance and success in the industry by integrating all the aspects of product development, including product function and design, product materials and manufacturing, product use and environmental impact, product marketing and costing, entrepreneurship and business management.

ENTRY REQUIREMENTS

a) the Bachelor of Engineering (Honours) degree with at least Second Class (Honours); or

b) the Bachelor of Science (Honours) degree with at least Second Class (Honours) in appropriate areas of study as approved by the Faculty Board; or

c) a qualification deemed by Senate, on the recommendation of the Faculty Board, to be equivalent to either of the above degrees.

Master of Science in Signals, Systems and Control

This Course delivers the necessary academic, practical and professional education to acquire high-tech competencies and advanced technological skills in the interlinked areas of signal processing, systems engineering and automatic control systems. Through this course, students will learn the basic theories, design methodologies and implementation techniques relevant to the areas of system modelling, signal processing, dynamics and systems, automatic control, computer vision, and machine learning. The acquired hightech skills would enable graduates to pursue professional careers in several sectors such as system automation, process control, biomedical engineering, transport and robotics to name but a few.

ENTRY REQUIREMENTS

a) the degree of Bachelor of Engineering (Honours) with at least Second Class (Honours); or

b) the degree of Bachelor of Science (Honours) with at least Second Class (Honours) in appropriate subjects as approved by the Faculty Board; or

c) the degree of Bachelor of Science in Information Technology (Honours) with at least Second Class (Honours); or

d) the degree of Bachelor of Science in Information and Communication Technology (Honours) with at least Second Class (Honours); or

e) any other Honours degree with a suitable mathematical and computer programming component which the Faculty Board deems comparable to the qualifications indicated in (a), (b), (c) or (d).

Master of Science in Biomedical Engineering

The M.Sc. in Biomedical Engineering provides students with multi-disciplinary scientific knowledge in engineering, biomedical and clinical fields required for the complete understanding, analysis and advancement of Biomedical Engineering with particular emphasis to health care. The heterogeneous cohort of students - engineers, medics, scientist and health care graduate, will be provided with all necessary skills, to augment and advance their capacity thereby providing a platform for collaborative work in the multidisciplinary area of biomedical engineering. The program is based on the expansion of engineering skills applied to biological systems and a solution of medical, pathological or trauma issues that will encourage the innovative and creative approach to problem solving that caters for unique individual patients.

ENTRY REQUIREMENTS

The Course shall be open to applicants in possession of one of the following qualifications:

(a) the degree of Bachelor of Engineering (Honours) from this University, or from any other higher education institution recognized by Senate, obtained with at least Second Class Honours; or

(b) the degree of Doctor of Medicine and Surgery from this University or equivalent obtained from any other higher education institution recognized by Senate; or

(c) the degree of Bachelor of Science (Honours) from this University, or from any other higher education institution recognized by Senate, obtained with at least Second Class Honours in one of the following areas: Medical Biochemistry, Applied Biomedical Science (or Medical Laboratory Science), Physiotherapy, Chemistry, Biology, Physics, or in another area of study deemed relevant by the Board of Studies.

Doctorate Degree by Research in Engineering

The Ph.D. in Engineering is a 3-4 year doctorate degree based on an innovative research project implemented by the student, supported by the extensive expertise of the departments in the Faculty and using the comprehensive range of equipment and facilities available.

FACILITIES

Department of Electronic Systems Engineering

Embedded Systems Laboratory

A computer network with Labview and Altium licenses to design PCBs and control electronic systems

50MHz Arbitrary programmable function generators

200Mhz Digital Storage Oscilloscopes

Triple Output programmable precision bench power supplies

3GHz Mixed Domain Oscilloscope (includes logic analyzer, spectrum analyzer and protocol analyzer)

National Instruments Data Acquisition Boards

FPGA Development Boards

Microcontroller Development Boards

Electronics Laboratory

20Mhz programmable function generators

100Mhz Digital Storage Oscilloscopes

Various bench power supplies

General purpose soldering stations

Electronics Manufacturing Laboratory

PCB Structuring Laboratory

UV Laser PCB structuring system

CNC PCB structuring system

Multilayer Press

Stereolithographic 3D Printer

Eyepiece-less Stereo Inspection Microscope (21x -120x magnification)

X-ray Inspection facility (up to 5600x magnification)

PCB Finishing Laboratory

Through-hole copper and tin plating facility

Hand operated mechanical through-hole plating facility

Vapour phase Oven

Reflow oven with 8 independently controlled heating zones

Dry film Solder mask Laminator

Brushing machine

Ultrasonic cleaner

PCB Assembly Laboratory

High speed, high accuracy solder paste dispenser

Weller high precision rework station

Advanced soldering/desoldering stations ideal for SMT soldering

Weller Hot air station

Manual pick and place systems

Semi-automatic pick and place systems

Eyepiece-less Stereo Inspection Microscope (10x - 60x magnification)

Department of Industrial Electrical Power Conversion

Energy Conversion and Power Quality Laboratory

- Grid Connected PV and Wind Systems
- Various Electric Bicycles
- Passive and Active Filters for Power Quality Improvement
- High Voltage and Current DC supplies
- Power Electronics, Power Systems and Electrical Machines software packages
- 100kVA Flywheel UPS
- Wave Energy Conversion Emulator Rig
- Linear Motor Rig
- Prototype AC Microgrid
- Various Power and Energy meters

Power Electronics Laboratory

- Induction Motor, Permanent Magnet Synchronous Motor and Switched Reluctance Motor rigs with Variable Frequency Drives
- Machine Loading Units up to 50kW
- Wind Energy Conversion Emulator Rig
- Various Power Electronic Converters
- High Bandwidth Instrumentation for Power Electronic Measurements

Electrical Machines Laboratory

- Various domestic scaled Combined Heat and Power Plant
- DC and AC motor and generator test beds
- Single phase transformer rigs

Electrical Mobility Laboratory

- Electric Car with Lithium Ion Battery Technology
- Electric Boats
- Solar Catamaran
- Battery Charging Equipment

Department of Industrial and Manufacturing Engineering

CAD/CAM Systems Laboratory

CAD Systems (2D, 3D, Animation)

CAD/CAM Systems

MoldFlow, 3D Studio max, AutoCAD, Autodesk Inventor

Tecnomatix - manufacturing development and simulation package,

Statistical process control and AI software

Picza LPX-250 3D Laser scanner

HP Plotter (up to A1 printing)

Concurrent Engineering Research Unit (CERU)

Concurrent Engineering Research Facilities

Thermoplastic Design Guidelines

DFX Design Guidelines

Industrial Automation Laboratory (IAL)

Six Mitsubishi FX1N-24 PLCs

Various Siemens Simatic S7 PLCs

Sony SRX3CH Robot

Two variable speed dual track conveyors

Reconfigurable 3D Gantry Robot - Cartesian System

Industrial Vision System

Other sundry equipment, oscilloscope, components and tools

Metrology Laboratory

Metrology Equipment Including CMM and Surface Roughness Measurement

Calibration of Metrology Equipment in Roundness, Linear and Angular Measurements

CNC Laboratory

CNC Vertical Milling Machine 2 ½ axis

CNC Vertical Machining Centre 3 axis

Advanced Manufacturing Laboratory

CNC Electric Discharge Machining (EDM) with Micro EDM capabilities

Additive manufacturing:

Polymer 3D printer - Fused Deposition Modeling (FDM) - Dimension 1200es

Polymer 3D printer - Stereolithography (SLA) - Form 2

Metal 3D printer - Electron Beam Melting (EBM) - ARCAM EBM S12

Thermoforming machine

2-component micro injection moulding machine (Boy 22E) with a clamping force of 200kN

Thermal imaging camera (Flir E6)

Sustainable Manufacturing Laboratory

Eco Materials Adviser

Kyoritsu Power/Energy Meters

Design Studio lab

Dedicated workstations for collaborative design and engineering design teamwork

Merkur modelling sets to build functional models of design concepts

Hitachi Smartboard to project presentations, to capture sketchwork generated in engineering design teamwork etc

Fuel 3D handheld scanner for reverse engineering purposes

Department of Mechanical Engineering

Formlabs Form 2 SLA 3D Printer to convert 3D CAD models into physical prototypes

Boxford CNC 3D Router to quickly obtain simple physical prototypes using a range of materials, including aluminium, plastics, wood and modelling foam

Rasberry Pi 2 B to develop innovative Internet of Things (IOT) product concepts

Empatica E4 wristband, a wearable wireless device to monitor physiological signals in real-time

University (Engineering) Workshop

Conventional Machine Tools including centre lathes, milling, surface and cylindrical grinding, gear hobbing, drilling and welding

Thermodynamics Laboratory

Laboratory experiments for thermodynamics and heat transfer

Testing beds of internal combustion engines

One electrical dynamometer, two water brakes and other smaller dynos

Demonstration type gas turbine

Testing of air conditioning setups, including variable speed (inverter)

Heat transfer in pipe facility

Heat exchanger testing facility

Supersonic nozzle setup

Labview and Keithley data acquisition systems

Structural Mechanics Laboratory

Strain gauge based experiments:

Strain gauge and monitoring of structural components

Tensile, compression and impact testing

PhotoStress® Plus analysis kit from Vishay Precision Group – Micro Measurements for experiments stress analysis

Residual stress hole drilling equipment from Vishay Precision Group – Micro Measurements

Vibration and Acoustic Monitoring:

Vibration monitoring

Human and hand vibration exposure measurements

Machine diagnostics using vibration analysis tools

Sounds/Noise level monitoring

Run-up and run-down vibration testing of rotating machinery

Dynamic balancing of machines/rotary systems

Monitoring of ground borne vibrations

Order Analysis

Modal analysis

CAE Lab - Computer Aided Engineering Laboratory

Computer facilities to run the following engineering software:

FEA – Finite Element Analysis – ANSYS

Linear and non-linear structural analysis: predict behavior of structural components for a wide range of materials and loadings (e.g. pressure vessels, biomechanics, modal analysis/ vibration responses etc.)

Thermal and thermo-mechanical analysis: predict the thermal and structural response of components of thermally driven processes (e.g. welding, laser cutting/ forming etc.)

CFD – Computational Fluid Dynamics Fluent – FLUENT/ANSYS

Advanced aerodynamic and hydrodynamic analysis of systems and components including conjugate heat transfer (bounded and unbounded flows, laminar and turbulent flows, subsonic, transonic, supersonic and hypersonic flows, single phase and multiphase flows, combustion, etc.). Typical applications include car bodies, ducting systems, electrical machines, aircraft wings / aerofoil sections, wind turbine blades, offshore wind turbine support structures etc.)

Naval Architecture Simulation – Bentley Academic SELECT:

To design, model, optimise and characterise hull forms

To perform stability (intact/damage) and strength calculations, analyse sea-keeping performance, resistance and powering prediction, sailing performance analysis for yachts

To perform 3D modelling using linear, non-linear and buckling analysis, static and dynamic structural analysis on the ship hull and structure

Maxsurf Enterprise

Multiframe Advanced

SACS Marine Enterprise

SACS Offshore Structure Enterprise

MOSES Advanced

MATLAB/Simulink

CAD – Computer Aided Design

SOLIDWORKS

Microstation

WindPRO (EMD)

WAVE/VALDYN (Ricardo)

FloTHERM

ESATAN-TMS:ITP Engines UK is kindly sponsoring the Department of Mechanical Engineering of the University of Malta with the software licence for the analysis and simulation software ESATAN-TMS for their undergraduate degree program

Fluids Laboratory

Wind Tunnel Testing, flow measurements using hot-wire anemometry, wind turbine performance and load evaluation

Low wind speed wind tunnel 38 x 38 cm

Low wind speed wind tunnel 900mm diameter

Water wave generator (8m x 0.75m x 0.8m)

Flow measurement equipment (including six-channel hot-wire anemometer)

Hydraulic pump/turbine demonstration equipment

Pelton wheel performance testing equipment

Model propeller/wind turbine performance testing rigs

Setup for flow visualisation over aerofoils using smoke generation

Thermal management of electrical machines

Robotic Systems Laboratory

Mitsubishi RV-6SL 6-DOF revolute robot, 91cm reach, 6kg payload, with controller upgrade, tracking card, and adjustable gripper, or vacuum gripper. Mounted on a highly reconfigurable table

Epson E2S651S 4-DOF SCARA robot, 65cm reach, 5kg payload

Two Cognex/DVT smart image sensors (machine vision)

Two flat belt conveyors (one with variable speed)

Machine vision lighting (ring light, strobe)

Other sundry equipment, components and tools

Various robot hands and glove devices, built in house

Department of Metallurgy and Materials Engineering

Process Equipment

- Plasma Assisted Physical Vapour Deposition (PA-PVD)
- Ion Beam-Assisted Deposition
- Gas Nitriding Furnace
- Vacuum Furnace with 5 bar overpressure
- Laser Added Manufacture Centre
- Air Furnace
- Foundry induction furnace
- Martempering/ Austempering salt bath
- 3-axis CNC machining station
- Planetary ball miller
- Tube and box furnaces

Mechanical Testing Equipment

- Charpy Impact tester with digital acquisition
- 10 ton bend testing centre
- 25 ton multipurpose dynamic testing centre
- Brinell/ Vickers Macro hardness tester
- Knoop/ Vickers Micro hardness tester
- IRHD/ Shore polymer hardness tester
- Pin-on-disk wear tester
- Reciprocating sliding tribo-corrosion tester
- Rotary bending fatigue tester
- Gear tribological tester

Calibration Equipment

- Load cell calibration system
- Temperature calibration system

Sample Preparation Equipment

- Precision cut off saw
- Thermosetting cold mounting station
- Hot mounting phenol sintering station
- Manual and automatic sample polishing stations
- Automatic electropolishing station

Characterisation Equipment

- Optical microscopy with real time image acquisition
- Incident light microscope with Nomarsky, UV and dark field attachments
- Side projected light stereo microscope
- Support metallographic microscopes
- Confocal microscope with 3 excitation lasers and multispectral analyser
- Potentiodynamic wet cell corrosion testers
- Laser Induced Breakdown Spectrocopy (LIBS)
- Dilatometer with inert gas chamber
- 3D stylus surface profilometer

Scanning Electron Microscope (SEM) with:

- In-lens backscattering detector
- In-lens secondary electron detector
- External secondary electron detector
- Solid state angular selective backscatter detector
- Energy dispersive spectroscope (EDS) detector

Wavelength dispersive spectroscope (WDS) detector

Electron Backscatter Diffraction (EBSD) detector

Ultra high vacuum Integrated Characterisation Facility including:

Surface analysis by electron kinetic energy analysis (XPS) through:

- Hemispherical electron energy analyser
- Ag/ Al Monochromated X-Ray source
- Ag/ Mg X-ray source
- High intensity electron source
- Low energy UV source (UPS)
- Rastering ion source
- Large area ion source

Quadrupole mass spectrometer

Low energy electron diffraction (LEED)

Secondary electron detector

Surface analysis by surface probe microscopy through:

- Atomic force microscopy (AFM)
- Scanning tunnelling microscopy (STM)

X-ray diffractometers

Nano-mechanical Indentation Testers

Department of Systems and Control Engineering

Biomedical Engineering Laboratory

- Vicon Optical Motion Analysis System
- Tekscan Body Pressure Measurement System
- Biopotential (e.g. EEG) Acquisition System
- Non-invasive Biomedical Data Acquisition System
- Diagnostic Ultrasound System
- Haptic Feedback System
- Rehabilitation Robotic Manipulator
- Thermal Imaging System
- Spectral Camera
- Signal Processing Boards
- Data Acquisition Boards
- High-end servers and computing equipment
- Matlab and Simulink Research Licences

Control Systems Engineering Laboratory

- Programmable Logic Control (PLC) units with state of the art Human Machine Interfaces (HMIs)
- Various mobile robot teams and other high end mobile robots
- Robotic manipulators
- Force, torque, laser and inertia sensors for robotic applications
- Embedded and tablet PC for real time computer control of mobile systems
- Fingerprint/palm and iris biometric scanners
- Stereo cameras with pan/tilt actuation
- Analogue and digital area scan cameras and smart cameras with LED illumination
- Various digital and analogue video grabbers and camera multiplexers
- Electronic test and measurement instrumentation
- PC interfaced servos and process control units
- Various PC interface units for computer control
- A computer network with various licenses for simulation and real-time control of systems

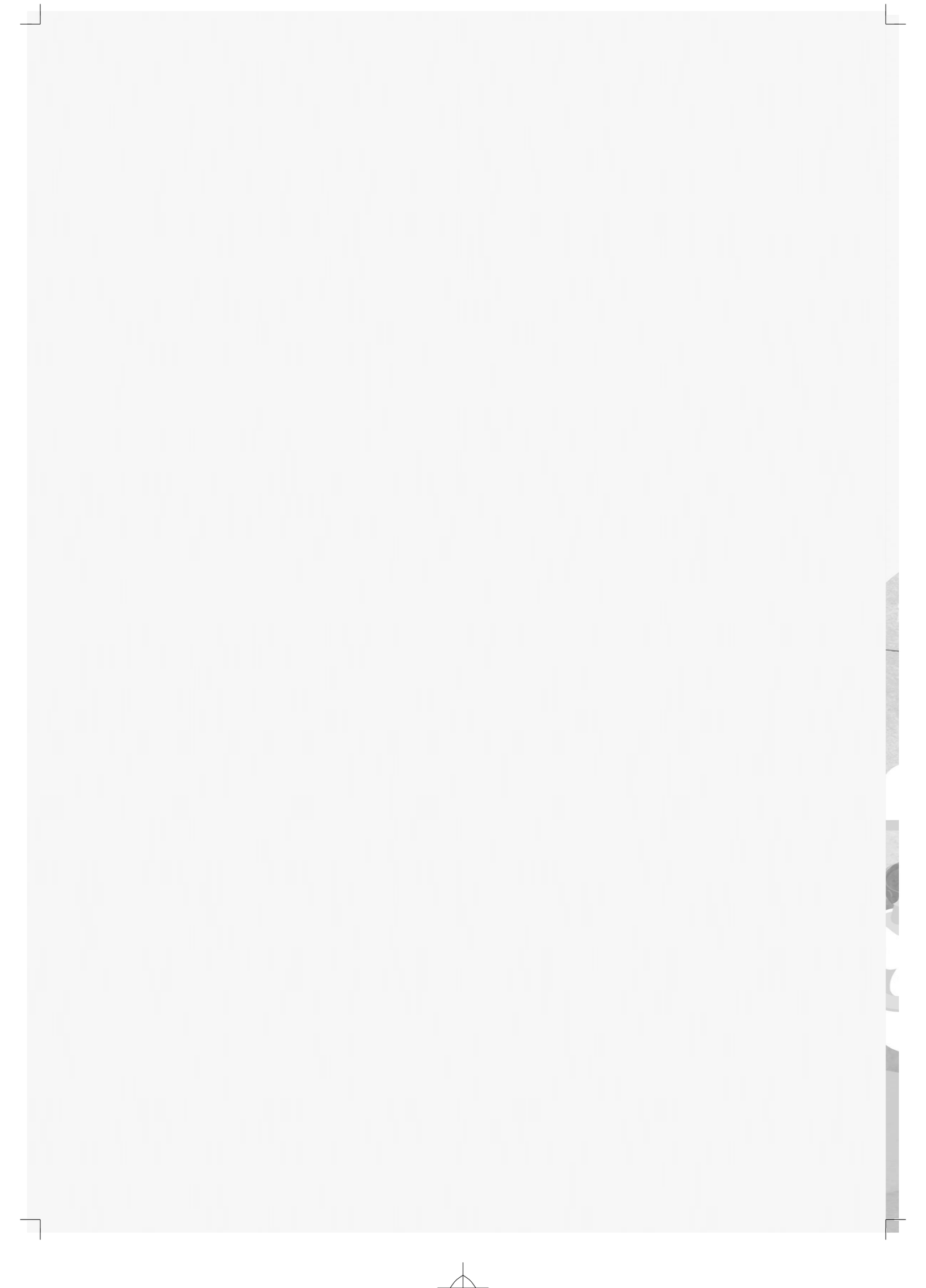
DEAN'S AWARD

In November 2017, Mr Mario Bonnici and Mr Alessandro Catania were awarded the Dean's Award for best students graduating in the Mechanical and Electrical and Electronic Engineering Degrees respectively, offered by the Faculty of Engineering and sponsored by the Farsons Foundation.

Mr Mario Bonnici and Mr Alessandro Catania consistently proved to be hard-working students of high capability in the engineering discipline, and achieved a 1st class Honours degree in their respective streams, with the highest average score in this degree in their year of graduation.

Deputy Dean Prof. Ing. Michael A. Saliba together with Mr Kenneth Pullicino presented these awards.

Mr Kenneth Pullicino from the Farsons Foundation presenting awards to Mr Alessandro Catania (left photo) and parents of Mr Mario Bonnici (in absentia, right photo)



ONGOING EXTERNALLY FUNDED RESEARCH PROJECTS

Development of a Low-Cost Floating Solar Distillation Device (Floating SolDi)

Funding Body: **Malta Marittima**

Project Fund: **€ 16,000**

UoM Workshare Value: **€ 16,000**

Principal Investigator: **Dr Ing. Paul Refalo**

Co-Investigators: **Dr Ing. Stephen Abela**

Consortium/Partners: **Department of Industrial and Manufacturing Engineering (UoM), Innova Ltd**

Project Start Date: **January 2018**

Project Duration: **1 Year**

Figure 1: Collection of contaminated water in rural areas (Source: https://thewaterproject.org)

The availability of safe drinking water is one of the most serious causes of health problems in the third world and in communities struck by natural disasters. It is estimated that by 2025, two-thirds of the world's population (circa 5 billion people) would be living under water stressed conditions. With the existing climate change scenario, by 2030, half the world's population will be living in high water stress regions (75 million to 250 million people of which live in Africa). The scope of this project is to develop an inexpensive, simple and easy to use device that can be quickly deployed on a body of water to distil sea, brackish or contaminated water using solar energy.

Micro Wastewater Treatment System using Photocatalytic Surfaces (MicroWATTS)

MicroWATTS shall develop a solar greywater treatment system, using surface engineered photocatalytic materials. This would be a step in the right direction when it comes to tackling the problem of water shortage that Malta and Sicily face.

Short term distinctive aspects include: cross border collaboration, transfer of technology, cross border mobility, adoption by SMEs of technology developed and non-financial assistance to SMEs. Long term objectives include: generation of green jobs, reduction of carbon and water footprint and better use of natural resources.

Funding Body: **Interreg V-A Italia-Malta**

Project Fund: **€ 2,415,048**

UoM Workshare Value: **€ 914,689**

Project Leader: **University of Malta (UM)**

Project Coordinator: **Prof. Ing Maurice Grech**

Co-Investigators: **Dr Stephen Abela, Dr Paul Refalo**

Consortium: **Dept of Metallurgy and Materials and Dept of Industrial and Manufacturing Engineering, UM, Consiglio Nazionale delle Ricerche, Malta College of Arts Science and Technology, Universita` degli Studi di Catania, Econetique Ltd, Plastica Alfa Srl**

Project start date: **15th May 2018**

Project duration: **3 years**

Engineering an Antigen Sensitive, Rapid Osteoregenerative, Bioresorbable Scaffold

Funding Body: **Reach High Funds (ESF)**

Project Fund: **€ 200,000**

UoM Workshare Value: **€ 200,000**

Principal Investigator: **Dr Malcolm Caligari Conti**

Co-Investigators: **Dr Ing. Joseph Buhagiar, Prof Pierre Schembri Wismayer MD, Dr Daniel Vella and Prof Emmanuel Sinagra.**

Consortium/Partners: **Department of Metallurgy and Materials Engineering, Faculty of Engineering, UoM; Department of Anatomy, Faculty of Medicine and Surgery, UoM; Department of Chemistry, Faculty of Science, UoM.**

Project Start Date: **March 2016**

Project Duration: **3 Years**

Dr Malcolm Caligari Conti: Post-doctorate researcher working on cytotoxicity testing

The development of successful scaffolds for bone replacement requires a concurrent engineering, chemistry and anatomy approach that combines the different research fields. Metallic biomedical implants are normally made from Ti- and Co-alloys. These materials have excellent corrosion resistance which makes them permanent. In the last five years, a paradigm shift with relation to permanent implants is happening and biodegradable metallic implants are now receiving ample attention. The idea is to have an implant which is removed slowly by the body and therefore as opposed to a permanent implant there is no need for a revision surgery to remove it. Iron-manganese alloys are a potential candidate material to be used in the production of biodegradable implant components. These materials are non-magnetic, have excellent mechanical properties and can be tailored to have good biodegradability rates. Over and above this alloy is also surface engineered in order to have an osteoconductive hydroxyapatite (HA) coating which is loaded with different antibacterial and chelating molecules. This will avoid infection, allow healthy bone growth and also release a drug that will chelate iron which is toxic in high quantities.

Development of a Low-Wearing Novel Metal on Metal Hip Joint Prosthesis for a Longer Lifespan (MALTAHIP)

The lifespan of a prosthetic hip joint is mostly limited by its vulnerability to wear. To eliminate the dire effects induced by the formation of wear debris, the patient may be required to undergo revision surgery, which unfortunately could further increase clinical complications. Motivated by the notion of eliminating revision surgery, this project intends to develop a new prosthetic hip design with reduced wear rates, in order to improve its lifetime upon commercial implants. The wear performance of the prototype implant will be tested in two phases; initially using a hip joint simulator that was developed in-house, and later on at an accredited implant testing company. To better understand the practicality of the new design during surgery, orthopaedic surgeons will implant the prosthesis prototype inside a cadaver. The overall study will provide better insight on the novel design of the implant during *in vivo* conditions.

Funding Body: **Malta Council for Science and Technology through the National Research and Innovation Programme 2015**

Project Fund: **€ 194,593.69**

UoM Workshare Value: **€ 145,674.19**

Principal Investigator: **Prof. Pierre Schembri Wismayer MD**

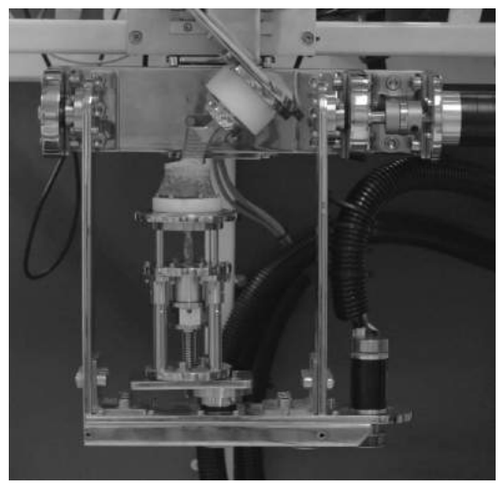
Co-Investigators: **Dr Ing. Joseph Buhagiar, Dr Ing. Pierluigi Mollicone, Mr Ray Gatt, Mr Donald Dalli**

Consortium/Partners: **Department of Metallurgy and Materials Engineering, Faculty of Engineering, UoM; Department of Anatomy, Faculty of Medicine and Surgery, UoM; Department of Mechanical Engineering, Faculty of Engineering, UoM; MCL Components Ltd.**

Project Start Date: **September 2016**

Project Duration: **3 Years**

MALTAHIP



MaltaHip Project: (left) Logo, (right) Hip joint simulator designed to mimic the in vivo conditions

Solar Wastewater Treatment Unit

Solar treatment of contaminated water has traditionally been accomplished by converting the electromagnetic waves from the sun into thermal energy. In recent years, the direct conversion of the light waves into chemical energy (photochemical effect) has started to be utilised in water treatment. This project involves the synthesis of new materials and modification of established materials to create photochemical devices efficient and compact enough to allow for greywater treatment at the micro scale for domestic applications.

Funding Body: **Guillaumier Ltd, through RIDT**

Project Fund: **€ 45,000**

UOM workshare Value: **€ 45,000**

Principal Investigator: **Dr Ing. Stephen Abela**

Co-Investigator: **Dr Ing. Paul Refalo**

Consortium/Partners: **Department of Metallurgy and Materials Engineering, Department of Industrial and Manufacturing Engineering**

Project start Date: **September 2017**

Project Duration: **3 years**

Solar water treatment prototypes tested at Pembroke RO treatment plant

Tribocorrosion Testing of Surface Modified Biomaterials

This project aims to develop novel surface treatments for the tribocorrosion protection of biomedical grade 316LVM stainless steel and CoCrMo alloys. Physical vapour deposition and low temperature diffusion treatments are being applied to produce surface modified layers to mitigate tribocorrosion damage of articulating biomaterials used inside the body. This work is contributing to better the current understanding of tribocorrosion mechanisms exhibited by surface engineered materials tested in a simulated body environment under controlled electrochemical conditions. This research shall lead to enhance the performance and success rates of permanent metallic implants.

Funding Bodies: **Internal Research Grant, Endeavour Scholarship and Student bench fees**

Project Fund: **approx. € 50,000**

UoM Share value**: approx. € 40,000**

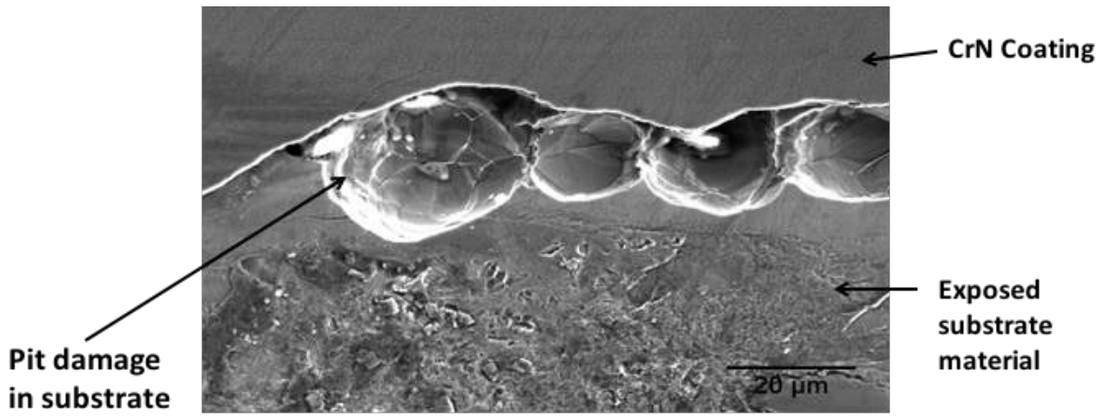
Principal Investigator: **Dr Ing. Bertram Mallia**

Co-Investigators: **Dr Ing. Joseph Buhagiar, Mr Antonino Mazzonello, Ms Raisa Chetcuti and Mr Luke Scicluna**

Consortium: **Department of Metallurgy and Materials Engineering,UoM, Boride Services Ltd. (UK), Bodycote Hardiff GmbH (DE), The Danish Technological Institute (DK).**

Project Start Date: **October 2016**

Project Duration: **Ongoing**



Interface corrosion between Cr(N) coating and 316LVM substrate leading to severe pitting corrosion of the substrate following tribocorrosion in simulated body fluid

MEMENTO: Multi camEra high fraMe ratE syNchronisaTiOn

MEMENTO is the Electronic Systems Engineering Department's first initiative at commercialisation of home-grown electronics hardware technology. After two successful rounds of research into high frame-rate vision hardware, and the completion of detailed commercial feasibility studies, the time has come to offer the technology with a range of products, and a sound business proposition that fills an existing gap in the high performance vision market. This product will address the problem of high precision synchronisation that arises between coupled cameras working at thousands, or even millions of frames per second. This will enable capturing transient events from multiple angles. The University of Malta already holds intellectual property in this domain (WO/2010/029040). However, through this project the technology will be polished to a high technology readiness level (TRL) and brought in line with market expectations. The ability to synchronize multiple cameras precisely enables a wide range of technical possibilities such as high speed 3D reconstruction, multi-camera resolution-augmentation, frame interleaving, and real-time stitching of video footage.

Funding Body: **MCST R&I Fusion 2015 (R&I-2015-024-T)**

Project Fund: **€ 195,000**

UoM Workshare Value: **€ 150,000**

Principal Investigator: **Dr Ing. Marc Anthony Azzopardi**

Co-Investigators: **Mr Andre Micallef**

Consortium Lead: **Dept. of Electronic Systems Engineering at the University of Malta**

Consortium Partners: **MST Audio Visual Ltd.**

Project Start Date: **April 2016**

Project Duration: **3 Years**

High speed vision equipment design for exacting scientific applications

Electrical Energy System Optimisation for the More Electric Aircraft

Recent advances in power electronics applied to commercial aircraft technology has brought about an increase in aircraft electrical systems (actuation, wing ice protection, environmental control and fuel pumping). The study in this project shall focus on the simulation of a More Electric Aircraft (MEA) power system to determine the optimal configuration in power generation, distribution (energy management) and end use. The research shall be concerned with both the generation systems and the electrical loads (power converters and electrical machines) and shall look into AC and/or DC distributed power systems or a hybrid combination allowing for flexible system reconfiguration aimed at achieving efficient operation. The study shall analyse the aircraft's electrical power operation for different flight mission scenarios with the aim to achieve stable and efficient operation whilst meeting the relevant power quality standards.

Funding Body: **University of Malta 2017**

Project Fund: **€ 60,000**

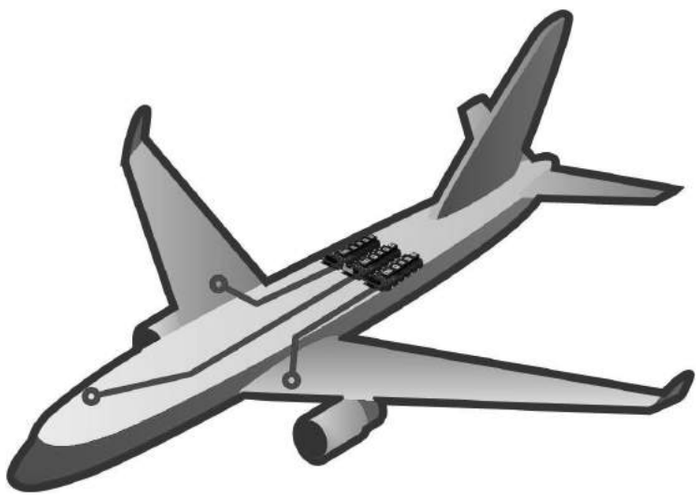
Principal Investigator: **Prof. Ing. Cyril Spiteri Staines**

Co-Investigators: **Prof. Ing. Maurice Apap, Dr Ing. Christopher Micallef,**

Consortium/Partners: **Department of Industrial Electrical Power Conversion and Department of Mechanical Engineering**

Project Start Date: **2017**

Project Duration: **2 Years**



The More Electric Aircraft

A Smart Micro Combined Heat and Power System

Cogeneration or combined heat and power (CHP) is the use of a heat engine to simultaneously generate electricity and useful heat. In separate production of electricity, some energy must be discarded as waste heat, but in cogeneration this thermal energy is put to use. This system increases the overall energy efficiency of the generator from about 40% to more than 85%.

A micro-CHP has been designed at the University of Malta. Small enough for households, which would increase the amount of renewable energy used as well as the attractiveness of using other renewable energy devices such as photovoltaic panels. The key design feature of the system is the fact that it treats the grid as an option and not as a compulsary source in meeting the energy needs of a household. The other advantage is that the micro-CHP using an asynchronous machine and the PV panels can be used to generate electricity during a power cut, which is not currently possible.

Funding Body: **Malta Council for Science and Technology through the FUSION R&I Technology Development Programme 2016**

Project Fund: **€ 194,956**

UM Workshare Value: **€ 146,207**

Principal Investigator: **Prof. Joseph Cilia**

Co-Investigators: **Ing. Matthew Schembri, Ing. Eryl Vella**

Consortium/Partners: **Department of Industrial Electrical Power Conversion, in collaboration with ABERTAX KEMTRONICs LTD.**

Project Start Date: **February 2017**

Project Duration: **3 Years**

A Smart Micro CHP with a Smart Home Energy System

Cable Pre-Tensioner for Quay Walls Civil Applications

Malta Freeport Terminals Ltd is seeking to expand its ports facilities to accommodate larger ship vessels. The expansion and increase in vessel tonnage requires adequate crane foundations and quay walls to withstand increases in crane loadings and mooring loads arising from ship windage. To this end the quay walls will be enforced by means of cables fixed to the quay and ground foundations. This project aims to design the appropriate cable tensioning mechanism to pre-stress cables and ensure adequate structural rigidity. Different design solutions are being considered. A numerical and an experimental modelling approach has been adopted to ensure the designed cable pre-tensioner is able to withstand loading conditions while meeting European Structural standards. The optimal cost effective yet structural fit cable tensioner mechanism that can pre-stress a set of cables in tandem will be identified.

Funding Body: **Research, Innovation and Development Trust (RIDT)**

Project Fund: **€ 40,000**

UoM Workshare Value: **€ 40,000**

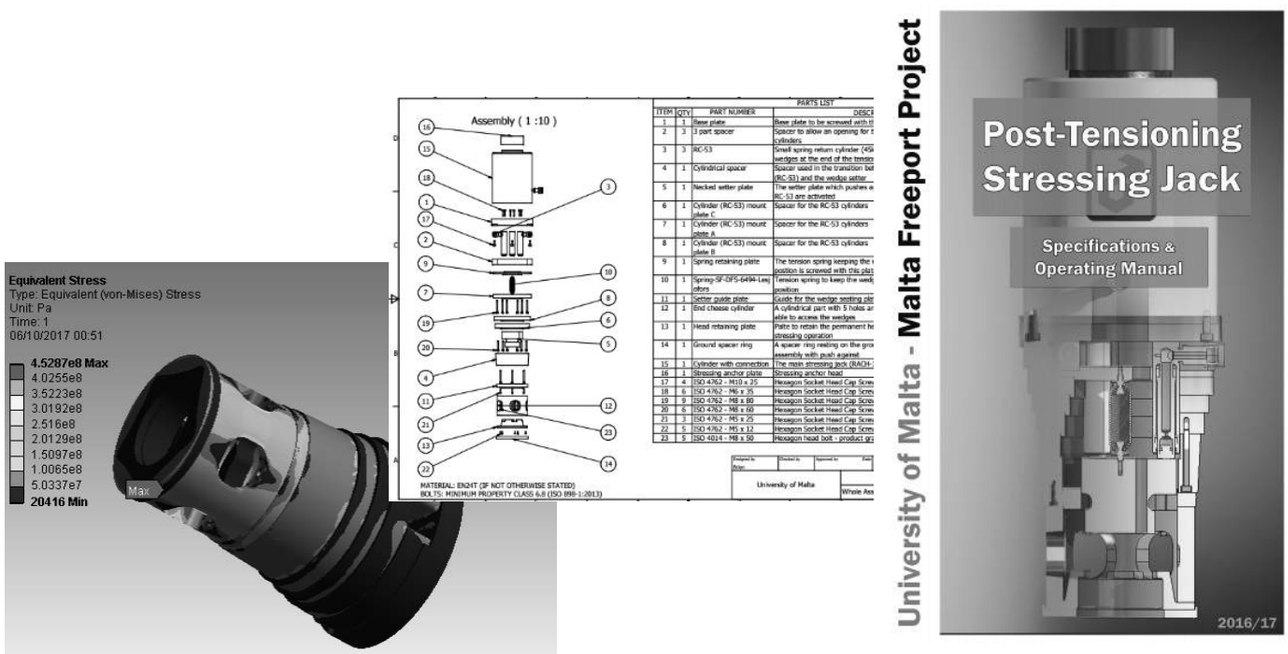
Principal Investigator: **Dr Brian Ellul**

Co-Investigators: **Prof. Ing. Duncan Camilleri, Dr Ing. Zdenka Sant**

Consortium/Partners: **Department of Mechanical Engineering at the University of Malta, in collaboration with Malta Freeport Terminals Ltd**

Project Start Date: **October 2016**

Project Duration: **2 Years**



Fibre reinforced cable pre-tensioner

ARIES: Accelerator Research and Innovation for European Science and Society

Project title at UM: Constitutive Models of Advanced Materials Subjected to High-Energy Particle Beam Impacts

Advanced experimental campaigns conducted at the European Centre for Nuclear Research (CERN) are a source of a large amount of data which can be used to derive constitutive models for advanced materials tested. These models, once verified in simulations and additional experiments, can be subsequently implemented in numerical analysis of full-scale components in nominal and accidental scenarios, such as in the modelling of collimators and other beam intercepting devices in CERN's largest facility, the Large Hadron Collider (LHC), the Future Circular Collider (FCC), and other high-energy particle accelerators and experiments.

Funding Body: **European Commission in Call, Horizon 2020**

Investigators at UM: **Dr Ing. Pierluigi Mollicone and Dr Ing. Nicholas Sammut (Faculty of ICT)**

Ph.D. Student: **Mr Marcus Portelli**

Consortium/Partners: **Department of Mechanical Engineering, Department of Micro and Nanoelectronics (Faculty of ICT) at the University of Malta, Coordinator: CERN The European Organisation for Nuclear Research, Geneva, Switzerland; full partners list on https://aries.web.cern.ch/**

Project Start Date: **2017**

Project Duration: **4 Years**

Advanced thermo-mechanical analysis of collimator components (adapted from screenshot of ANSYS® Academic Research Mechanical, Release 18.1)

Project FLASC: Development of a Hydro-Energy Storage System for Offshore Multi-Purpose Floating Platforms

Despite its advantages, use of offshore renewable energy is hindered by numerous challenges, particularly the mismatch between renewable energy supply and consumer demand. FLASC is an interface between offshore renewables and the grid. It smoothens out the intermittent output of renewable sources by storing surplus energy and dissipating it in periods of higher demand. FLASC is a hydro-pneumatic energy storage system that integrates into an offshore floating platform. It has a unique design with a high efficiency and a stable operating pressure. Since it stores energy as pressurised, cold, deep seawater, it can also be integrated into LNG liquefaction and Water-Injection Oil Wells.

FLASC is patent pending: PCT/IL2016/050100

Funding Body: **Malta Council for Science and Technology through the National Research and Innovation Programme 2015**

Project Fund: **€ 198,206**

UoM Workshare Value: **€ 142,545**

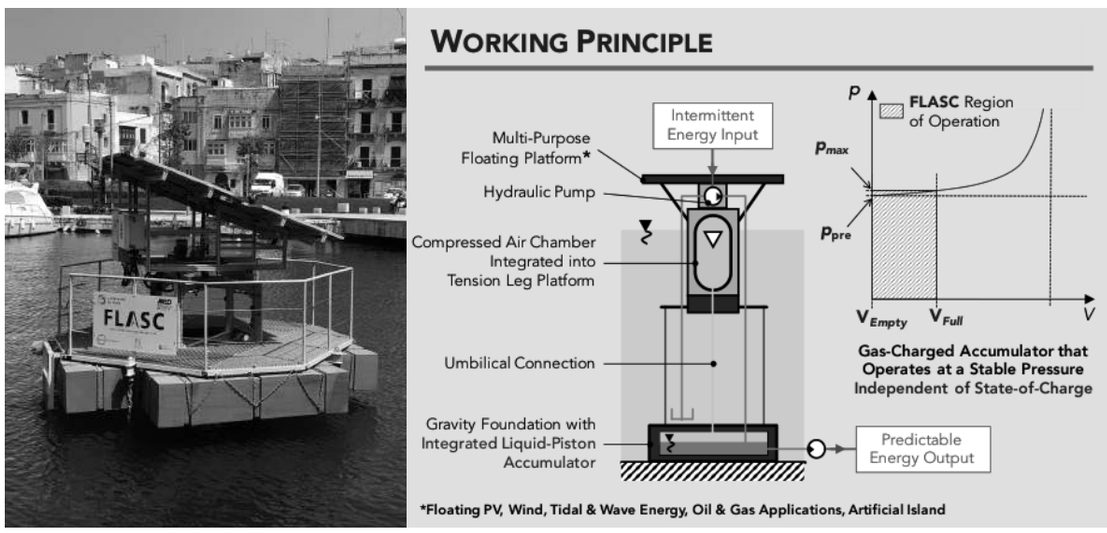
Principal Investigator: **Prof. Ing. Tonio Sant**

Co-Investigators: **Dr Ing. Daniel Buhagiar, Dr Ing. Robert N. Farrugia**

Consortium/Partners: **Department of Mechanical Engineering at the University of Malta, in collaboration with MedServ plc., and with support from the Institute for Sustainable Energy.**

Project Start Date: **July 2016**

Project Duration: **3 Years**



FLASC small-scale prototype (left) and working principle (right)

Thermo-Mechanical Studies of Novel MEMS Microgrippers for Manufacturing in Malta

Micro-electro-mechanical systems (MEMS) are advanced commercial microchips currently available on the market. These devices are composed of a microelectronic part and a miniaturised mechanical sensor/actuator that are embedded on the same semiconductor microchip using the techniques of microfabrication. The advances in MEMS technology have been instrumental in the development of new devices and applications, as well as in the creation of new fields of research and development.

This project deals with research on MEMS microgrippers which is a relatively new field for Malta. Microgrippers are typical MEMS devices whose compact size, low power consumption and low cost make them ideal tools in microassembly and micromanipulation fields. The primary function of microgrippers is to handle and manipulate micro-objects, such as micromechanical parts and biological cells, without causing damage. The focus of this research project is the design, modelling, fabrication and experimental testing of a silicon-based electrothermal microgripper for the deformability characterisation of human red blood cells.

Funding Body: **Reach High Post doc scholarship, Malta**

Principal Investigator: **Dr Ing. Marija Demicoli (née Cauchi)**

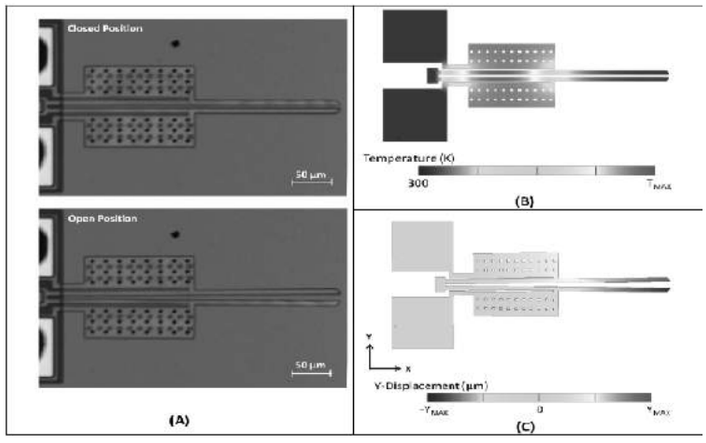
Main Academic mentor: **Dr Ing. Pierluigi Mollicone**

Co-Investigators: **Dr Ing. Nicholas Sammut , Prof. Ivan Grech, Dr Ing. Bertram Mallia,**

Consortium/Partners: **Department of Mechanical Engineering, Department of Metallurgy and Materials Engineering, Faculty of Engineering and Department of Microelectronics & Nanoelectronics, Faculty of ICT, University of Malta; ST Microelectronics, Malta**

Project Start Date: **April 2016**

Project Duration: **3 Years**



MEMS-based electrothermal microgripper. (A) Optical images showing the fabricated polysilicon microgripper when not actuated (closed position) and when each arm is actuated under an applied potential (open position). (B),(C) Simulated steady-state temperature and displacement plots of the designed microgripper at an applied potential in CoventorWare®

Thermal Imaging for Peripheral Vascular Disease Monitoring in Diabetics (TIPMID)

In this project the use of thermography as a monitoring tool for patients with diabetes is being investigated. Specific temperature patterns in individuals suffering from diabetes may serve as early indicators of peripheral vascular disease. These indicators could in turn lead to earlier preventive action or treatment, reducing the risk of complications.

Funding Body: **Malta Council for Science and Technology through the National Research and Innovation Programme 2013**

Project Fund: **€ 165,252**

UoM Workshare Value: **€ 121,602**

Principal Investigator: **Dr Owen Falzon**

Co-Investigators: **Mr Jean Gauci, Prof. Kenneth P. Camilleri, Dr Cynthia Formosa, Dr Alfred Gatt, Dr Stephen Mizzi, Ms Anabelle Mizzi, Mr Christian Ellul, Prof. Nachi Chockalingham, Prof. Kevin Cassar, Ms Cassandra Sturgeon**

Consortium/Partners: **Centre for Biomedical Cybernetics, University of Malta**

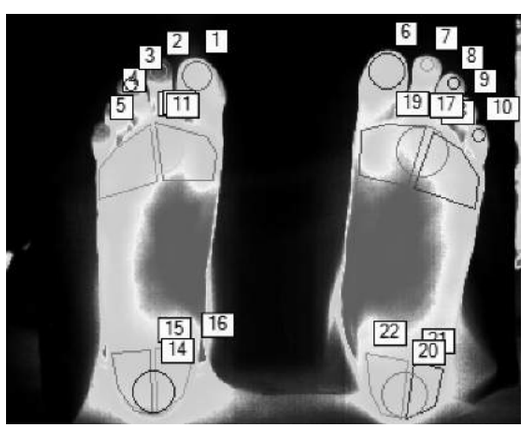
Department of Systems and Control Engineering, Faculty of Engineering, University of Malta

Department of Podiatry, Faculty of Health Sciences, University of Malta

Department of Surgery, Mater Dei Hospital

Project Start Date: **1st March 2015**

Project Duration: **32 months**



Foot temperature monitoring using thermography

R&I-2015-032-V - Brain Controlled Application (BrainApp)

This project proposes the development of a novel application controlled directly with brain signals, opening up accessibility to individuals suffering from motor disabilities, and providing alternative access methods to healthy individuals.

BCIs acquire the electrical brain activity using electroencephalography (EEG) electrodes, relying on brain phenomena such as those evoked by flickering visual stimuli, known as steady state visually evoked potentials (SSVEPs). In the proposed system, stimuli are associated to commands, and EEG signals are processed to detect the intent associated to the brain pattern. A BCI challenge is to have BCIs operating in real environments amidst the nuisance signals generated by normal user actions. The project proposes solutions to this challenge, operating in real-time at the user's will. It also aims at addressing the annoyance factor of the flickering stimuli, ensuring that the system can be used comfortably for long periods of time.

Funding Body: **FUSION R&I Technology Development Programme 2016, MCST**

Project Fund: **€ 181,793.22**

UoM Workshare Value: **€ 136,335.72**

Principal Investigator: **Dr Tracey Camilleri**

Co-Investigators: **Ing. Rosanne Zerafa, Dr Owen Falzon, Prof. Kenneth P. Camilleri**

Consortium/Partners: **Department of Systems and Control Engineering, and Centre for Biomedical Cybernetics at the University of Malta, and 6PM Ltd.**

Project Start Date: **July 2017**

Project Duration: **36 months**

Brain controlled application based on steady-state visually evoked potentials (SSVEPs)

R&I-2016-010-V WildEye - Eye-Gaze Tracking in the Wild

This project proposes a passive eye-gaze tracking platform aimed to provide an alternative communication channel for persons with physical disabilities, permitting them to perform mundane activities such as to operate a computer, or for normal individuals as an additional access method.

In the proposed platform, eye and head movement are captured in a stream of image frames acquired by a webcam, and subsequently processed by a computer (and possibly mobile devices) in order to estimate the gaze direction according to the eye and head pose components. mapping the eye-gaze to a computer screen permits commands to be issued by the selection of icons on a suitably designed user interface. This project addresses challenges associated with eye-gaze tracking under uncontrolled daily life conditions, including handling of head and non-rigid face movements, and reduction or elimination of user calibration for more natural user interaction.

Funding Body: **FUSION R&I Technology Development Programme 2016, MCST**

Project Fund: **€ 193,943.38**

UoM Workshare Value: **€ 141,312.67**

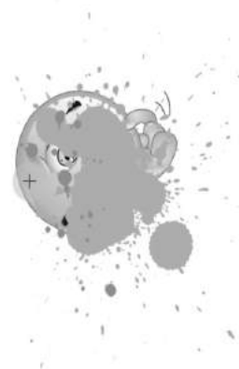
Principal Investigator: **Prof. Kenneth P. Camilleri**

Co-Investigators: **Dr Ing. Stefania Cristina**

Consortium/Partners: **Department of Systems and Control Engineering at the University of Malta, and Seasus Ltd.**

Project Start Date: **July 2017**

Project Duration: **30 months**



Controlling the mouse cursor by the eye movements alone, demonstrated by an interactive game that requires the user to hover the cursor over randomly appearing smileys

EyeControl

This project focuses on the use of eye movements to control applications within an intelligent environment. Rather than using standard video based eye gaze trackers that are susceptible to lighting conditions and subject's head movements, this project proposes an alternative solution using electrooculography (EOG), which refers to the electrical signals generated during eye movements. The project makes use of a recent Japanese EOG glasses that can be found on the market, called the MEME glasses, comprising of three electrodes at the nose bridge and nose pads to record the electrical signals in real time, thus offering a sleek and cost effective solution to the standard gel based, wired, six-electrode conventional EOG setup.

The work carried out in this project involves the development of signal processing tools to identify saccades and blinks in real time, translate the saccadic movements to ocular gaze displacements and use these to interface with an asynchronous QWERTY virtual keyboard. The performance of the MEME glasses when used by 10 subjects to interface with the virtual keyboard was compared to that of the conventional EOG setup involving two pairs of electrodes around the eyes instead of the MEME configuration having only three dry electrodes on the bridge and nose pads. A journal publication and a conference paper have been submitted on this work and are currently under review. Mr Nathaniel Barbara has also presented this work for his Masters by Research degree and obtained a pass with distinction.

This project was also presented for the Malta Innovations Award 2016 and took the first prize for the Scientific Innovations Award and received the WIPO IP Enterprise trophy from the World Intellectual Property Organization.

Funding Body: **JINS Company Ltd**

Project Fund: **€ 9,858**

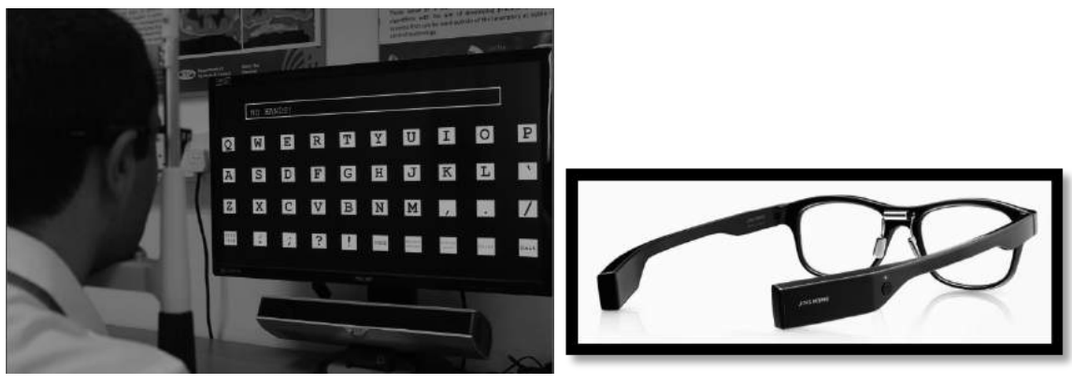
Principal Investigator: **Dr Tracey Camilleri**

Co-Investigators: **Prof. Kenneth P. Camilleri, Mr Nathaniel Barbara**

Consortium/Partners: **Department of Systems and Control Engineering at the University of Malta**

Project Start Date: **October 2016**

Project Duration: **18 months**



Typing using eye movements recorded through the Jins Meme EOG glasses

Development of a Novel Device to Support Children with Language Impairment in a Bilingual Context (SPEECHIE)

Language impairment (LI) in children is often attributed to various factors including intellectual disability, autism and hearing loss. However, it is reported that approximately 7% of the global childhood population experience LI in the absence of evident causative factors. Children with LI are often faced with social communication, behavioural, educational and vocational difficulties. Although bilingualism does not cause LI, such disorders can be complicated when children have bilingual or multilingual exposure, which is a common occurrence worldwide. This has particular relevance to the language-learning context of Maltese children. LI in children can often be addressed by a customised intervention programme drawn up by a professional speech-language pathologist (SLP) on the basis of assessment and regular review of the child's speech and language skills. However, children often lose engagement when subjected to repetitive therapy activities and lengthy assessment procedures. This impinges on the effectiveness of intervention. Moreover, speech-language sessions offered in the public health clinics often take place during school hours, disrupting children's routine. Furthermore, with guardian(s) often being engaged in full-time work, it becomes an issue to accompany children during the sessions. At the time of writing, the research team has managed to produce a physical prototype of the device. In addition, the research team is seeking to protect the idea of SPEECHIE via a patent application.

Within this context, the project's goal is to develop a novel, multi-modal device, nicknamed SPEECHIE, to facilitate language therapy for children with LI both within and beyond the clinical setting. SPEECHIE will be developed as a smart educational toy that entices children to engage with the designated exercises by creating a more rewarding and motivating environment.

Funding Body: **Malta Council for Science and Technology through the 2015 FUSION Technology Development Funds**

Project Fund: **€ 194,960**

Principal Investigator: **Dr Ing. Philip Farrugia**

R&I-2018-009V - Innovative 3D Printer

For 3D printing of high performance polymers such as polyetheretherketone (PEEK) for heavy-duty applications e.g. in automotive and medical sector, worldwide there are currently only two 3D printers available on the market. Both are based on filament extrusion, a.k.a. fused deposition modelling (FDM), with known disadvantages such as a material-unfriendly process due to twice extrusion/heating of the material causing changes in the material's properties , a very limited selection of materials, a high filament price, part warpage and peeling-off problems, among others.

In light of this, the project aims to develop an innovative 3D printing technology that is material-friendly based on a one-time extrusion step and user-friendly in terms of material selection and price as well as added novel printing modes.

Funding Body: **Malta Council for Science and Technology through Commercialisation Vouchers Programme 2018**

Project Fund: **N/A**

Principal Investigator: **Dr Arif Rochman**

Co-Investigators: **Dr Ing. Joseph Buhagiar and Dr Alfred Gatt**

Consortium/Partners: **Department of Industrial and Manufacturing Engineering, Department of Metallurgy and Materials Engineering, Department of Podiatry, at University of Malta, in collaboration with Abertax Quality Limited**

Project Start Date: **April 2018**

Project Duration: **8 Months**

ONGOING MASTERS and Ph.D. RESEARCH PROJECTS

Ongoing Master's and Ph.D. Research Projects

Projects supervised by members of the Department of Industrial and Manufacturing Engineering

M.Sc. by Research

Matthew Vassallo	Development of a Rapid Prototyping Solution for the Production of Vulcanized Rubber Components, Master by Research in cooperation with Trelleborg Sealing Solutions Malta.
James Mamo	A Computer-based System For Supporting Sportsbikes, Masters by Research.
Luca Caruana	Development and Analysis of a Floating Solar Distillation Device
Alec Fenech	Investigating Kansei Engineering in Industrial Product Development
Ryan Magro	An Approach for Implementing Cyber-Physical Production in Legacy Machines

M.Sc. IPD

Miguel Borg	A Kansei Engineering Approach to the Development of Street Lighting Systems
Dinah Marie Brincat	An IPD approach for Enhancing Supply Chain Efficiency in Manufacturing SMEs
Norbert Brincat	Sustainable transition towards factory of the future within the Polymer industry
Darryl Calleja Stafrace	Concurrent Engineering Approach to Tool Design of a Smart Toy Device
Janice Camilleri	Sustainability Analysis of Single-Use Medical Devices

Ph.D.

Emanuel Balzan	A User-Centred Design Framework for Persuasive Products Toys in Remote Therapy for Children

Projects supervised by members of the Department of Metallurgy and Materials Engineering

M.Sc. by Research

Michael Fiott	The Development of Surface Engineering Treatments for Magnesium Medical Implants.

Clayton Farrugia	Investigation of Electrochemical Corrosion Problems in Industrial Diesel Engines
Mark Anthony Bonello	Fe Based Powder Metallurgy Alloys: Tailoring Biodegradability through Silver addition
Matthias Debono	PIRAC Nitriding of a NiTi Shape Memory Alloy; Augmentation of Degradation Resistance
Marlon Attard	Study of Shot-Peened and PVD Coated Aerospace-Grade Titanium Alloy
Raisa Chetcuti	Coated Versus Coated Tribopairs: A Bio-tribocorrosion Appraisal of a Dual Layer PVD Coating
Luke Scicluna	Tribocorrosion of PVD Coated Bio-Medical CoCrMo Alloy
Cristina Cardona	Optimisation of the Calcium Tartrate Consolidation Treatment on Globigerina Limestone

Ph.D.

Diana Kusova Cini	Protective Coatings for Heritage Metals
Antonino Mozzanello	Surface Engineering of Biomedical Orthopaedic Implant Alloys: A Tribological Study
Mary Grace Micallef	Solar Wastewater Treatment Unit
Anthea Agius Anastasi	Molecular Simulation and Atomic Probe Studies of Graphene
Donald Dalli	Development of a Low-Wearing Novel Hip Joint Prosthesis for a Longer Lifespan
Maria Magro	Graphene and Graphene Oxide for Nanostructured Membranes

Projects supervised by members of the Department of Electronic Systems Engineering

M.Sc. by Research

Johann Cassar	Optimization of a Three Axis Teslameter for the Calibration of the Next Generation of Undulators
Mark Dalli	Development of a Magnetic Measurement Bench for Insertion Devices of a Free Electron Laser
Darren Debattista	Design of an Attitude Determination and Control System for the UoMBSat1 Pico-Satellite
Karl Galea	Image Processing of High Speed Imagery using FPGAs
Charles Grech	Design of a UHF Passive Phased Array Ground Station for the UoMBSat1 Pico-Satellite

Projects supervised by members of the Department of Industrial Electrical Power Conversion

M.Sc. by Research

Andrea Brincat	Design and Development of Electronic Control Systems for Hybrid PV+CHP Residential Grid Connected Set-ups with Battery back-up
Jonathan Palombi	Design of an Electric Power Train for Malta's FSAE Team

M. Phil.

Daniel Zammit	Control of Microgrids for Distributed Generation including Energy Storage

Ph.D.

Kris Scicluna	Sensorless Control in Steer-by-Wire Application

Projects supervised by members of the Department of Mechanical Engineering

M.Sc. by Research

Luke Aquilina	Performance and Efficient Analysis of a Model Underwater Compressed Air Energy Storage System
Owen Parnis	Investigating the Influence of Mooring Design on Floating Wind Turbine Aerodynamics
Anthony Saliba	Investigating the Aerodynamic Characteristics of Small-Scale UAV Propellors with Vortex Generators
Leo Scicluna	Investigation of Wind Flow Conditions on the Flight Endurance of UAV in Hovering Flight
David Bartolo	An Investigation of Different Welding Manufacturing Procedures to Minimize Distortion
Yesenia Aquilina	Towards Robot-Assisted Living through Universal Design of the Environment
Paul Joseph Borg	Design, Development and Building of Mobile Load Cells for Use in Laboratory Experiments
Adrian Camilleri	Simulation and Feasibility Study for Two Cycle Engines with Scavenging Through Poppet Valves

M. Phil.

Mahmoud Ayad Almehat	Development of Benefits Accruing from Implementation of Environmental Management Systems in Wasteserv Malta Ltd

Jean Paul Azzopardi	Dual Fuel Internal Combustion Engines – Alternative Fuels for Diesel Engines
Carl Caruana	Heat Transfer and Friction Analysis in Pressurised Motored Compression Ignition Engine
Marcus Portelli	Models of Advanced Materials Subjected to High-Energy Particle Beam Impacts
Donald Dalli	Development of a Low-wearing Novel Hip Joint Prosthesis with a Longer Lifespan

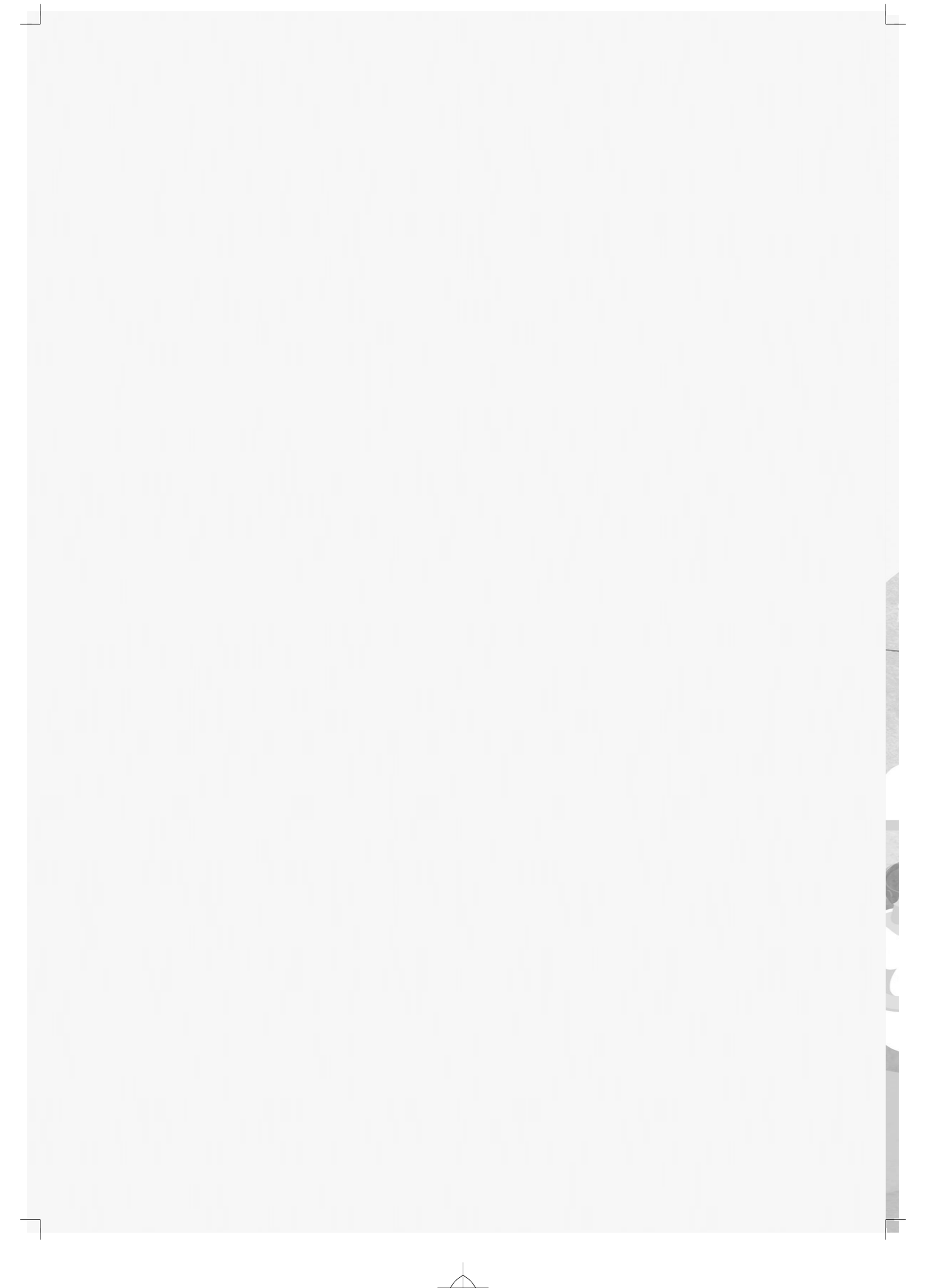
Projects supervised by members of the Department of Systems and Control Engineering

M.Sc. by Research

Jean Luc Farrugia	Swarm Robotics for Object Transportation
James Attard	A Speech Recognition and Analysis System for SPEECHIE: A Device Supporting Children with Language Impairment
Clare Saliba	Development of a Training Simulator for Teleoperated Robots Deployed in Hazardous Environments at CERN
Charlotte Camilleri	Localisation and Detection of Barcodes using Aerial Robots
Lucianne Cutajar	Combined Visual and Thermal Imaging for Non-Contact Physiological Signal Measurement
Darren Debattista	Design of an Attitude Control and Determination System for the UoMBSat1 Pico-Satellite

Ph.D.

Rachael Nicole Darmanin	Coordination and Control of Multi-Robot Systems
Nikiforos Okkalidis	An Enhanced Wearable System for Kinematic and Kinetic Gait Analysis
Luana Chetcuti Zammit	Autonomic Control for Road Network Management
Idris Garba	CT Radiation Doses in Nigeria: Establishment of Diagnostic Reference Levels and Radiation Dose Optimisation
Mark Borg	Automatic Video-based Sign Language Recognition
Marc Tanti	Visual Object Recognition based on Textual Descriptions
Carl Azzopardi	Quantifying Atherosclerosis Using Freehand 3D Ultrasound Imaging
Rosanne Zerafa	Switching Multiple Models for SSVEP-based Brain-Computer Interfaces
Nathaniel Barbara	Gaze Angle Estimation using a Dense Multi-Channel EOG Electrode Configuration with Varying Head Pose Compensation



FINAL YEAR ENGINEERING PROJECTS

ELECTRICAL STREAM

Implementation of Control Techniques for a Semi-Autonomous Underwater Vehicle

Student: Joel Cassar / Supervisor: Dr Ing. Brian Zammit / Co-Supervisor: Dr Ing. Marvin Bugeja

Introduction

One of the most important sub-systems that constitute a remotely operated underwater vehicle (ROV) is the propulsion system. This system often consists of several motors that need to be operated at the same time in order to command the desired underwater trajectory. For the remote operator, controlling the trajectory of the ROV is challenging unless automation support is provided.

Project Objectives

The aim of this project was to design and implement semi-autonomous control systems for an underwater ROV. These systems would provide a degree of autonomy which would assist the operator in maneuvering the vehicle with less effort.

Project Methodologies

A mathematical model was derived and then simplified by applying a number of assumptions [1]. This model was then linearized to enable the use of linear control techniques to be adopted for the nonlinear ROV system.

Cascaded PID control techniques were selected for designing controllers for the position and velocity of the ROV in four degrees of freedom. These controllers were implemented and tested in simulation using MATLAB and Simulink packages.

The four thruster configuration chosen for this project is shown in Figure 1.

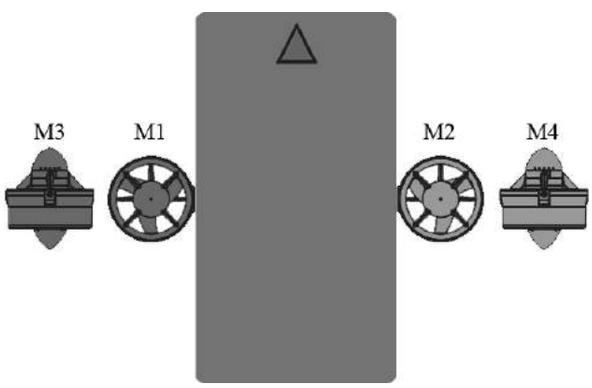


Figure 1: Thruster Configuration

Results and Achievements

The suitability of the designed linear controllers when applied to the nonlinear ROV model was tested by comparing the performance of the controllers using both the linearized and nonlinear models. The results showed that the integral action of the PID controllers is crucial in compensating for the nonlinearities present in the nonlinear model.

Four controllers were required to implement two semi-autonomous control modes, namely the velocity control mode and the depth control mode. In the velocity control mode, the operator is able to control the speed of the vehicle in the surge, yaw and heave degrees of freedom. On the other hand, using the depth control mode, the heave degree of freedom is automated, thus allowing the user to request a particular depth and then focus on controlling the ROV in the surge and yaw degrees of freedom.

All control modes were tested in simulation. Figure 2 shows the resulting trajectory of the ROV using the depth control mode. During testing, it was concluded that with the appropriate control system, the task of controlling the ROV is simplified significantly, thus allowing the operator to follow pre-determined paths and execute maneuvers with more precision and less effort.

References

[1] J. Vervoort, “Modeling and Control of an Unmanned Underwater Vehicle,” University of Canterbury, Christchurch, New Zealand, 2008.

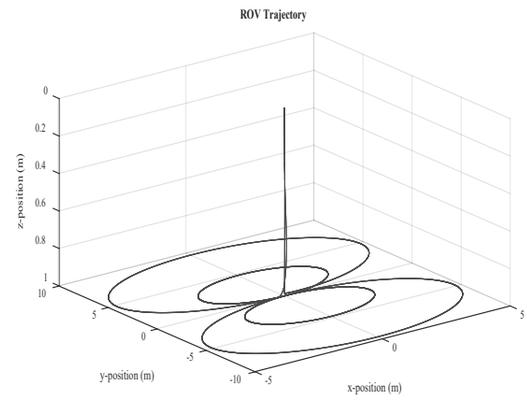


Figure 2: ROV Trajectory Plot

Race Track Position Estimation for UoMR

Student: Kurt Dalli / Supervisor: Dr Ing. Andrew Sammut

Introduction

Data-driven engineering decisions require a platform for data management, simplifying the process of data gathering and analysis [1]. In the case of University of Malta Racing (UoMR), this process requires human intervention, leading to inefficiencies. Moreover, the sensory data being gathered is not tied to a positional measurement, diminishing its

Project Objectives

This project aims to create a system for streamlining the process of data management and analysis, while also designing and implementing a system which provides accurate positional measurements.

Project Methodologies

These main objectives of the project are achieved through the implementation of a system made up of three main parts: the rover, the back-end and the web application. The rover is the part of the system installed on the vehicle under test, and is tasked with gathering data. The data is relayed to the back-end subsystem for processing and online storage, where a position estimation algorithm is implemented. This calculates an estimated path, which is made accessible for analysis via a cross-platform web application (Figure1). This allows the user to control the system, select a dataset, and analyse the data.

Results and Achievements

The system was tested under different scenarios using positional estimates calculated through different techniques (Figure 2). This included using the Inertial Measurement Unit (IMU) as a standalone system, using the standalone GPS receiver, fusing the data from both sensors using a complementary filter, as well as using a Kalman filter. The data fusion techniques resulted in an estimate which has more resolution than the GPS, and more accuracy than the IMU, thus outperforming both standalone systems.

Different criteria were selected and used to assess the performance of each technique. The Kalman filter was determined to give superior results, as expected, due to its inherent averaging properties [2].

References

[1] Ramamoorthy C.V. and Wah B.W., 'Knowledge and Data Engineering', IEEE Transactions on Knowledge and Data Engineering, March 1989, Vol. 1, No. 1, pp.9-15

[2] Rhudy M.B., Salguero R.A. and Holappa K., 'A Kalman Filtering Tutorial for Undergraduate Students', International Journal of Computer Science and Engineering Survey (IJCSES), Februrary 2017, Vol. 8, No. 1, pp.1-5

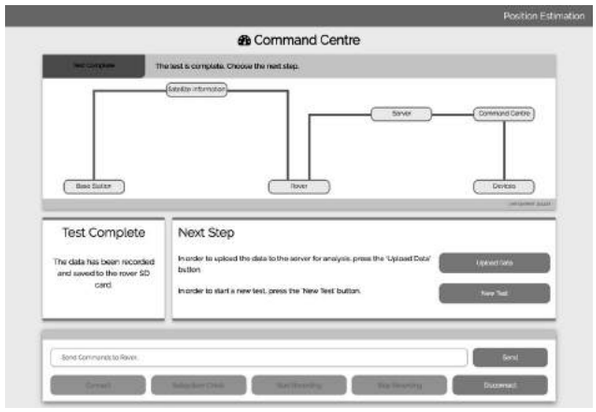


Figure 1: The developed web application

Figure 2: Path tracked using different techniques

A Smart Wearable System for Tracking Human Interactions

Student: Neil M. Gauci / Supervisor: Dr Ing. Brian Zammit / Co-Supervisor: Ing. Nicholas Borg

Introduction

The acquisition and processing of complex human behaviour is becoming increasingly possible with improving technologies, cloud computing and artificial Intelligence. There are several areas which could benefit from a deeper understanding of human behaviour including health [1], team coordination [2] and targeted advertisements [3].

Project Objectives

The project objective was to design a system consisting of hardware and software components which enable the tracking of face-to-face human interactions. The engineering challenge was to create a low power and compact electronic hardware which gathers interaction data and transfers it remotely for storage.

Project Methodologies

Face-to-face human interactions constitute of various features such as speech and head orientation. However, for this project only proximity estimation was used for sensing interactions due to its simplicity and practicality. The system designed consists of three main components namely battery powered smart wearables, wall powered devices and a cloud interface. The smart wearables and wall devices are used to sense interactions. The wall powered devices are also responsible of uploading data to the cloud which is designed to receive, process and store a large stream of interaction data. A block diagram of the system is illustrated in Figure 1.

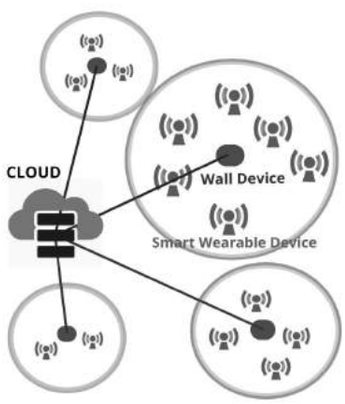


Figure 1: Interaction sensing system

Results and Achievements

The two hardware devices developed for tracking interactions were designed, built and tested successfully. Received signal strength indicator (RSSI) was used for proximity sensing. The wireless technology chosen for this purpose was Bluetooth Low Energy (BLE) which was determined to be the best choice with regards to power efficiency and RSSI interference. The smart wearable also includes an accelerometer which was configured to detect spatial movement and set the hardware to sleep mode during periods of stationary movements, to improve the power efficiency of the wearable device. Besides acting as a BLE scanner, the wall device successfully uploaded data to the cloud through a WiFi connection. Both devices were designed to be compact and unobtrusive. The wrist wearable prototype is shown in Figure 2.

References

[1] Asier Aztira, Somaya Ben Allouch and Hamid Aghajan Chih-Wei Chen, "Understanding the Influence of Social Interactions on Individual's Behaviour Pattern in a Work Environment," 2011.

[2] Alessandro Montanari, "Mobile Sensing for Social Interaction Monitoring".

[3] A. E. Hühn, "Location-based advertising in context : the effects of location-congruency, goal relevance & medium type," 2016.

Figure 2: Smart wearable device

Automation of a real-time stage Followspot

Student: Joeloui Grima / Supervisor: Dr Ing. Brian Zammit / Co-Supervisor: Mr Andre Micallef

Introduction

The theatre followspot is a type of profile lantern used by an operator to light a specific performer acting on stage. The operator is usually situated somewhere in the front of house and is required to manually track the performer as accurately as possible. The operator is also able to manipulate some other aspects such as the brightness and the beam angle. Controlling all the inputs while accurately tracking the actor requires good judgement and a great deal of skill and experience [1].

Project Objectives

The proposed project deals with designing and developing a system that automates the process of operating the followspot. To this end, a system consisting of an indoor human tracking system together with a control system for the followspot was implemented. The actor position is found in real time and then converted to pan and tilt values compatible with the followspot inputs (known as a “moving head”).

Project Methodologies

After reviewing several indoor localisation schemes, a system based on the Time-of-Flight (ToF) of a Radio Frequency (RF) signal was chosen. The strength of RF waves has the ability to penetrate through solid objects, thus ensuring localisation even in Non-Line-of-Sight (NLoS) scenarios between the transmitter and the receivers. The implemented hardware platform consists of four sensors: three fixed anchors and a wearable tag. The anchors are mounted above the stage whilst the tag is attached to the performer. Signal time-of-flight data is captured and processed using a *Qt* software development kit (SDK). The coordinates of the performer are then computed using a trilateration algorithm. The pan and tilt values for the moving head are then calculated (these values represent the equivalent rotation in the ‘x’ and ‘y’ direction respectively). The control data is converted in a DMX-512 compatible format together with other data fields such as brightness, beam angle, etc. and sent over to the moving head.

Results and Achievements

Various tests were performed to characterise the system reliability, accuracy and response. First the communication data link was tested and then the system was tested for static response on fixed targets. From this test, the accuracy and precision of the system were characterized. A test bench consisting of an array of light dependent resistors (LDRs) was also constructed to accurately detect the intensity of the incoming light beam. Dynamic tests were also required and to this effect two additional test benches were developed. A 2D rotatable arm was used to characterise the delay of the system whilst a conveyor system mounted on variable height stands, was used to find the response in 3D. Finally, real-life tests were conducted by setting up the complete system in the Sir Temi Zammit theatre hall as shown in Figure 1.

Figure 1: Testing Setup on Stage

References

[1] T. N. Hay and S. Weiss, “Design and Implementation of an Automatic Followspot Tracking System,” vol. 44, no. 0, pp. 1–3, 2004.

Design of a Fault Tolerant Embedded System for an Automotive Application

Student: Nicholas Micallef / Supervisor: Ing. Evan Joe Dimech / Co-Supervisor: Dr Ing. Marc Anthony Azzopardi

Introduction

The use of electronic systems predominates within modern vehicles. Features such as electronic stability control as well as emerging technologies such as autonomous vehicles are directly targeted at reducing hazards encountered by drivers. With embedded systems being continually relied upon to provide high levels of safety, the importance of both hardware and software is intensified. This drives the necessity for a well-structured development process for designing, testing and producing such systems.

Project Objectives

The aim of this project was to study the relevant standards in practice, along with the corresponding development processes used in industry. Reviewing literature pertaining to possible error causes as well as their mitigations provided the knowledge with which to tackle such issues.

Project Methodologies

A design process emphasising on reliability was used to modify an existing system with redundant electronic subsystems which was developed for an automotive application. The modifications were applied to both hardware and software to provide an increased level of mission-critical reliability. This was also done while minimising the impact on safety as much as possible. All inputs and outputs were maintained, such that the modified system could effectively replace the original as seamlessly as possible.

To this end, the main focus of the redesign involved the introduction of the ability for microcontrollers to override one another. Various design concepts were considered to provide this feature, as well as some additional elements. Major requirements such as temperature, component certifications and cost were considered during selection of the preferred concept. The resulting system was subject to a failure modes and effects analysis (FMEA) as a part of the design process, which aided in uncovering and solving the highest priority threats.

The software development process described within the ISO 26262 (Road vehicles – Functional safety) [1] standard was then followed. This involved the use of the V-Model with the corresponding design and testing phases. Along with established software development guidelines, such as MISRA C [2], and good programming practices, this served to correctly design the software and provide the required documentation. Test plans were drawn out to validate the results of each of the design phases in accordance with the pre-established requirements.

Results and Achievements

The final system was compared to a simple system with no software safety measures. The results displayed a significant reduction in invalid outputs provided by the system, along with an increased amount of overall errors. This result proved the advantages of redundant systems while highlighting the disadvantages of the corresponding system complexity in both hardware and software. This further proves the need for a heightened emphasis on correct software development and testing, especially in the case of safety focused systems.

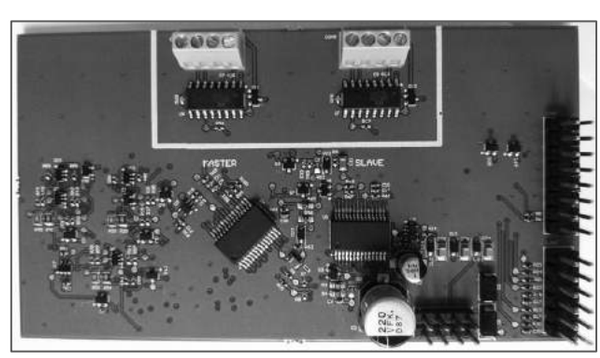


Figure 1: Final system PCB

References

[1] International Electrotechnical Commision, Functional Safety, Geneva, Switzerland, 2010

[2] Motor Industry Software Reliability Association, MISRA C:2012, Nuneaton, Warwickshire: MIRA, 2012

Pulsed Plasma Thrusters for Pico Satellites

Student: Matthew Sammut / Supervisor: Dr Ing. Marc Anthony Azzopardi / Co-Supervisor: Dr Ing. Maurizio Fenech

Introduction

The Pulsed Plasma Thruster (PPT) is a mechanically simple electric propulsion device which makes use of a solid propellant. Pico-satellites require active propulsion to maintain their meta-stable lower altitude orbit where they will naturally de-orbit in a short time if any malfunctions occur. Additionally, the PPT allows for orbital manoeuvres to be performed.

Project Objectives

These include running a simulation on the thrust generating mechanism, improving the controllability of the high voltage discharge circuit, building and programming a suitable discharge controller, and testing the circuit in its representative environment while improving its functionality as necessary.

Project Methodologies

Four prototypes were designed in total, three of which were assembled on a printed circuit board (PCB). The circuits were tested at atmospheric pressure and inside a vacuum chamber capable of reaching 6.9×10^{-6} mbar. Figure 1 depicts the plasma plume generated by the fourth prototype.

Additionally, the datasheet of each component implemented within the PPT system was thoroughly analysed to ensure that they can withstand the electromagnetic interference (EMI) caused by the PPT, the ultra-high vacuum environment, and the cosmic radiation.

Results and Achievements

Firstly, the controllability of the high voltage discharge circuit was improved, and it was found that the voltage on the capacitors in the Cockcroft-Walton voltage multiplier increases at a non-linear rate as higher voltages are generated. The electric field strength, direction and profile of the PPT in high vacuum were observed by running a simulation.

The surface of the PPT was examined after testing, and a carbon layer had formed on the propellant as observed by researchers [1]. It was noted that the discharge path of the plasma was dictated by sharp edges at a microscopic level. Furthermore, the 3D profile of the Teflon surface (Figure 2) shows that ablation occurred next to the main discharge points and close to the PPT inner electrode.

References

[1] M. Keidar, I. D. Boyd, R. L. Burton, E. L. Antonsen, D. White, J. H. Schilling, S. Bushman, G. G. Spanjers, D. R. Bromaghim, C. J. Lake and M. Dulligan, “AFRL MicroPPT Development for Small Spacecraft Propulsion,” in 38th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, Indianapolis, 2002.

[2] D. Cumbo, “Electric Propulsion for Pico Satellites ” University of Malta,” 2017. [Online]. [Accessed 10 July 2017].

[3] P. V. Shaw, “Pulsed Plasma Thrusters for Small Satellites” University of Surrey, 2011. [Online]. Available: http://epubs.surrey.ac.uk/26851. [Accessed 15 March 2018].

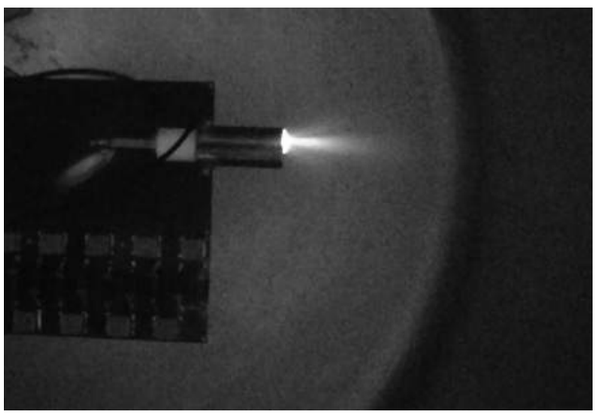


Figure 1: The Plasma Plume of the Fourth Prototype

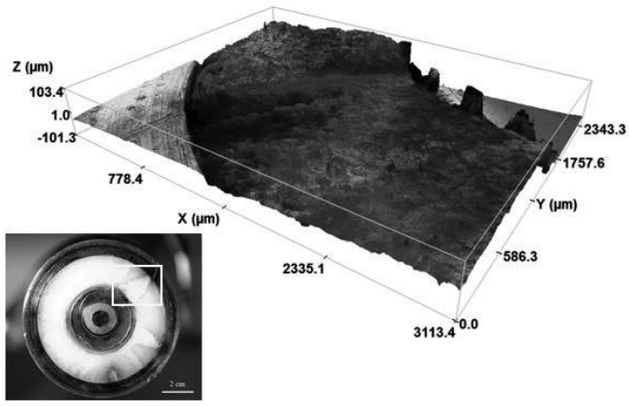


Figure 2: The 3D Profile of the Teflon Propellant

Design of a Software Radio Hardware Platform for a PicoSatellite

Student: Oliver Vassallo / Supervisor: Dr Ing. Marc Anthony Azzopardi / Co-Supervisor: Prof. Victor Buttigieg

Introduction

The development of the CubeSats Standard has allowed universities and other institutions to make satellite design and experimentation a feasible project in terms of costs and development time. The most recent boom in CubeSats technology is the pico-satellite standard, which is the size of 5cm cube. This comes at a cost of reduced power generation, volume and surface area when it comes to the implementation of the various systems within the satellite. Nevertheless, in any satellite system, no matter the size, a communication platform is required in order for any data to be exchanged. This dissertation presents a preliminary design for the hardware necessary to sustain a software defined radio based communication system.

Project Objectives

The project objectives were to design a preliminary hardware architecture for a communication system that can be used in a PicoSatellite. The PicoSatellite form factor imposes strict requirements which must be abided by the newly design architecture.

Project Methodologies

The project analyzed various architectures available to implement the communication system. One way to do this is by using a software radio whereby the modulation and other signal processing functions are implemented almost completely in software, which results in higher flexibility and minimal hardware use. Various architectures to implement this were discussed, analyzed both the power consumption, the processing power required and making sure it fits within the available resources as well as designing the system to be as small as possible thus having the required a minimal area on the board.

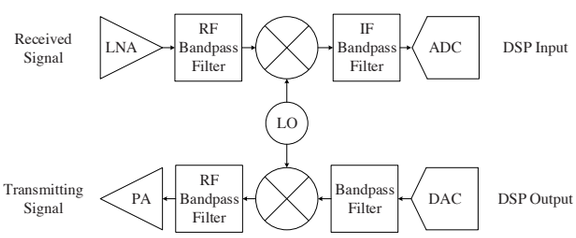


Figure 1: System Block Diagram

Results and Achievements

The system designed transceiver operates on the UHF band with a frequency ranging between 435MHz and 438MHz. Starting from the transmitter section, the two remaining options for data generation and synthesis are to use either a PWM or PDM signal, or to use an IC to create the baseband data. Baseband data generation is preferred as it minimizes the processing load on the FPGA. Moreover, generating the signal using a PWM is preferred over the other two variants mainly because when compared with the PDM generation technique, the PWM has finer control while when compared with the specific IC, the power required, and area used are far less. Moving on to the receiver, a single stage heterodyne receiver with a narrow bandpass filter is preferred. This requires minimal area as a single mixer and oscillator are being used, reducing the power consumption since not many components are active at the same time. Given that a single stage filter is used, the best sampling technique would be sub-sampling simply because should the oversampling or sampling the signal at Nyquist options were to be adopted, the FPGA will not be able to cope with the high data rate. Furthermore, the sub-sampling technique has an added processing gain, which increases its SNR of the digital signal and due to the added IF amplifier, the IF gain can be increased, further increasing the SNR of the signal and hence improving the BER.

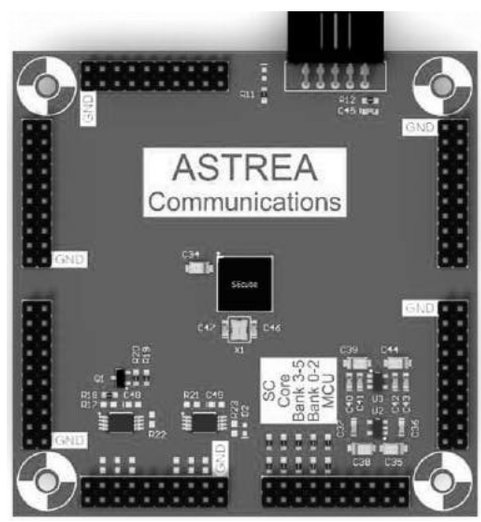


Figure 2: Designed development board

Thermoelectric Design for a High Speed Camera

Student: Jamie Willoughby / Supervisor: Dr Ing Marc Anthony Azzopardi / Co-Supervisor: Mr Andre Micallef

Introduction

The shutter speed of a high speed camera is typically limited by the signal-to-noise ratio (SNR) created by the image sensor itself. This noise generally has a thermal origin and therefore cooling the given image sensor will reduce this SNR thereby increasing the maximum achievable frame rate for a given dynamic range.

Project Objectives

The project required the construction of a mock-up thermal heat pumping circuit such that two thermoelectric modules (TEM's) may be correctly sized. These would be limited to an area constraint of 40 x 40mm as this setup would eventually be placed inside a vacuum chamber in order to eliminate convective heat loads as well as reduce water condensation effects. The next requirement was that of the design and implementation of two thermal feedback control loops in order to accurately control the TEM's chosen given any required temperature difference. With the completion of these tasks the design of the thermoelectric heat pump controller would be completed.

Project Methodologies

Thermal Circuit Design

The design and construction of an adequate multistage thermal heat pump circuit with properly sized TEM's was required. Figure (1) shows the thermal circuit constructed including the chosen heat dissipation method as well as the heat load imposed on the designed circuit.

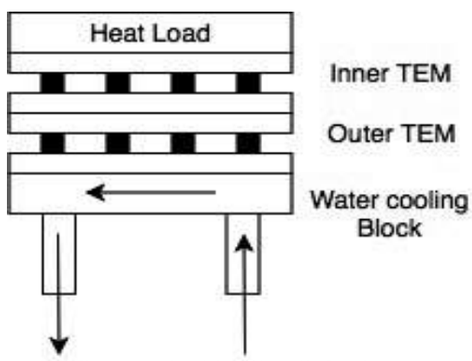


Figure 1: Thermoelectric Circuit Design

Control Loop Design

The next requirement involved the design of two individual controllers using the necessary temperature sensing together with specific linearization blocks in order to achieve quick and accurate responses given any desired temperature difference. These linearization blocks were required as TEM's typically have non-linear responses and therefore require linearization in order to achieve a linear control system. The temperature difference response versus the respective voltage of the TEM was characterized for a fixed load. An inverted version of this response was subsequently included in the control loop in order for the system to supply adequate voltages to the TEM's given a particular temperature difference. Properly tuned PI controllers were also included in the control system in order to produce responses with no steady state error together with minimal peak overshoot. Software amendments were also included in order to divide the overall required temperature difference into respective contributions to each TEM using a splitting variable. This therefore completed the design of the thermoelectric circuit required and such was tested in order to understand the maximum temperature difference achievable.

Results and Achievements

The maximum temperature difference achievable was tested and resulted in a 52°C difference. Figure (2) shows the result achieved. Heat transfer inefficiencies resulted in a reduced maximum temperature difference achievable. This would be improved with proper insulation inside the vacuum chamber in order to improve heat transfer.

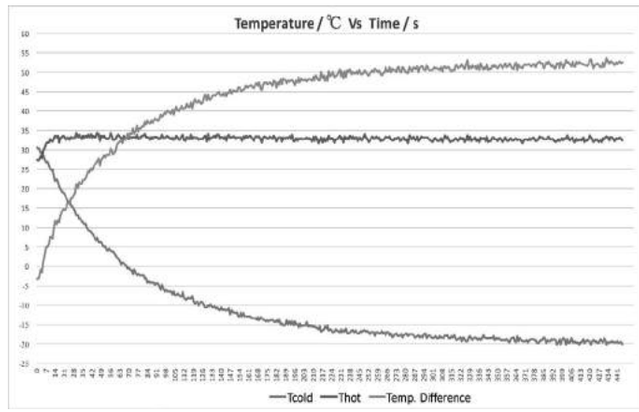


Figure 2: Maximum Temp. Difference Achieved

Modelling the Impact of Load Changes on a Notional All-Electric Ship Power System

Student: Kenneth Barbara / Supervisor: Dr Cedric Caruana / Co-Supervisor: Dr Alexander Micallef

Introduction

Electric propulsion is becoming the standard for future ships. Electric propulsion brings several advantages such as increased fuel efficiency, reduced emissions and flexibility in power system design. All-electric ships are powered by generators that feed various shipboard loads. Load changes are reflected in the system voltage and frequency and must be controlled to maintain system stability.

Project Objectives

The aim of this project was to design a software model on PSCAD that represents an actual all-electric integrated ship power system., implement the frequency and voltage droop controllers and simulate the system to test its behaviour under realistic operating conditions.

Project Methodologies

Actual parameters from generator and machine manufacturers were utilised to model the system such that it reflects an actual ship power system. The model was based on a low-voltage system that can be found on a Product Tanker and was provided by Siemens Low-Voltage Solutions. The system consists of different sized generators supplying two propulsion machines, a bowthruster and general ship loads. Droop control was employed to enable the sharing of active and reactive power depending on the generator ratings. The simulation was subjected to various loading scenarios to verify whether the system maintains stability during and after the load transients.

Results and Achievements

The power system was tested by applying different load scenarios that reflect different operating conditions such as an increase in propeller load torque due to adverse sea conditions. The results show that the power system does in fact react differently in different loading scenarios. By implementing frequency and voltage droop control, the generators shared the active and reactive load power depending on their respective droop settings. Figure 2 illustrates the active power supplied from a 2.53MVA generator and an 800kVA generator. The 2.53MVA generator was set to have a 3% droop setting, while the 800kVA generator was set to have a 5% droop setting. The different droop settings enabled the generators to share the per-unit active power differently. One can check whether the generators are supplying the per-unit active power as desired by calculating the ratio of active powers. This should reflect the speed droop settings, i.e. $\frac{3}{5} = 0.6$. Similarly, with voltage droop control, the generators shared the amount of reactive power according to their respective settings. The power system did not become unstable in any scenario as it was able to reach steady-state operating conditions after applying several load changes.

It is recommended that further research in this field will focus on the improvement of the overall system power quality due to the effects of non-linear loads such as VV/Vf (Variable Voltage/Variable Frequency) drives.

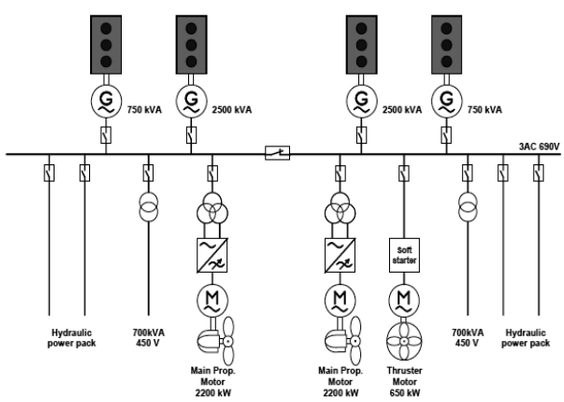


Figure 1: Power System Configuration

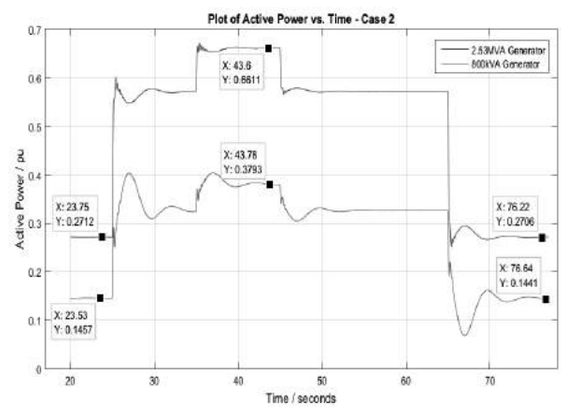


Figure 2: Generator Active Power Sharing

Smart Loads based on “Electric spring” Concept

Student: Racquel Ellul / Supervisor: Dr Ing. Alexander Micallef / Co-Supervisor: Dr Ing. John Licari

Introduction

The integration of renewable energy sources into the grid has been significantly increasing in recent years. This increase in renewable energy sources is creating new challenges for electrical engineers because of the power quality problems due to these distributed generation sources are also on the rise.

Project Objectives

In this project the performance of smart load based on the electric spring (ES) concept in order to mitigate voltage fluctuations on critical loads was analysed.

Project Methodologies

In electrical networks, electrical loads can be classified in two categories: ‘non-critical loads’ which are loads that can withstand a range of supply voltage variations without affecting the operation or performance of the same equipment; ‘critical loads’ which are loads that does not support voltage variations over a wide range. For the latter, regulation of the supply voltage is critical to ensure that the electrical equipment does not sustain any damage during normal operation.
The voltage regulation is done using the ES, which uses the concept of Hooke’s law applied to electrical energy stored in capacitors and batteries.

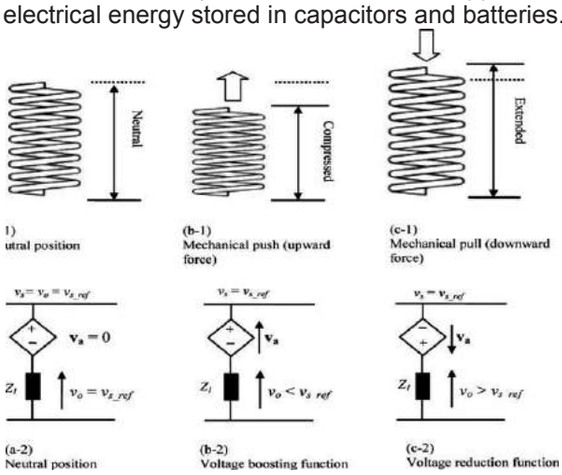


Figure 1: ES operating modes

Results and Achievements

The ES was tested for different scenarios. Initially it was tested for an undervoltage condition and an overvoltage condition, then it was tested with varying conditions in order to emulate RES in practice.

In all conditions the ES was effective, as it can be observed in Figure 2, which shows the voltage across a critical load. Initially the voltage across the critical load is below or above $325V_{peak}$ then after some time it settles to $325V_{peak.}$

From the tests done it was concluded that the most effective type of ES is ES-2, as defined in literature. This type uses a battery as a storage system. Hence, it compensates for both reactive and active power.

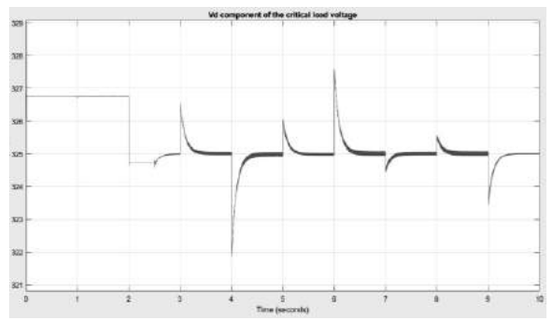


Figure 2: Peak of the critical load voltage reaching steady state

References

[1] S.-C. T. C. S. Yan Shuo, “Electric Spring for Power quality Improvement”.

[2] M. I. a. S. Y. (. H. Chi Kwan Lee, “Reduction of Energy Storage Requirements in Future Smart Grid Using Electric Spring”.

[3] S. M. I. B. C. S. M. I. Zohaib Akhtar, “Smart Loads for Voltage Control in Distribution Networks”.

Three Phase Inverter with Droop Control

Student: Daniel Farrugia / Supervisor: Dr Alexander Micallef / Co-Supervisor: Prof. Ing. Maurice Apap

Introduction

In early years, electricity was only supplied to the grid from centralized power plants without any additional energy sources. Recently, there has been significant progress and development in energy storage systems and renewable energy sources which nowadays play an important role in the supply of electricity. This vast increase in distributed energy resources (DER) causes a large network which is much more difficult to control safely and efficiently [1].

Consequently, power engineers decided to form small segregated networks consisting of these DERs in controllable systems, thus forming a microgrid.

Project Objectives

The aim of this project was to design a droop controlled three phase inverter within an AC microgrid. This includes the design and simulation of the required control loops, the hardware interface for a three phase inverter and several testing to ensure adequate hardware functionality.

Project Methodologies

The project was divided into three stages. Primarily, the system modelling was designed and various simulations were carried out in order to ensure a correct design. The simulations investigated the three phase inverter switching, the output signals with and without an LCL filter, the nested current and voltage control loops using vector control and lastly the primary control using the droop technique.

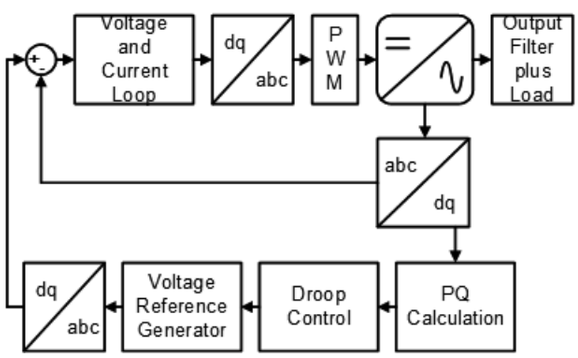


Figure 1: Block Diagram of Droop Controlled Inverter

In the second stage, the design of the hardware interface for the three phase inverter was implemented. This included the LCL filter, multiple sensing boards, a gate drive interface board and a signal conditioning with protection board.

The final stage consisted of sensor calibration and protection tests which were carried out to ensure the correct operation of the hardware interface. A digital signal control was also used to apply the appropriate three phase inverter switching and test the system. The nested current and voltage control loops were also implemented on hardware.

Results and Achievements

The results obtained indicated that readings from both the simulation design and experimental setup were close to the theoretical values. Correct dynamic responses of controllers resulted in the desired output waveforms with zero steady state error.

References

[1] Hatziargyriou N., Asano H., and Marnay C., 'Microgrids', IEEE Power and Energy Magazine, 2007, Vol. 5, No. 4, pp.78-94

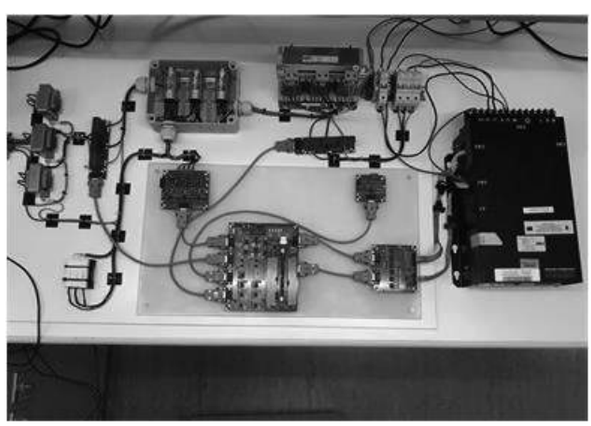


Figure 2: Hardware Interface Setup

Design of an Electric Kinetic Energy Recovery System

Student: Matthew Galea / Supervisor: Dr Ing. Reiko Raute

Introduction

The increasing worldwide concerns regarding the rising negative effects on climate change and the alarming pollution levels being recorded in all major cities has created a surge in market share and sales of electric cars. Technology has kept pace with these demands with constant development and improvement of hybrid technology, battery efficiency, manufacturing costs, etc

One such development in technology has been the implementation of KERS - Kinetic Energy Recovery System for recovering a moving vehicle's kinetic energy, upon braking. The recovered energy is stored in a reservoir (accumulators or high voltage batteries) for later use in operation or under acceleration.

Project Objectives

The main objectives of this project were the design, assembly and implementation of an electric KERS applied to a DC motor. This entailed the design of a switch-mode DC-DC converter and the design and testing of a PI current controller.

Project Methodologies

This project was split in different sections, namely, the literature review, the design of the DC-DC converter and the PI current controller, the implementation stage and finally the testing stage.

The literature review being a general overview of an electric KERS system and how it functions and an outline of the different switching methods and the components used to build a DC-DC converter.

The design section involved the actual design and eventual construction of the DC-DC converter and the mathematical approach towards designing a PI current controller.

Following the design of the converter and current controller, these were implemented on a PCB and by using the different modules of the microcontroller, including the PWM module and ADC module, the PCB was tested and the current controller was implemented on the microcontroller.

Results and Achievements

Successful operation of the hardware was achieved by testing the forward sequence and reverse sequence on the DC-DC converter.

The current controller though implemented did not function as expected, due to some non-linearity issues of, due to this not being calibrated. the current sensor and some technical difficulties with the micro controller software.

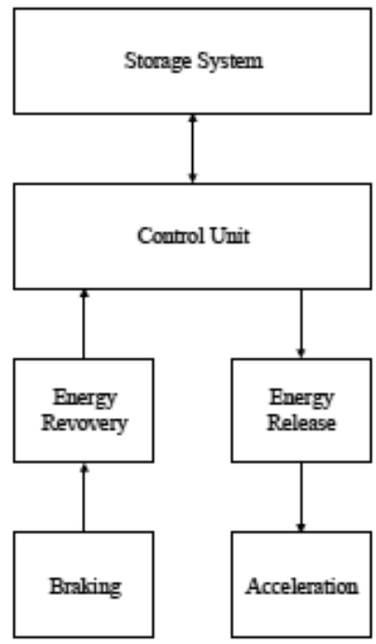


Figure 1: Block Diagram of an Electric KERS

References

Conference
[1] Harsh Gupta (January 2003)
https://www.slideshare.net/harshgupta161/kinetic-energy-recovery-system-kers

Book
[2] K.Ogata. Modern Control Engineering Pearson, 2010

Analysis of Solar Photovoltaic System operating under Partial Shading Conditions

Student: Glen Borg / Supervisor: Dr Cedric Caruana Mifsud / Co-Supervisor: Dr Ing. John Licari

Introduction

The demand for photovoltaic (PV) systems continues to increase due to their reliability, relatively low prices, and availability of government grants. As most open areas have already been taken up, PV systems are being installed closer to obstructions making partial shading a reality as evidenced in Figure 1. It is thus important to study the performance of PV systems under partial shading conditions which makes understanding of their behavior causing unnecessary heating of panel and damage.

Project Objectives

The aim of this project is to analyze the characteristics of PV strings and the performance of popular MPPT techniques under various partial shading conditions. The objectives are the development of a software model capable of operation under various shading patters; investigation of the impact of the use of bypass diodes on the string characteristics; enhancement of a popular MPPT technique to cater for multiple peaks and experimental test under real conditions.

Project Methodologies

A software model based on [1] was developed as a base platform, which was then converted into multiple configurations. A three-cell configuration with bypass diodes, emulating a typical PV module, was used to study the local and global peaks of the power-voltage characteristic under partial shading condition. A classical MPPT algorithm was applied to the model to examine its limitations under partial shading conditions. A simple enhancement was applied to the algorithm which enabled it to track the global maximum.

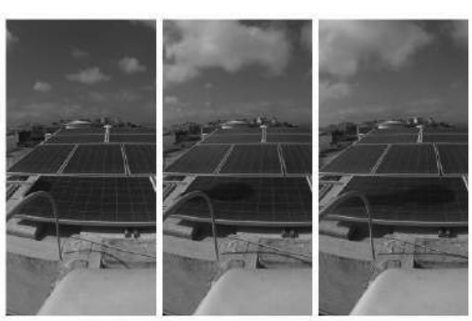


Figure 1: Shading of panel throughout a day

Data was collected from an actual system affected by partial shading to corroborate the studied characteristics. Further, a sample of 100 systems was considered to determine the impact of partial shading on energy yield.

Results and Achievements

From the simulation results, it was concluded that the number of peaks expected from a partially shaded PV string corresponds to the number of different shading present. The first peak corresponds to the least shaded cell/s while the last peak corresponds to the most shaded cell/s. The voltage at which these occur depends on the number of cells exposed to the particular irradiance and the contribution of the other cells for the latter case. The location of the global peak can vary and depends on the relative irradiance on the different cells, as shown in Figure 2.

From the MPPT analysis, it was confirmed that classical algorithms can get stuck at local maxima. The introduction of a sweep algorithm which searches for the global maximum every defined number of minutes allowed the algorithm to track correctly.

Data from an actual module showed operation under partial shading conditions, where the operating point was shifted to a local maximum. Partial shading was seen to affect around 33% from a sample of 100

References

[1] S. Pukhrem, “A PHOTOVOLTAIC PANEL MODEL IN MATLAB/SIMULINK,” Research Gate, Wrocław, 2013.

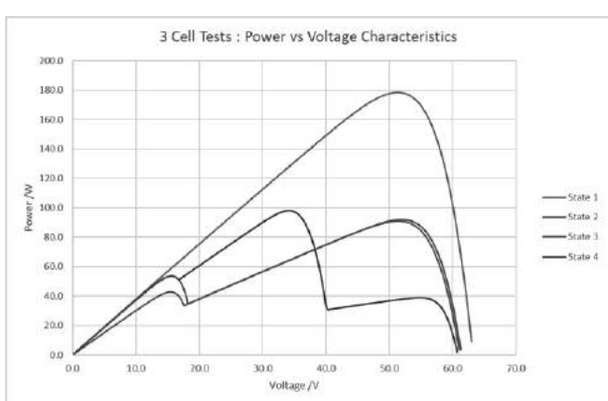


Figure 2: Peaks at different shading irradiances

MPPT Control of a DC/DC Converter for a HAWT

Student: Justin Xuereb / Supervisor: Prof. Ing. Spiteri Staines / Co-Supervisor: Dr Ing. John Licari

Introduction

This dissertation concerns, the application of Maximum power Point Tracking (MPPT) for a small wind turbine. A small wind turbine is a type of turbine which does not exceed 100kW and is mainly found installed close to urban areas where large scale wind turbines cannot be installed. The MPPT algorithm used in this project is based on the Hill-Climb technique.

Project Objectives

The main objectives of this project are to create a model of the micro-wind turbine and a DC/DC converter using MATLAB SIMULINK and to construct a power converter and its control system for implementation in an experimental setup.

Project Methodologies

This project was split in 4 main parts, which are the literature review and system design, the modeling of the system on MATLAB SIMULINK, the construction of the power converter with its control system, its testing and results.

In the literature review, an analysis of the MPPT algorithm and the closed loop control system of the DC/DC converter was carried out. The design of the system involving the wind turbine, the DC Motor with the DC Drive, the PMSG and the power converter were carried out.

The modelling was carried out on SIMULINK. The wind turbine was modelled at its rated power of 1.4kW at 500rpm. The DC drive which was used to emulate the wind turbine was controlled by a current reference. The PMSG was modelled and cascaded with the wind turbine and the DC drive. The DC/DC converter was first tested at a fixed input voltage at a fixed duty cycle. Following its successful testing it was connected to the other components of the system. For testing, a fixed current reference was fed to the DC/DC converter to observe the performance of the system at a fixed current. Following this the MPPT algorithm was implemented to provide the current reference.

Afterwards the power converter with its control system were constructed on a PCB.

Results and Achievements

Maximum Power Point Tracking of the FORTIS-based small wind turbine PMSG was successfully achieved on SIMULINK. At a wind speed of 12m/s, a power of 1kW was obtained.

The power converter with its control system were implemented on a PCB and were tested under various conditions. An experimental test rig consisting of a DC drive and the FORTIS PMSG was used to emulate the small wind turbine system. The power converter was fed by the three-phase output of the PMSG.

However, due to noise issues in the current sensing, the current control and the MPPT algorithm could not be implemented in practice.

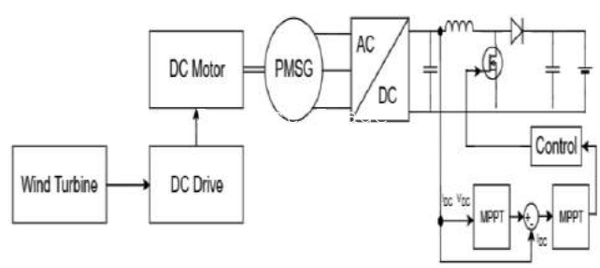


Figure 1: System Block Diagram

References

Paper
[1] Zammit D, Spiteri Staines C, and Micallef A, 'Incremental Current based MPPT for a PMSG Micro Wind Turbine in a Grid-Connected DC Microgrid', Malta, 2017

Paper
[2] Zammit D, Spiteri Staines C, and Micallef A., 'MPPT with Current Control for a PMSG Small Wind Turbine in a Grid-Connected DC Microgrid', Malta, 2017.

Book
[3] Abela N., 'Small Scale Wind Energy Conversion', Malta, 2013.

PMSM Servo Drive with Resolver

Student: Daniel Lendi / Supervisor: Dr Ing. Reiko Raute

Introduction

When it comes to applications of electric motors in general, some sort of control always has to be applied. In the case of the Permanent Magnet Synchronous Motor (PMSM), which is an alternating current machine, vector control is the most commonly used type of control. Vector control requires the position of the magnetic field produced by the rotor's permanent magnets to control the motor as desired.

Project Objectives

The aim of this dissertation is to implement a servo drive for a PMSM using a resolver to achieve position, speed and current/torque control. Circuitry to interface the resolver with an inverter's micro controller and firmware for the servo drive are to be developed.

Project Methodologies

A resolver is a system containing a rotary transformer and is used to read the angular position of a motor's rotor. Since a resolver is an analogue device, its angular position data must be digitised such that the micro controller of the inverter can process it. For this purpose, a resolver interface circuit was designed and implemented on a printed circuit board.

For the implementation of a versatile PMSM servo drive, a three-stage cascaded vector control loop was implemented. This three-stage control loop comprises current/torque, speed and position control including second order position trajectory planning.

Figure 1: PMSM with inertia disk

Results and Achievements

The resolver interface circuit was successfully implemented, providing 16-bit angular position data to the inverter's micro controller through a serial peripheral interface. All the necessary machine parameters were obtained, such that it may be modelled and controlled efficiently.

Cascaded current/torque, speed and position control loops using vector control were successfully realised. These control loops were implemented using PI-controllers and a P-controller for the position loop. The performance of the designed controllers has been evaluated, yielding rise times of 3ms, 50ms and 500ms respectively when issued a step reference.

A braking resistor mechanism has been added in parallel to the DC link voltage of the inverter, such that fast deceleration may be achieved without damaging the DC link capacitor.

The developed PMSM servo drive was subjected to several tests in order to evaluate its performance. The maximum speed achievable with a DC link voltage of 120V is approximately 900rpm. The servo drive may also accelerate by 240rpm with a rise time of 50ms. Speed reversal from clock-wise to anti-clockwise direction or vice versa and rapid braking of the motor is also possible. The implemented second order trajectory planning calculates smooth motion profiles with user defined parameters for maximum speed and acceleration to transition from one angular position to another.

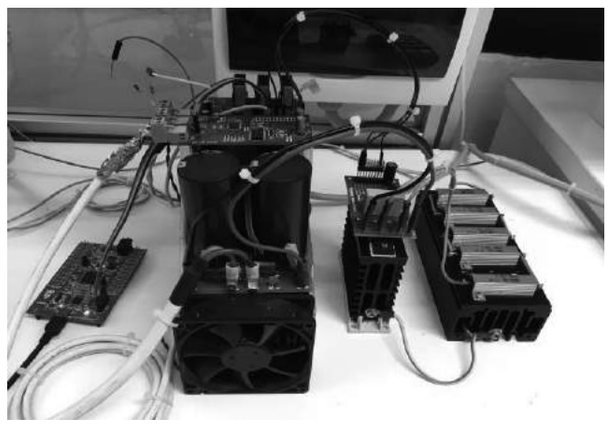


Figure 2: Inverter and interface board setup

A 1kW Drive for an Electric Bicycle

Student: Nicholas Zammit / Supervisor: Prof. Joseph Cilia

Introduction

This project involved the designing, building and testing of a drive system for an electric bicycle (e-bike). These included the battery, the power electronic controlling circuitry, and the electronic, microcontroller based controller board. This drive system was built in order to reach the power rating of 1kW.

Project Objectives

Objectives included the design and building of a lithium battery capable of delivering a peak power output of 1kW. Also a reprogrammable, microcontroller based controller was required to process the rider's inputs and control the brushless DC motor (BLDC) bicycle motor. Figure 1 shows a block diagram of the complete system.

Project Methodologies

The systems currently used in electric bicycles, including the types of batteries and motors used were investigated in the literature review. The different methods of rotor position detection for a BLDC motor were also explored. Reference was made to the operating principle of a BLDC motor described in [1].

An existing e-bike without a battery or controller was acquired, and the systems developed in this project were designed to fit onto this bicycle.

Considering the peak power output requirements, a battery was designed from individual lithium-ion cells. The battery was required to fit into the original battery compartment of the provided e-bike, including the required balancing and protection circuitry.

This battery was built in a way that individual cells could easily be replaced, as opposed to traditional battery construction methods which use spot welding, making them unserviceable.

A microcontroller was sourced and programmed in order to react to the user input of the throttle and brakes and provide an output current onto the motor based on these inputs. This control board was designed to read the states of hall sensors inside the motor and hence provide the correct control signals.

The current in the motor was controlled by a closed loop proportional integral (PI) controller.

A three phase inverter using MOSFET switches driven by a high and low side driver circuit was built in order to power the motor from the battery.

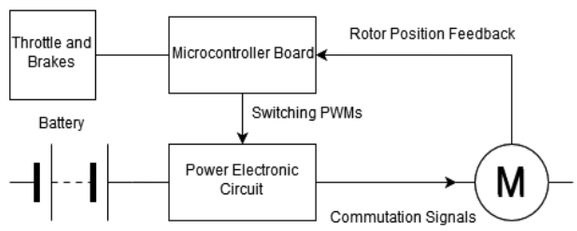


Figure 1: The implemented control loop

Results and Achievements

Hence the complete drive system was designed, built and implemented.

A battery capable of supplying a peak power output of 1kW was built and tested with different loads. The battery protection and balancing circuitry was also tested.

The electronic controller was successfully built and implemented, being able to control the motor of the bicycle at different speeds and power levels.

The microcontroller based controller correctly responded to the hall sensor based input signals of the motor and the user brake and throttle inputs.

The closed loop PI controller was used to control the current to the reference provided from the throttle signal, as shown in Figure 2.

References

[1] Moreira, 'Indirect Sensing for Rotor Flux Position of Permanent Magnet AC Motors Operating Over a Wide Speed Range' IEEE Transactions on Industry Applications, 1996, Vol. 32, No. 6, pp.1394 -1401

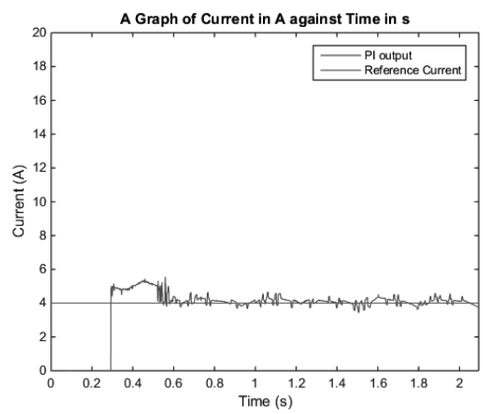


Figure 2: Response for a 4A reference input on the Motor

Design and Implementation of a Smart Wheelchair

Student: Matthew Aquilina / Supervisor: Dr Ing. Marvin K. Bugeja / Co-Supervisor: Prof. Ing. Simon G. Fabri

Introduction

Wheelchairs have improved the lives of many people with limited mobility. Yet, even after decades of development, conventional wheelchairs are still not a viable option for millions of people with some particular needs. Many medical conditions, for example, Cerebral Palsy or Amyotrophic Lateral Sclerosis (ALS), prevent people from having the right amount of coordination or strength to propel or steer a conventional or Powered Wheelchair (PW).

A possible solution for these people is a Smart Wheelchair (SW). A SW is the product of the merging of mobile robotics and artificial intelligence with current PW technology. SWs overcome many of the limitations of normal wheelchairs by adding an extra layer of intelligence to the system.

Project Objectives

The aim of this project was to pioneer SW research at the University of Malta through the design and implementation of a new SW system utilising modern hardware. To this end, a computerised sensor system, a software architecture and a number of autonomous functions needed to be built on top of a normal PW.

Project Methodologies

To design and build the hardware components of the SW (Figure 1), a set of navigational sensors and a computer system were installed onto a standard PW chassis. The original manufacturer motor driver was removed and replaced by a software-controlled driver. The SW was powered through a custom-built power system using the PW battery. A Python-coded software infrastructure using Robot Operating System (ROS) was built on top of this hardware, connecting each sensor and hardware unit together into a unified parallel and modular system of nodes. Various semi-autonomous and autonomous algorithms were designed and implemented onto the wheelchair using the VFH and A* path planning algorithms. These were designed to allow the SW to take control of its own navigation in both a known and unknown environment. A mapping and localisation system was also included, allowing the SW to act as a mapping agent for its own autonomous functions.

Results and Achievements

The PW was upgraded successfully into a Smart Wheelchair. All hardware units were incorporated into a single operational unit through the implemented electrical and software system. The SW was enhanced through the inclusion of a joystick/remote sensitive navigational aid unit and a fully-autonomous map-based navigation system. These algorithms were incorporated into one GUI-controlled system, easily accessible through the touchscreen installed on the wheelchair. Each navigation module was tested out and verified through typical use scenarios in indoor environments. Figure 2 shows one of the tight-space scenarios the wheelchair was capable of traversing autonomously. Whilst the SW was built as a complete and finished system, this project has also laid the foundations for further and deeper analysis into making the SW a tool for restoring autonomy to people unable to use a standard wheelchair.

Figure 1: The finished Smart Wheelchair

Figure 2: Navigational aid guiding wheelchair through tight spaces autonomously

A Flight Control Scheme for a Quadcopter: Implementation and Validation

Student: Elysia Bonello / Supervisor: Dr Ing. Marvin K. Bugeja

Introduction

A quadrotor is a type of Unmanned Aerial Vehicle (UAV) composed of four equally-spaced rotors which provide the required thrust via a fixed-pitch propeller. The attitude and position of the quadcopter are controlled by varying the angular speed of each motorised propeller. In this manner, the quadrotor is able to move autonomously through its six degrees of freedom.

Project Objectives

This project presents an in-depth study of the control schemes designed for the *Pixhawk Mini* flight controller, which are based on the PX4 open source platform. This study includes both realistic simulation and experimental validation of the control system used for the custom-built quadrotor shown in Figure 1.

Project Methodologies

A general familiarisation with the real quadcopter and its software architecture was required. In particular, the *PX4 Flight Stack* was thoroughly analysed to gain an understanding of each flight mode concept and its control algorithm. The flight controller has several flight modes, for which the degree of autonomy and type of user input response is varied. The control strategy adopted by *Pixhawk* includes a cascade control architecture using P/PID control loops.

The flight modes were simulated on *Gazebo*, which is a powerful 3-D robotic simulation environment, using the real *PX4 Firmware* and a realistic physics input commands applied from the Radio Controlled (RC) system, which resulted in a realistic response. The simulated results were analysed and compared with the response expected from the *PX4 Flight Stack*.

This procedure was crucial prior to testing the flight control algorithms on the real quadcopter. Hence, the expected behavioural response of each flight mode was determined from the simulated results. Subsequently, the tuning parameters of the flight controller were changed in a heuristic manner, according to the real-life desired response.

Additionally, a laser range finder was installed on the vehicle to obtain altitude control, such that the quadcopter is held at that particular absolute altitude, even when it is flown over uneven terrain. The main flight modes were then verified on the real quadrotor and analysed with respect to the simulated response.

Results and Achievements

This study successfully validated, both by realistic simulation and thorough real-life experiments, the robustness and versatility of the PX4 software architecture. The flight modes found on the *Pixhawk Mini* ranged from manual to fully autonomous flights.

A pre-programmed mission was uploaded on the quadcopter through a ground control station, to validate the Position Control Mode. The trajectory obtained is shown in Figure 2, in which the markers represent the respective take-off, waypoints and landing positions. Evidently, the quadrotor follows the desired setpoints, while holding two of the three positions steady. This flight mode is useful for swarm robotics, autonomous rescue missions and more.

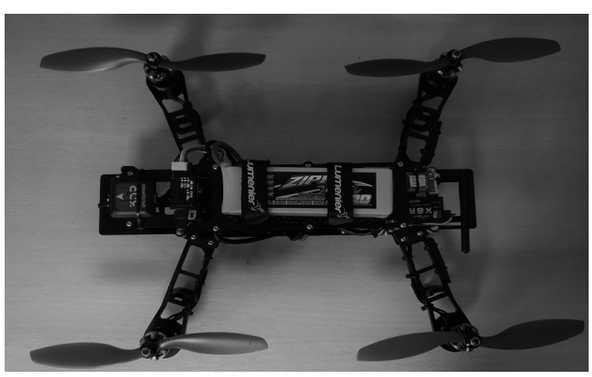


Figure 1: QAV400 custom-built Quadcopter

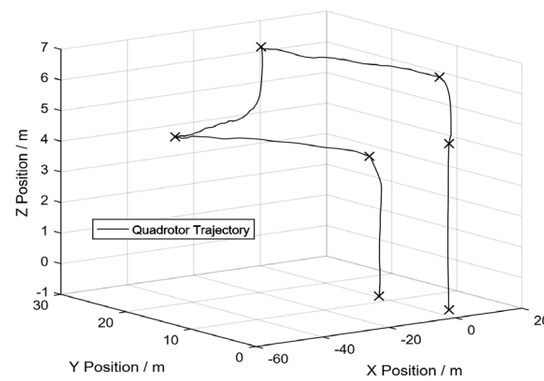


Figure 2: Quadcopter Trajectory Plot

A Self-Balancing Unicycle Robot

Student: Nicole Bonello / Supervisor: Prof. Ing. Simon G. Fabri

Introduction

This project presents the design process of the mechanical, electronic and control aspects of a self-balancing robot that stands on one wheel which propels the robot forwards or backwards.

As shown in Figure 1, two wheels are mounted onto the robot. Whenever forward or backward tilt is sensed by the on-board sensors, the unicycle wheel is actuated so as to bring the robot's centre of gravity in line with the pivot of the robot. On the other hand, as soon as any sideways tilt is sensed, the laterally-mounted flywheel is actuated with enough torque in the same direction of tilt so as to counteract any falling motion, thus achieving balance in two axes.

Project Objectives

This project involves the design and implementation of the physical structure and control system of the unicycle robot, complete with appropriate sensors and actuators.
This involves: system modelling, simulation and control design, testing and implementation of the control algorithm on the relevant electronic hardware, and the design and construction of the physical system.

Project Methodologies

The ensuing methodology was followed in the design process. Firstly, the system was modelled by mathematical equations describing the dynamics of the physical structure of the robot. The model obtained was verified through the use of simulation in Matlab and Simulink. A linear quadratic regulator was then designed to control the state of the system. Several iterations of the controller followed, each time optimizing the control algorithm so as to reduce the torque requirements from the two actuators.

During the simulation process, the design of the physical structure of the robot was ongoing such that the parameters from the system could be input to the simulation and prediction on the system's behavior could be done, including whether successful control of the system could be obtained through the chosen controller.

Two brushless DC motors were chosen according to the knowledge gained from the simulation. Finally, the motor controllers and other necessary sensors, namely an Inertial Measurement Unit (IMU) and the Hall Effect sensors embedded in the motors were interfaced and integrated on two circuit boards.

Results and Achievements

A sensor fusion technique on the basis of a Kalman filter was successfully used to combine the data from the accelerometer and the gyroscope housed by the on-board IMU. The tilt angle and angular velocity estimates obtained were compared to the measurements obtained from the sensors as standalone devices, showing that the Kalman filter exceeds the performance of both of the sensors alone.

Furthermore, the design of the digital controller proved to be successful when tested through the use of simulations. In simulation, the unicycle robot manages to remain balanced in the two axes under consideration, even when subject to external physical disturbances.

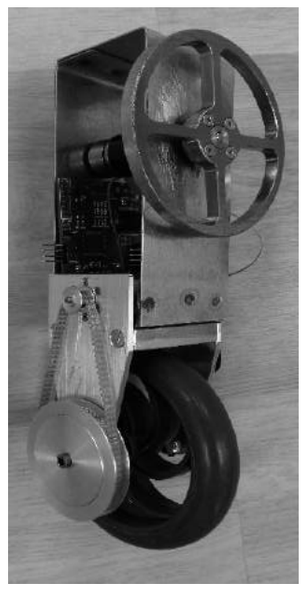


Figure 1: The unicycle robot setup

Model Predictive Control for a Quadruple Tank Level System

Student: Nicholas-Kane Grixti / Supervisor: Prof. Ing. Simon Fabri

Introduction

Model Predictive Control is a modern control technique wherein a mathematical model of a real world system is used in order to formulate a control law which the model predicts will lead to the desired response of the system. The Quadruple Tank System as seen in Figure 1 is a popular laboratory process that is used to demonstrate the difficulties in controlling multivariate non-linear systems.

Project Objectives

The project's main objectives were to design, implement and test an MPC algorithm that is able to control the liquid levels in the bottom two tanks in the QTS with desirable response characteristics, all the while ensuring stability.

Project Methodologies

Initial methodology involved the assessment of the existing literature on the topic as well as the design of the physical QTS rig to be implemented. Versions of the non-linear and linear models of the QTS which could be implemented in software were designed and implemented. Further to this several controllers (PI, decoupled PI, and MPC) were designed based on these models and had their performance simulated in software.

These controllers were then implemented on the physical rig and their performance was compared to their simulated counterparts and to one another.

Figure 1: The Quadruple tank system (QTS)

Results and Achievements

The results of these experiments showed that the MPC controller that was designed performed better than the classical controllers both in terms of speed of response as well as in terms of minimal deviation from the ultimate desired value. Versions of the MPC controller designed to include the use of state estimators such as the Luenberger observer and the Kalman Filter were also found to perform at or about the same level. The MPC controller was also able to control the QTS in its much more difficult to control non-minimum phase configuration. In this configuration the majority of the water pumped into the system is pumped into the top two tanks meaning it becomes difficult to meet the objective of controlling the liquid levels in the bottom two.

The main project objective of the design of a suitable MPC controller for the QTS was achieved. Several sub-objectives such as the building of a physical QTS and others which helped to achieve the primary objective were also achieved.

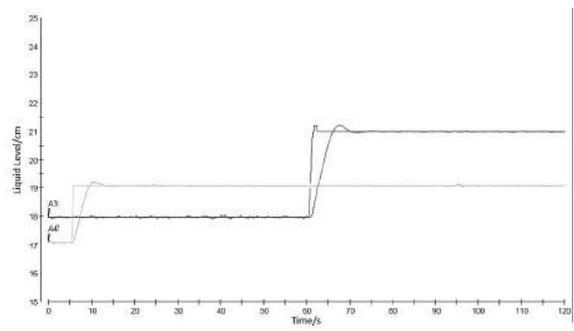


Figure 2: MPC controller performance

Knee Joint Angle Prediction with the use of Electromyography

Student: Nicholas Patiniott / Supervisor: Prof. Kenneth Camilleri / Co-Supervisor: Prof. Simon Fabri

Introduction

Mobility in humans is something which is normally taken for granted, that is until a person's mobility has been impaired. This reduction in mobility can either be caused by an illness or by an accident, and in either case it requires a lot of rehabilitation in order overcome this limitation. For example, a stroke or a spinal cord injury could cause muscle degradation in the lower limb, thus not allowing a patient to bend or straighten their knee. Using surface electromyography (sEMG) technology, the recovery period can be significantly reduced. This technology will allow the muscle impulses to be captured, which are then filtered and used to train a neural network which would give an estimation of the required knee joint angle. The need of this project is supported by several papers [1-4], and by Orthopaedic Consultants within Mater Dei Hospital, Malta.

Project Objectives

The scope of this dissertation was to provide the initial groundwork for an external orthosis (leg brace) placed around the knee joint which would aid in the rehabilitation of patients who have reduced or restricted mobility of the lower limb. To achieve this, the sEMG signals acquired from the muscles were processed to provide suitable features which were used for joint angle estimation through an appropriate estimation algorithm. Two estimation algorithms were tested, a Back-propagation neural network BPNN and a Time Delay neural network TDNN.

Project Methodologies

The first step was to attach the surface EMG electrodes to five of the muscles which are used to bend (flex) and extended the knee joint. The muscles used are divided into two groups, the extensor muscles consisting of the Rectus Femoris, Vastus Lateralis and Vastus Medialis, and the flexor muscles which are the Biceps Femoris and the Semitendinosus. Additionally, special markers were attached the subjects hip, knee and ankle such that the positional data of the lower left limb could be captured. These markers are respectively labelled as Upper Marker UM, Middle Marker MM and Lower Marker. Once the signals from each muscle was obtained, the method of root-mean-square RMS was applied such that the amplitude of the desired signals could be extracted. The RMS method is defined by:

$$RMS_{sEMG} = \frac{1}{T}\left[\int_{t}^{t+T} sEMG^2(t)dt\right]^{\frac{1}{2}}$$

where sEMG(t) is the amplitude of the raw signal at time instant t and T is the sampling period (1/100 Hz). The five signals were then passed through a 10^{th} order low-pass Butter worth filter with cut-off frequency at 5 Hz. Using the Euclidean Geometry, specifically the dot product in 3 dimensions, the actual knee joint angle was calculated. The filtered and processed EMG signals, as well as the actual knee joint angle, were then used to train the neural networks.

Results and Achievements

The performance of the optimal BPNN and TDNN were compared and it was determined that for flexion and extension of the knee joint, a TDNN with a delay of 20 and 100 neurons in the hidden layer gave the best joint angle estimation with an average percentage angular error of 0.3882 percent and actual angular error of 7.2242 degrees, and a correlation coefficient of 0.9659. Figure 1 below shows the results obtained for the TDNN described above, where the blue plot represents the estimated angle and the red plot represents the actual angle.

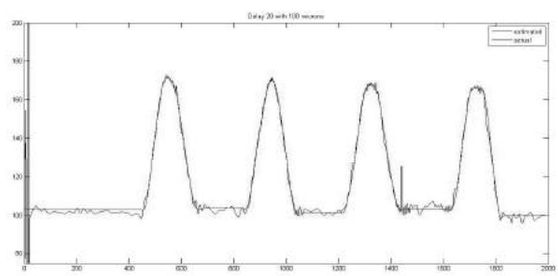


Figure 1: Actual knee joint angle vs Estimated Knee joint

References

[1] Feng Zhang, Pengfeng Li, Zeng-Guang Hou, Zhen Lu, Yixiong Chen, Qingling Li and Min Tan, “sEMG-based continous estimation of joint angles of human legs using BP neural network”, Neurocomputing 78 (2012) 139-148

[2] Lina Tong, Feng Zhang, Zeng-Guang Hou, Weiqun Wang and Liang Peng, “BP-AR-Based Human Joing Angle Estimation using Multi- channel sEMG”, International Journal of Robotics and Automation, Vol 30, No 3, 2015

[3] David G. Lloyd and Thor F. Besier, “ An EMG-driven musculoskeletal model to estimate muscle forces and knee joint moments in vivo”, Journal of Biomechanics 36 (2003) 765-776

[4] Gunter Hommel, Technische Universitat Berlin, “EMG-Driven Human Model for Orthosis Control”

Eye-in-hand Visual Servoing with a Robotic Arm

Student: Abigail Spiteri / Supervisor: Prof. Simon G. Fabri / Co-Supervisor: Prof. Kenneth Camilleri

Introduction

The concept behind visual servoing is using image information obtained through the use of a camera and then applying this information as feedback to control the position and orientation of a robot in real time. This term was first introduced by Hill and Park in 1979 [1]. Hence, by the use of real-time visual feedback, robotic manipulators can accomplish autonomous tasks.

Project Objectives

The aim of this project is to design, implement and test an eye-in-hand robotic arm system that is able to position its end-effector above a static object in the workspace. To set up this eye-in-hand architecture, a camera has to be physically mounted on the end-effector of the robot as illustrated in Figure 1.

Project Methodologies

A camera having the appropriate vision processing hardware and software was selected and interfaced. Image processing and image-based visual servoing control algorithms were designed, implemented and tested. The eye-in-hand closed loop control system with visual servoing was implemented and tested.

The target object had three of its corners marked in red and the aim was to extract the location of these corners which in turn define the current position of the target. These will be referred to as features. The image processing method chosen to analyze the images and extract the necessary features was colour recognition. In this approach, the Red, Green and Blue (RGB) content found in the image is evaluated and the areas which fall under preset thresholds are extracted from the whole image. Then the image processing algorithm takes care of finding the centroid coordinates of the extracted areas in pixels. This algorithm was implemented in MATLAB. To move the robotic manipulator's end effector above an object, on every iteration, the image processing algorithm compares the current results for the centroid of the object to the target results and calculates the difference. Through this error, the X, Y, Z, pitch and roll velocities of the end-effector are calculated using a velocity control law. Once the error is zero then the robotic arm is in the desired position. The velocity controller for the robotic manipulator was implemented in Simulink.

Results and Achievements

The system is able to detect the three features, extract them and find their centroids. Data is also sent successfully from a MATLAB script file to a Simulink model controlling the actuation of the robotic manipulator through a velocity controller. Although the robotic manipulator follows the correct path towards the target, a problem was encountered since it does not stop actuating once it reaches the target. One of the main difficulties when debugging the overall system was that since the system is working in real-time, data could not be monitored in Simulink.

Figure 1: Robotic arm and camera setup

References

[1] Hill, J. and Park, W., 'Real time control of a robot with a mobile camera.' In Proceedings 9th International Symposium on Industrial Robots, pp.233-246, 1979.

Discrimination of Ceramic Types using Image Processing

Student: Amy Tanti / Supervisor: Dr Alexandra Bonnici / Co-Supervisor: Dr Ing. John C. Betts

Introduction

Numerous areas of archaeological relevance have been excavated all over the Maltese Islands. During excavation, several different artifacts are recovered, which include pottery fragments. Some pottery fragments may have historical significance hence it is of importance that these are analyzed. The analysis is done under a microscope, where inclusions (particles) are outlined.

Project Objectives

- Enhance the image for better quality prior to obtaining features about the image
- Segment image of pottery fragment such that black inclusions are found
- Obtain information about the inclusions, for example size

Project Methodologies

The image is first enhanced using histogram equalization so that effect of shadows is removed. Features of the image, such as the colour of each pixel is obtained, in three different space: RGB, HSV and L*a*b*. The features are used to classify each pixel in a class. The classification methods which are used are: Adaptive Resonance Theory (ART) [1], K-means clustering [2], and Density Based Spatial Clustering of Applications with Noise (DBSCAN) [2]. The features of each pixel will determine whether the pixel should be in one class or another depending on the clustering parameters. The final result will be cleaned of noise, and the information about the inclusions will be extracted.

Results and Achievements

The results of the classification methods were each evaluated such that the performance can be measured using a percentage. Two measures which were used were the sensitivity and specificity, where the sensitivity results in how good the performance is and the specificity shows how bad the performance was. Below is a comparative table where the results of the sensitivity and specificity are shown.
The features used are the colour spaces, RGB, HSV and L*a*b*, while the classification algorithms are ART, k-means and DBSCAN.

	ART			k-means			DBSCAN		
	RGB	*HSV*	*L*a*b**	*RGB*	*HSV*	*L*a*b**	*RGB*	*HSV*	*L*a*b**
verage Sensitivity (%)	71.42	31.88	63.63	76.42	96.82	79.73	1.65	70.61	80.42
verage Specificity (%)	18.35	0.72	78.93	7.59	27.96	19.99	29.09	6.40	10.78

References

[1] Carpenter, G. A. and Grossberg, S. Adaptive resonance theory. *The Handbook of Brain Theory and Neural Networks*, 1998

[2] Baxter, M. J. Spatial k-means clustering in archaeology – variations on a theme. 2015

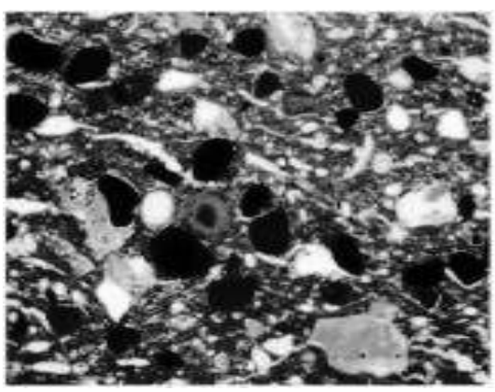


Figure 1: Microscope Image of a Pottery Fragment

Figure 2: Classification Result for ART classifier using RGB colour space

Attitude Determination of a Pico-Satellite

Student: Peter Valletta / Supervisor: Dr Ing. Marvin K. Bugeja / Co-Supervisor: Prof. Ing. Simon G. Fabri

Introduction

Attitude determination is a crucial part of any satellite and aims to estimate the direction in which it is pointing relative to some fixed point on Earth. This dissertation presents the design of an attitude determination system (ADS) for UoMBSat-1 (Figure 1), a 5x5x5cm pico-satellite currently being designed by the astrionics research group, ASTREA, at the University of Malta.

Project Objectives

The aim of this dissertation is to devise an ADS for UoMBSat-1, with suitable sensors and fusion algorithms to effectively utilise these measurements. This system shall be implemented in simulation for testing and validation under realistic conditions.

Project Methodologies

The initial stage of this project involved a review of varied attitude representations and attitude determination algorithms. The quaternion was identified as an ideal attitude representation, while the Extended Kalman Filter (EKF) was selected for attitude determination given its computational efficiency and effortless, direct application of the quaternion [1], [2].

Within UoMBSat-1, gyroscopes, magnetometers and solar panel measurements shall be used for attitude determination, therefore, accurate models were designed for each of these sensors. Following this, these models were implemented in Simulink and tested to validate their operation.

To obtain attitude information from the magnetometer and solar panel measurements, corresponding models were required to predict these quantities at the satellite's position. Thus, a magnetic field model and solar irradiance model were also implemented within the simulation.

The implemented EKF-based algorithm is centred around equations describing the satellite's motion, based on real physical parameters [3]. This is beneficial for estimation since it includes all relevant information on the system and is robust against measurement errors and system noise.

Results and Achievements

During testing, the accuracy of the implemented ADS was observed to be significantly affected by the precision of the sensor calibration parameters and the amplitude of the gyroscope bias drift. This result highlights the importance of calibration accuracy and suggests the incorporation of bias estimation.

Under realistic conditions, the simulated ADS obtained a pointing accuracy of 5.42 degrees when the satellite is outside of solar eclipse and 64.66 degrees inside eclipse. This is a promising result, however it may be improved through additional tuning and the inclusion of other models, enhancing the system's knowledge about its environment.

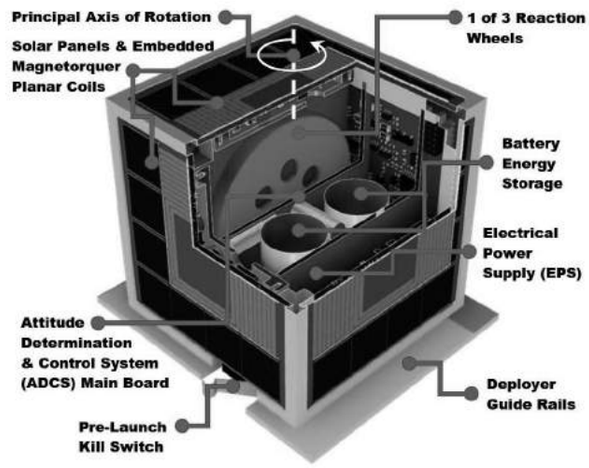


Figure 1: Cutaway of the UoMBSat-1 PicoSatellite [4]

References

[1] F. L. Markley and J. L. Crassidis, Fundamentals of Spacecraft Attitude Determination and Control. Springer New York, 2014.

[2] J. R. Wertz, Spacecraft Attitude Determination and Control, Kluwer Academic Publishers, Dordrecht, 1978.

[3] T. Bak, Spacecraft Attitude Determination: A Magnetometer Approach, PhD Thesis, Aalborg University, 1999

[4] D. Cachia et al., "Feasibility Study of a PocketQube Platform to Host an Ionospheric Impedance Probe", in the ESA/CNES 4S Symposium: Small Satellites go Viral, Valletta, Malta, 30 May-3 Jun, 2016.

Vision-based Sensory and Reinforcement Biofeedback System

Student: Gail Vella / Supervisor: Prof. Kenneth P. Camilleri

Introduction

The main purpose of the dissertation is to create a vision-based sensory and reinforcement system that can be developed to provide feedback (visual, auditory or tactile) to individuals having complex learning disabilities or Autism Spectrum Disorder. The feedback will serve as a form of biofeedback, encouraging the individuals to repeat their movements. Such repetition is expected to trigger a learning process by which the individual is able to gain awareness and control over physical action.

Project Objectives

The objectives of this work were to:

- become familiar with the context of MATP for individuals with PCLD and/or ASD;
- develop a system and any technical requirements for a vision-based sensory and reinforcement system;
- identify suitable video processing methods to sense the object properties and motion;
- implement and test the identified methods in real scenarios on playback videos;
- verify that the system can be converted to real-time such that in the future, it may be deployed at San Miguel School.

Project Methodologies

A detailed study on various object detection algorithms, classification techniques and tracking methods was carried out. Two object detection techniques were selected and implemented, namely the template matching algorithm and the colour detection algorithm.

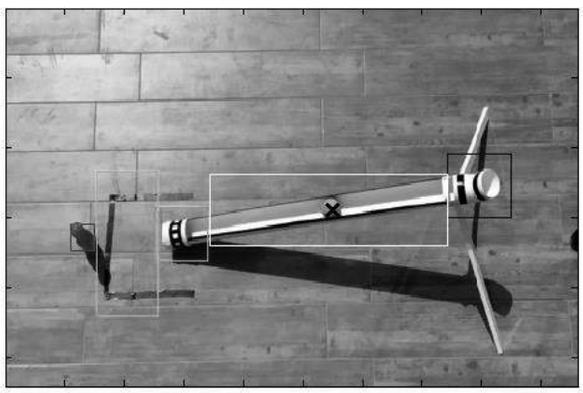


Figure 1: Setup with detected regions and moving objects

The former technique detects the salient regions in the scene, which consists of an inclined hollow semi-circular gutter, a ball and a skittle, while the latter approach detects the moving objects of interest on the basis of their colour.

The location of the ball was computed by dividing the setup into four sections detected by the template matching technique which are used to specify the ranges required for detecting the ball's position. The system was tested under various circumstances and graphs indicating the ball's position in every frame, were generated computationally for each case and compared to their ground truth.

Results and Achievements

The results achieved when testing the system under various circumstances conclude that the goal of the dissertation is met since audible feedback, indicating the ball's location can be provided successfully in the majority of the cases. However the system has some constraints including the fact that varying lighting conditions affect the threshold ranges which define the colours of the ball and the skittle. Also, the template images are not scale or rotation invariant, hence any slight size or orientation variation might cause issues when attempting to locate the template image on the frame. It was then verified that the system can be converted to real-time such that in the future, it may be developed and deployed at San Miguel Primary School, so that individuals with intellectual disabilities, who are often unaware of their own movements or lack of movements, are provided with an opportunity to engage with external objects through voluntary activity.

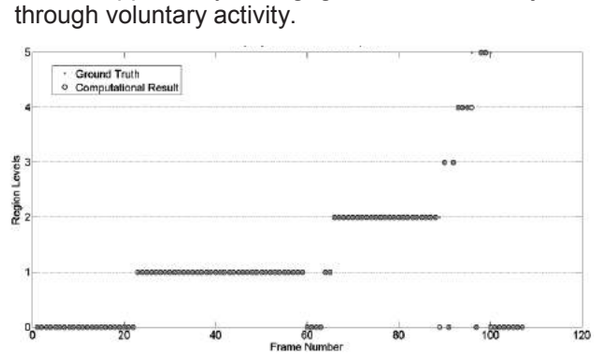


Figure 2: Superposition of the ground truth and the computational result

FINAL YEAR ENGINEERING PROJECTS

MECHANICAL STREAM

Design, Construction and Testing of a Compressed Air Test Bed

Student: Kyle Abela / Supervisor: Dr Ing. Paul Refalo / Co-Supervisor: Dr Ing. Emmanuel Francalanza
Sponsored by AIM Enterprises Ltd.

Introduction

Industrial manufacturing companies are recognizing the benefits of meeting sustainable targets concerning waste and excessive energy consumption. Compressed air systems provide a significant improvement opportunity in this regard. Typical systems have an output efficiency of 10 – 12% [1], with leakages and excessive input pressures identified as some of the major sources of waste and inefficiencies.

Project Objectives

The project objectives consisted of the design and construction of a modular and mobile compressed air test bed. An experiment was also designed to simulate and analyse the sustainability impact of various leakage scenarios encountered in industry.

Project Methodologies

Throughout the project, the Sequential design methodology was adopted to develop the features of the system from various conceptual notions, to the detailed design and the eventual construction of the physical compressed air test bed.

To demonstrate the capabilities of the test bed, an experimental procedure was designed to measure the air flow rates and energy consumption required for various input factors in terms of different leakage diameters at specific input pressures. The results were investigated in the form of multiple single factor experiments to analyse the impact of each condition in terms of the three pillars of sustainability (financial, environmental and social).

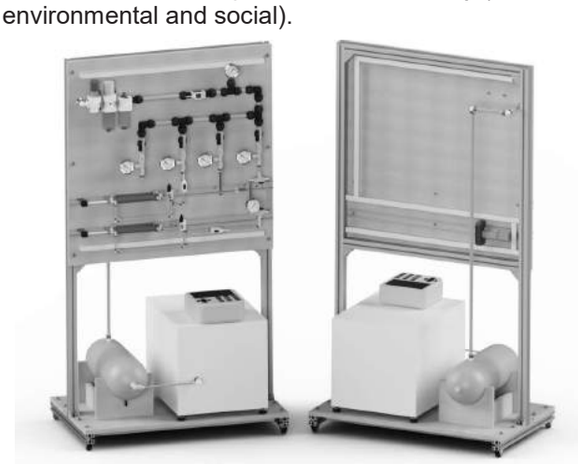


Figure 1: CAD representation of the designed test bed

A set of low and high values from each of the input factors (leakage diameter and pressure) were selected to analyse the correlation of the inputs on the output responses in a two-level factorial experiment.

Results and Achievements

One of the main achievements of the project involved the implementation of the conducted design process. Figure 1 shows the computer aided design (CAD) model of the compressed air test bed. From the experiments, it was observed that both the energy consumption and the air flow rate increased quadratically with an increase in leakage diameter. The extrapolated energy consumption results were then considered over a period of a year to conduct the sustainability analysis. Figure 2 shows the additional electrical costs required as a consequence of various leakage diameters at a particular pressure. At the typical pressure setting of 6bar, a leakage of 1.5mm would increase the electricity cost by €470. The procedure was repeated to analyse the sustainability impact on the environmental and social pillars. Through the two-level factorial experiment, it was confirmed that leakages had a higher impact on the energy consumption when compared to the input pressure.

References

[1] S. Mousavi, S. Kara and B. Kornfeld, “Energy Efficiency of Compressed Air Systems,” Procedia CIRP, vol. 15, pp. 313-318, 2014.

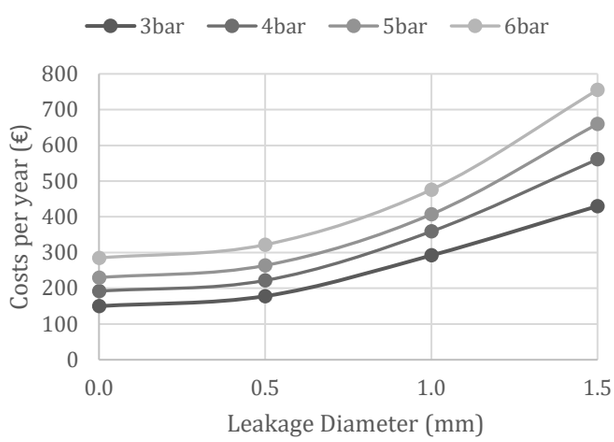


Figure 2: Additional electrical costs over a year of operation

Effect of Surface Roughness on Tensile Properties of Micro Injection Moulded Parts

Student: Michel Bezzina / Supervisor: Dr Arif Rochman / Co-Supervisor: Dr Ing. Pierre Vella

Introduction

With an increasing trend in miniaturized parts, the development of micro-manufacturing technologies is on the rise. Injection moulding is a key technique for cost-efficient mass production of micro parts [1]. Most often, during manufacturing of polymer parts, factors related to the surface quality are neglected. However, in the micro-scale, such factors may play a significant role [2].

Project Objectives

The main objective of this project was to analyse the effect of mould roughness on tensile properties of a set of micro-injection moulded parts. In order to produce these micro-specimens, mould inserts with micro-cavities of different surface roughness were required to be designed and manufactured.

Project Methodologies

Micro-cavities of different surface roughness were machined on micro inserts using micro electron discharge machining by varying the machining parameters. These micro-inserts as shown in Figure 1 were injection moulded using two different materials (polyoxymethylene and polypropylene), to produce tensile specimens of different surface roughness. The surface roughness of the tensile specimens was measured using a non-contact 3D surface measuring optical profiler.
The specimens were then subjected to tensile testing to determine the tensile properties and correlate the results with the measured surface roughness.

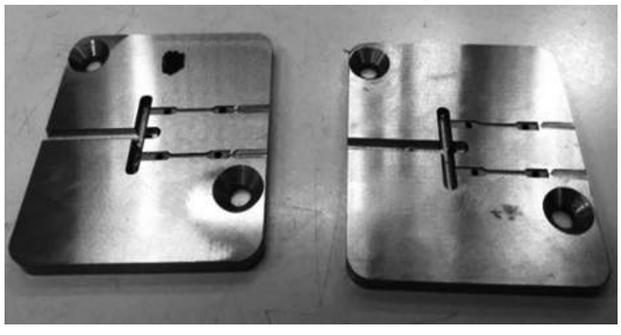


Figure 1: Mould inserts with micro-specimen cavities

Results and Achievements

Results from the tensile testing indicate that the tensile properties vary for specimens of different surface roughness. As shown in Figure 2, the yield strength decreases with a rougher surface finish. This could be related to the crevices formed at the surface during injection moulding of the parts, which serve as crack initiation sites. The higher the surface roughness, the higher the probability of having initiation sites for cracks, resulting in a decrease in strength.

However, this decrease in yield strength is not linear. As the surface roughness increases, the decrease in yield strength and stress sustained during strain hardening is relatively lower. Moreover, the surface roughness does not determine the Young's modulus and the yield strain of the part.

References

[1] R. Surace, G. Trotta, I. Fassi, and V. Bellantone, The Micro Injection Moulding Process for Polymeric Components Manufacturing. INTECH Open Access Publisher, 2012

[2] H. L. Zhang, N. S. Ong, and Y. C. Lam, "Mold surface roughness effects on cavity filling of polymer melt in micro injection molding," Int. J. Adv. Manuf. Technol., vol. 37, no. 11–12, pp. 1105–1112, Jul. 2008

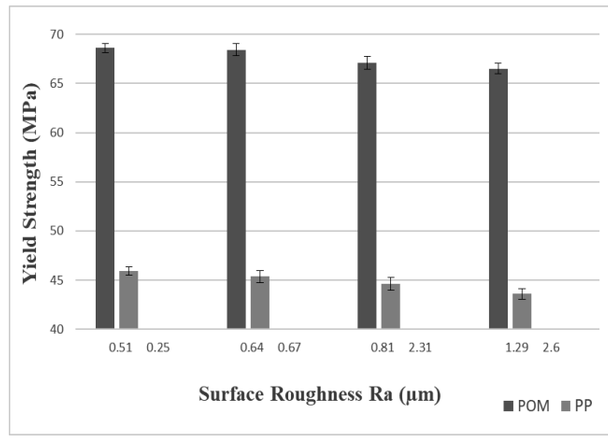


Figure 2: Effect of surface roughness on yield

Design of an Innovative Airtight Sealing Mechanism for Lip Gloss Packaging

Student: Andreas Calleja / Supervisor: Prof. Ing. Jonathan Borg

Introduction

Lip gloss composition is changing since organic and volatile ingredients are being used. These cause the lip gloss to dry out quicker creating the need for a hermetic lip gloss container. Current lip gloss containers found on the market use a screw thread for opening, closing and sealing which complicates production tooling and is a burden for users [1].

Project Objectives

The objective of this project was to design a sealing mechanism for lip gloss packaging which provides hermetic sealing. Additionally, the design must be easy to manufacture, cost effective, user friendly and aesthetically pleasing.

Project Methodologies

By using the basic design cycle, the final solution was developed systematically [2]. The problem was analysed and the design objectives were set using a PDS. Conceptual designs were analysed and compared with the set objectives and the best design was chosen. The solution was developed into a CAD model and an improved detailed design was created. Engineering tools including Design for Manufacturing and Assembly, Mould Design and Mould Flow Analysis were used to ensure that the product is suited for mass production.

A prototype was machined from Polyoxymethylene and a leakage test and a weight loss test were performed to check the hermeticity of the design. The leakage test compared the performance of the designed sealing mechanism with a standard lip gloss container under pressure by checking which container leaked first when subjected to a pressure of 0.004 bar. The weight loss test was done to compare the evaporation performance of both containers when heated to a constant temperature of 40°C for 7 days.

The leakage test revealed that the designed mechanism performed better than the screw thread under pressure since no leakage was observed. The hermetic performance of the seal was confirmed during the weight loss test where it lost a negligible amount of weight due to evaporation.

Results and Achievements

This designed sealing mechanism consists of an internal O-ring inside the cap, which mates with the container. The cap and container lock together through a locking bump on the container and a locking groove inside the cap. The CAD models for the designs can be seen in Figure 1.

The sealing mechanism is manufactured through a collapsible core, which during injection moulding, collapses on itself decreasing the diameter of the mould. This allows the undercuts present in the design to be manufactured easily and cost effective especially when compared to rotating cores currently used in the production of current screw thread containers [1, 3].

Thus, the aim of the project was achieved by designing a cost effective, hermetic lip gloss sealing mechanism.

Figure 1: CAD models for the lip gloss container

References

[1] Bryce D.M., 'Plastic Injection Molding… Mold design and construction fundamentals' Society of Manufacturing Engineers, Michigan, 1998

[2] Roozenburg N.F.M. & Eekels J., 'Product Design: Fundamentals and Methods' Wiley, Chiseter, 1991.

[3] Malloy R.A., 'Plastic Part Design for Injection Molding' Hanser Publications, Cincinnati, 2010

Customised & Modular Design of Stylish 3D Printed Prosthesis

Student: Cristian Chetcuti / Supervisor: Prof. Ing. Jonathan Borg

Introduction

Prostheses must have unique geometry matching that of the user's residual limb. Being a very flexible manufacturing technique, 3D printing can be used for the manufacturing of such devices [1]. However, in order to be accepted by the users, prostheses must provide both functionality and style.

Project Objectives

The aim of this project was to therefore design a modular and stylish 3D printed prosthesis which can be customised to fit different users.

Project Methodologies

Based on the basic design cycle, the problem was initially analysed through market research and an interview and questionnaire with a Prosthetist [2]. This provided enough information for the development of a QFD followed by PDS.

After analysing the problem, the conceptual design was initiated by a FMA tree and a Morphological Chart. Five different concepts were generated after a detailed Means Analysis. The two most promising concepts were systematically selected by a Decision Matrix after which they were combined into one, by a SCAMPER exercise.

Once the concept was selected, the embodiment design stage took place. The material for the prosthesis was selected and physical prototypes were generated. This lead to a more detailed design where the use of engineering methodologies such as DFX facilitated this stage. Solution analysis through FMEA was also conducted and feasible improvements were implemented to the design. Detailed drawings of the final design were generated.

FEA was utilised in order to virtually simulate forces on the product. This was essential for the evaluation of the components making up the prosthesis. The physical prototypes were then evaluated through interviews and questionnaires with upper limb below-elbow amputees. Additional feedback was also received from a group of physiotherapists.

To conclude this project, a product-service system was proposed.

Results and Achievements

As a result, an upper limb below-elbow prosthesis was designed. This design allowed the use of different attachments in order to facilitate different daily tasks. Hence modularity of the product was achieved.

Some of the parts were designed to be custom-made after the necessary 3D scanning of the user's residual limb is performed. This resulted in a customised prosthesis which can be altered to fit different users.

Customisability of the form and colour of the product were incorporated in order to obtain a stylish prosthesis. This allowed the user to alter the design of the patterns found on the prosthesis together with its colour according to their likings.

A customised, stylish and modular prosthesis was successfully designed and positive feedback was received from the evaluation of the product.

Figure 1: The designed prosthesis having different terminal devices

References

[1] Noorani R., 'Rapid Prototyping' John Wiley & Sons, Los Angeles, 2006.

[2] Roozenburg N., 'Product Design: Fundamentals and Methods' John Wiley & Sons, Chichester, 1995.

Modular Design of a Reconfigurable Cyber-Physical Production System

Student: Mark Mercieca / Supervisor: Dr Ing. Emmanuel Francalanza / Sponsored by Methode Electronics Malta Ltd.

Introduction

Manufacturing is changing. If a manufacturing enterprise's goal is longevity and profitability then it must be able to adapt to new, ever-changing scenarios. Industry 4.0 aims to tackle these challenges by providing new types of manufacturing systems which are interconnected so as to achieve "smart" manufacturing. A reconfigurable cyber-physical production system developed on modularity concepts can help to achieve such capabilities within a manufacturing system.

Project Objectives

The project objectives included the following: Carrying out a literature review on reconfigurability, modularity and cyber-physical systems. The designing of a feasible system based on the three mentioned concepts by applying a modular design methodology. The implementation and testing of such a system. This system aims to show what is currently achievable in industrial scenarios using current existing technologies and to create a platform for the further development of cyber-physical systems.

Project Methodology

This project was developed using a combination of two design methodologies. The first being a methodology used for the design of the modules developed by Erixon et al. [1] called Modular Function Deployment (MFD). The interfaces were then designed based on a methodology developed by Scalice et al. [2]. These two methodologies were then combined and this resulted in the modified MFD methodology, this new methodology has been named MFD 4.0, a portmanteau of modular function deployment and Industry 4.0.

Results and Achievements

Before the manufacturing system could be designed a reference modular architecture was required. The reference architecture was created by developing two models, a physical model and a cyber-physical model. The physical model was responsible for the creation of the physical processes present in the system whereas the cyber-physical model would be responsible for the creation of the virtual model. The cyber-physical model would augment the physical model. Thus adding cyber-physical capabilities which would result in the creation of the virtual model.

The implementation of the system was based on the developed modular architecture. The new system is called RSMS (**R**econfigurable and **S**mart **M**anufacturing **S**ystem). RSMS is integrated with another system that was already developed called ORCA (**O**pen and **R**econfigurable **C**onveyor (**A**)) and this results in a smart manufacturing cell observed in Figure 1.

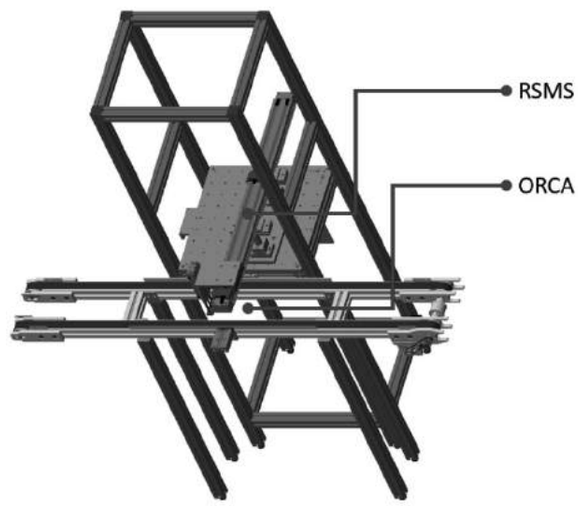


Figure 1 - Smart Manufacturing Cell

References

[1] G. Erixon and T.-M. R-, 'Modular Function Deployment - A Method for Product Modularisation', p. 188.

[2] R. K. Scalice, L. F. S. de Andrade, and F. A. Forcellini, 'A Design Methodology for Module Interfaces', in *Collaborative Product and Service Life Cycle Management for a Sustainable World*, Springer, London, 2008, pp. 297–304.

Design and Prototype of a Self-Assembly Heart Valve

Student: Marie Claire Scicluna / Supervisor: Dr Ing. Philip Farrugia / Co-Supervisor: Mr Aaron Casha

Introduction

The human heart consists of four heart valves (Figure1), however the two most affected by valvular diseases are the aortic and the mitral valve.The replacement of the aortic heart valve is consistently increasing especially amongst young people [2]. Thus, the creation of a heart valve that can be used in young people and is durable for a

Project Objectives

The main aim is to design a self assembly Rapid Deployment Valve that is a bio-prosthetic

that works as a mechanical valve. The idea is to create a hybrid design that has the beneficial aspects of both types. Thus the patients will have the valve implanted for longer time and do not experience biocompatibility issues.

Project Methodologies

The methodology followed throughout the project is that of Roozenburg et al's basic design cycle [1]. Initially an extensive literature review was carried out for the better understanding of the environment the valve will be exposed to. A deep patent search was also performed. Combining the knowledge acquired with the feedback from a cardiac surgeon, a defined Product Design Specification was developed. Design tools such as Brainstorming, SCAMPER, and morphological chart were used to design concepts. The chosen design was then refined into a physical prototype after it has been evaluated using practical methods.

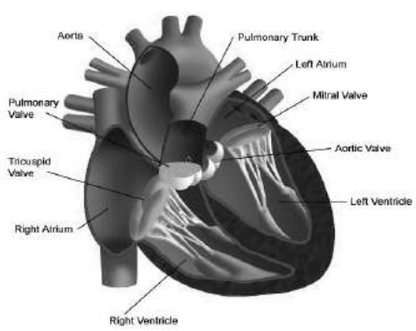


Figure 1: The Heart Chamber

Results and Achievements

The final result is a self-assembly Rapid Deployment heart valve that makes use of memory shape alloys and biocompatible materials to prevent the patient from taking warfarin and prevent calcification and thrombogenic build up upon the valve. Results on the success of the implant were obtained using theoretical and practical procedures. The former refers to the mathematical analysis of the stresses, bending moments and safety factors. The latter was simulator that was built to assess the functionality of the valve. These tests (Figure 2) were used to determine whether the valve would open and close when subjected to the pressures in the heart. The design was also evaluated by surgeons and knowledgeable personnel in the field. It was highlighted that the designed implant could be easily implanted while allowing the surgeons to have a better view of the surrounding area. Finally, they referred to the fact that the valve could be sterilised without hesitation due to its minimal amount of parts and the choice of materials.

References

[1] Roozenburg N., 'Product Design: Fundamentals andMethods' John Wiley & Sons, Chichester, 1995.

[2] "Heart Valve Problems and Causes", Heart.org, 2017. [Online]Available: http://www.heart.org/HEARTORG/Conditions/More/HeartValveProblemsandDisease/Heart-Valve-Problems-and - Causes_UCM_450755_Article.9.[Accessed: 08- Sep- 2017].

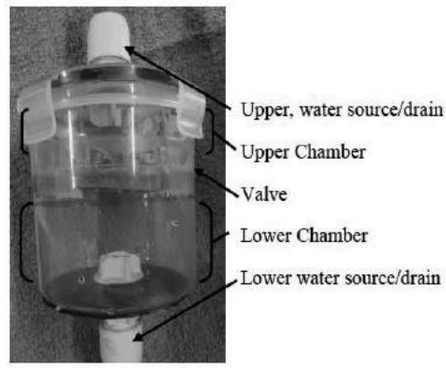


Figure 2: Closed Dry testing jig

PECVD Coating of Injection Moulded Elastomer Seals

Student: Andrew Spiteri / Supervisor: Dr Arif Rochman / Co-Supervisor: Prof. Ing. Maurice Grech

Introduction

Elastomer seals usually have a high coefficient of friction (COF), creating difficulties in feeding and assembly. Plasma enhanced chemical vapour deposition (PECVD) can be used to deposit a thin coating to reduce the COF of elastomers. PECVD utilizes electrical energy to create plasma. In turn this will change the precursor gas into reactive radicals, ions, neutral atoms, molecules. These will react with the substrate and deposit a coating [1].

Project Objectives

The objective of this project was to study and understand the effect of different coating parameters of ethylene acrylate rubber (AEM) and ethylene propylene diene terpolymer (EPDM). Bonding quality, resultant COF, durability and coating thickness were examined.

Project Methodologies

Three different coating parameters were chosen to be varied throughout testing: coating time, mixing ratio and radio frequency (RF) power. The coating gases used were hexamethyldisiloxane (HMDSO) and oxygen. Twenty-seven different coatings were applied on AEM, while for EPDM only eighteen different coatings were applied due to part supply. Before coating, the O-rings were sputtered using argon with the same coating RF. The coated O-rings were tested for COF and durability for a distance of 6 m. The results were then plotted and compared as can be seen in Figure 1 and 2. Scanning electron microscope (SEM) imaging was done to check bonding and coating thickness.

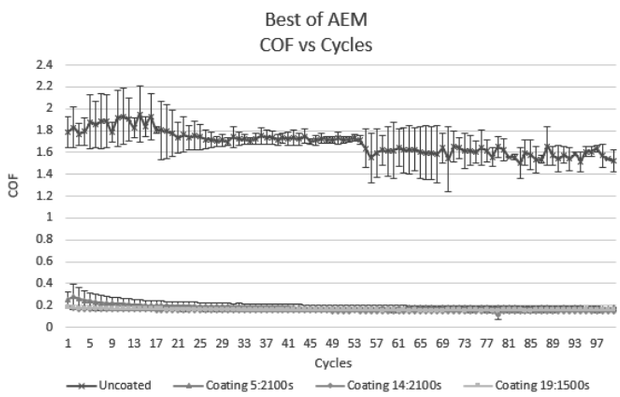


Figure 1: Best Of AEM Coatings

Results and Achievements

For both AEM and EPDM, the best reduction in COF was when 100 per cent HMDSO was used. For AEM, the deposition time of 1500s was the most beneficial. The RF used for AEM was that of 450 W. This would explain why higher deposition time didn't give the best coating, as prolonged time would act as a deterrent for the coating to grow due to heavy ion bombardment. The reduction in COF for the first cycles was 90 per cent which kept constant throughout the wear test. The coating thickness for AEM was that of 450 nm. After wear testing the coating reduced to 376 nm. For EPDM, a RF of 350 W was the most beneficial with a longer deposition time that of 2700 s. The thickness was that of 628 nm before wear testing and 500 nm after testing. The reduction in COF for EPDM on the first cycle was that of 88 per cent which continued to reduce to 90 per cent by time. This probably means that the coating had some surface roughness and by time it wore down to a better surface finish. The thickness shows that the AEM coating lost the least thickness throughout the test, implying that the coating is denser than that of EPDM.

References

[1] A. Jilani, M. S. Abdel-wahab, and A. H. Hammad, "Advance Deposition Techniques for Thin Film and Coating," in *Modern Technologies for Creating the Thin-film Systems and Coatings*, N. N. Nikitenkov, Ed. Rijeka: InTech, 2017, p. 442 DOI 10.5772/63326.

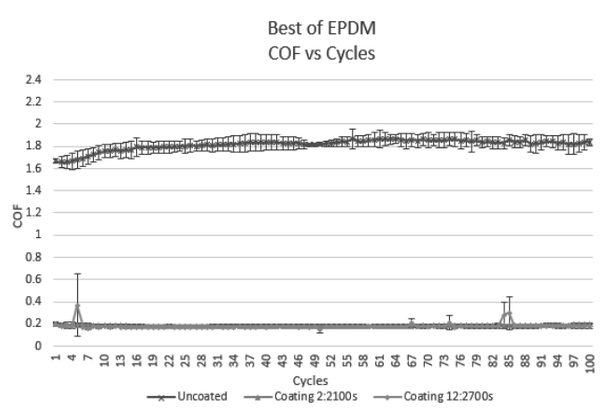


Figure 2: Best Of EPDM Coatings

Sustainability Analysis of Recycling of Injection Moulded Plastic

Student: Karl Tanti / Supervisor: Dr Ing. Paul Refalo / Co-Supervisor: Dr Arif Rochman

Introduction

Plastic injection moulding forms a substantial part of the growing manufacturing industry, consuming a number of different resources, mainly material, energy and water. Such resources are facing significant pressures and huge efforts are being exerted to reduce their demand and hence mitigate their effects on the environment, climate change and also human beings. The implementation of sustainable manufacturing (SM) ensures the retention of potential economic growth while mitigating these negative impacts.

Project Objectives

This project aims to analyse the technical, financial, environmental and social sustainability of recycling plastic injection moulded waste. Additionally, the optimum recycled plastic ratio and recycling approach from a sustainable point of view were studied. Through these objectives, this project ventures to further SM within a local manufacturing company – Toly Products Ltd – by analysing the conventional recycling system currently implemented at the manufacturing facility together with possible alternative systems that can sustainably improve upon it.

Project Methodologies

The objectives above were achieved by analysing three new ratios of virgin to recycled material, one of which consisted of only recycled material, and by also analysing the reprocessing capability of the materials involved. In addition, different ways of granulation and waste disposal were studied. All this was tested with regard to the manufacture of the Tivoli Large Compact (Figure 1), a product regularly produced by the industrial partner. Factors affected by these changes were studied, including product quality; material, energy and water consumption; maintenance, and also human labour. The effects of such variables were then analysed in terms of appropriate sustainability indicators, relating to the three pillars of sustainability, being: economy, environment and society.

Figure 1: Product - Tivoli Large Compact

Results and Achievements

Through this sustainability analysis, it was shown how a cascading regrind system can be applied to the product in question, in which manufacturing starts with just virgin resin and cascades to the following generations of recycled material without blending with virgin resin along the process. With the resources and time available for this project, this was proved viable up to the three reprocessing cycles tested. Furthermore, based on an annual production of 1 million products, this project concludes that the implementation of such a system with the product in question at Toly Products Ltd would:

- add 84 hours of labour a year,
- reduce CO_2 emissions by 11 tonnes per year,
- reduce water requirements during primary material production by 480 m^3 annually,
- save around €8,000 a year.

These benefits are further enhanced when the proposed system is compared to one that does not practise in-house recycling. Figure 2 below displays some of the above-mentioned results in the form of percentage savings.

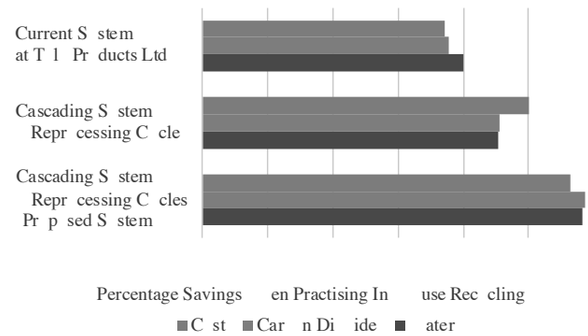


Figure 2: Comparison of different recycling opportunities

Effect of Material Selection on the Sustainability of Plastic Injection Moulded Parts

Student: Chantel Vassallo / Supervisor: Dr Ing. Paul Refalo / Co-Supervisor: Dr Arif Rochman

Introduction

Injection moulding is a very popular process in the plastic manufacturing industry. Owing to this, it has considerable impact on the three pillars of sustainability, especially since the process is energy intensive. This is dependent on a number of factors, with the choice of material being one of the main influences. Hence, the careful selection of materials is crucial to achieve a process that is environmentally, socially and economically benign.

Project Objectives

The aim of this project is to determine how different virgin and reground materials affect the energy consumption of the injection moulding process and the final quality of the part. This is done through a material selection process, the collection of energy consumption and quality data, and the evaluation and analysis from a sustainability point of view.

Project Methodologies

For the case study, a bottle opener part was used. A stress analysis was performed using Autodesk Inventor. The resulting maximum stress value was used to determine the minimum yield strength required for the part. This was one of the material selection criteria along with cost, material shrinkage, primary polymer moulding energy and embodied energy. From a shortlist of materials with these criteria, three materials were selected, namely Acrylonitrile Butadiene Styrene (ABS), Polylactic Acid (PLA) and Polypropylene with 30% glass-fibre reinforcement (PP30GF).

Additionally, each material was studied at six different regrind variants, including 0%, 20%, 40%, 60%, 80% and 100% regrind content. These materials were used to produce the bottle opener part by means of a hydraulic injection moulding machine (IMM). The ancillary equipment included a temperature control unit (TCU) and a chiller unit. A plastic grinder was also required to produce the regrind material. For each material variant, the energy consumption of the IMM, TCU, chiller and grinder was recorded by means of power loggers, connected separately to each of the equipment. Quality testing and inspection was then performed on the injection moulded parts.

Results and Achievements

The material requiring the highest energy consumption was PLA, while PP30GF had the lowest energy consumption values. This is mainly because of the cycle time difference between the two, with cooling time being the main contributor. On the other hand, the quality results showed that PLA had the highest maximum force endured until failure, followed by PP30GF and lastly ABS, as shown in Figure 1.

The regrind content did not have any effect on either the energy consumption or the quality results that were tested for this project. The only significant difference was in terms of cost. When considering both material and energy cost, PP30GF was the cheapest to procure and produce while ABS was the most expensive. The cost of the parts made of 100% regrind content for all three materials were significantly cheaper than the parts produced with virgin material. From the sustainability analysis, it was concluded that PLA and PP30GF are far superior than ABS from an environmental standpoint. Regarding embodied energy and water usage for primary production, PLA is a better choice, however PP30GF has a lower carbon and environmental footprint.

After considering all quality and environmental factors for each tested material, it was concluded that the most apt material for the production of the case study part from a sustainability point of view is PP30GF, with a 100% regrind content.

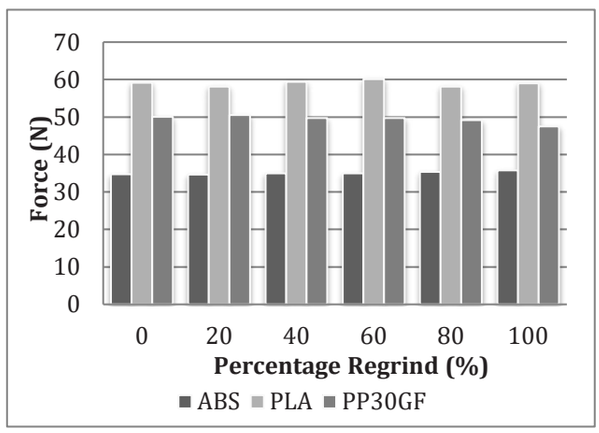


Figure 1: Maximum endured force until part failure

Innovative 3D Printed Mould Insert for the Production of Rubber Injection Moulded Prototypes

Student: Aaron Xuereb / Supervisor: Dr Arif Rochman / Ind. Partner: Trelleborg Sealing Solutions Malta

Introduction

3D printing is continuously becoming more popular, especially in large manufacturing companies like Trelleborg Sealing Solutions Malta. When customers approach the company for a quote to produce a product, they expect functional prototypes of the product. By using 3D printing to produce the moulds, the process of producing the requested prototypes can be shortened to a few days, as opposed to weeks when using conventional machining.

Project Objectives

The aim of this project was to produce a series of mould insert designs that can be 3D printed and used to produce rubber injection moulded prototypes. This comprised various challenges; firstly, the ability of 3D printed tools to hold up for the rubber injection moulding environment, secondly, the functionality of the injection moulded parts produced and finally, the surface finish of the parts produced.

Project Methodologies

The project started by selecting the ideal 3D printing solution and material. PEEK printing, using a fused deposition modelling printer, was selected. Then, various mould insert designs were proposed which were analysed using a decision matrix for each design. The advantages of all the designs proposed were merged together to form three new improved designs which were further analysed using Moldflow.

When the designs were finalised, they were 3D printed in PEEK, as seen in Figure 1. The PEEK inserts were then fastened onto an injection moulding machine, one pair at a time. Several runs were done until failure, and the parts produced were post processed and then tested further to check their dimension and mechanical properties.

Results and Achievements

The first pair of inserts survived for 27 runs while the other two pairs lasted for 6 and 0 runs respectively. The design of the runners played a huge role in the performance of the inserts and was the deciding factor of which inserts worked and which did not. Since the parts produced, as seen in Figure 2, consisted of a lot of flash, they were de-flashed manually using a thin blade and polished on a rotating mandrill using a sand paper.

Further testing was done on the O-ring produced. By measuring the dimensions, it was noted that overall the O-rings produced were smaller than required which could be an effect of shrinkage inside the mould. Hardness and compression set tests showed that the properties of the moulded parts were within tolerance however, the polishing technique used, had a slight negative effect on the hardness of the parts. Overall, the project was successful, as rubber prototypes were produced from a 3D printed mould insert. With further improvements, this prototyping method can be easily implemented and used.

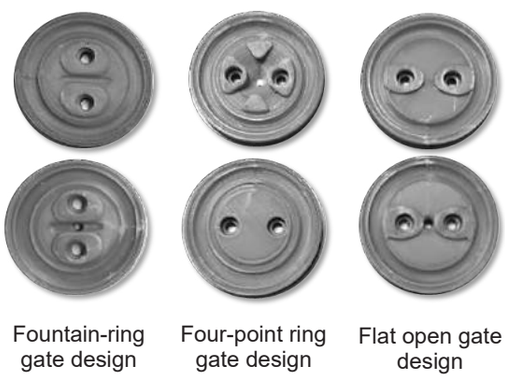


Figure 1: The finished 3D printed inserts

Figure 2: The demoulded parts were de-flashed using a blade and polished using a sand paper

Development of a Prosthetic Hand

Student: Gabriel Agius Pascalidis / Supervisor: Prof. Michael A. Saliba / Co-Supervisor: Mr Donald Dalli

Introduction

The amputation of a human's body part will have drastic physical and psychological effects on a person's life. The hand is the most dexterous part of the body having various grasp capabilities and manipulations, making it very difficult when designing an anthropomorphic robotic hand to mimic a human hand in its form, mechanical behaviour and control.

Project Objectives

The main objective of this project was to evaluate the grasping and manipulation performance for the physical prosthetic hand model, the UMPRO-1 by designing a control glove and implementing haptic feedback on the glove.

Project Methodologies

A glove was produced using bend sensors across the thumb, index and middle fingers, controlling the flexion and extension of the prosthetic hand. Another 2 smaller bend sensors were used, placing one between the index and middle finger for abduction / adduction motion and the other one was used for the thumb opposition movement.
With regards to the touch sensing, Force Sensing Resistors were used on the fingertips of the UMPRO-1 with vibrating motors on the fingertips of the glove acting as haptic feedback to the operator.
The whole system was controlled via an Arduino [1] Mega 2560 which was placed in the black control box shown in Figure 1.

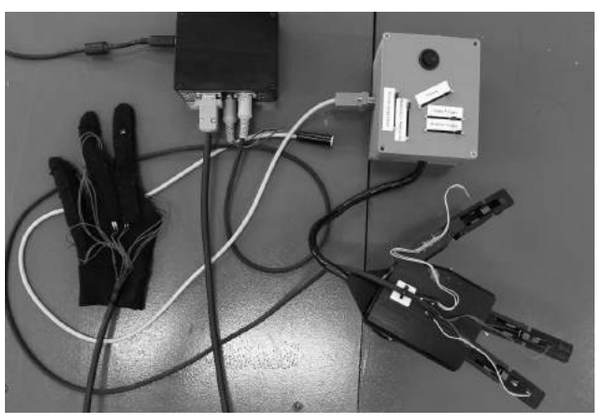


Figure 1: Glove control system with UMPRO-1

Results and Achievements

The objective of this dissertation was accomplished effectively in building a glove having total control on the UMPRO-1 hand copying all the hand gestures performed from the control glove. The touch feedback response was also satisfactory with the vibrating motors on the glove's fingertips increasing intensity as more pressure was being applied on the robotic hand's finger tips.
Tests being carried out involved in performing different hand grasps and comparing them with previous years results obtained. [2]
Dexterity tests were also achieved which included the nine-hole peg test and the box and block test (Figure 2) [3], [4]. Taking into account multiple restrictions from a 3 fingered under actuated robotic hand, results deemed to be satisfactory.

References

[1] D. Mellis, *ARDUINO IDE 1.8.5*. Northern Italy: Arduino, 2018.

[2] M. Cutajar, "An Exploratory Study on the Development of a Prosthetic Variant of the UM-MAR Hand", B.Eng. (Hons.) dissertation, Department of Mechanical Engineering, University of Malta, Msida, Malta, 2017.

[3] V. Mathiowetz, K. Weber, N. Kashman and G. Volland, "Adult Norms for the Nine Hole Peg Test of Finger Dexterity", *The Occupational Therapy Journal of Research*, vol. 5, no. 1, pp. 24-38, 1985.

[4] V. Mathiowetz, G. Volland, N. Kashman and K. Weber, "Adult Norms for the Box and Block Test of Manual Dexterity", *American Journal of Occupational Therapy*, vol. 39, no. 6, pp. 386-391, 1985.

Figure 2: Box and block dexterity test

Evaluating the Energy Requirements of UAVs for Wind Turbine Blade Inspection in Wind Farms

Student: Jean Paul Aquilina / Supervisor: Prof. Ing. Tonio Sant / Co-Supervisor: Dr Ing. Robert Farrugia

Introduction

The wind turbine industry is growing continuously due to the demand of renewable energy resources. Wind turbines require frequent inspections to keep them in working order. A wind turbine inspection can be a lengthy and dangerous procedure. However, the recent developments in the UAV industry have left a significant impact on the wind energy industry as drones are being used to carry out the inspections.

Project Objectives

The main objective of this project was to identify how certain parameters effect the energy consumption and flight duration of the drones when performing a wind turbine blade inspection. The parameters investigated were the wake model used, the undisturbed wind speed, the downwind spacing and the wind direction.

Project Methodologies

In order to determine the energy and time requirements for a drone to inspect the wind turbine blades of an entire wind farm, the analysis was first performed on a single wind turbine.

A numerical model named WindDRONE was developed using MATLAB [1] in order to be able to predict the energy and inspection time required by the drone. The variable in WindDRONE was the local wind speed at the hub height of the wind turbine. The energy consumption of the drone increases with local wind speed, hence different inspection routes were designed depending on the number of battery changes which were required in order to perform the complete the wind turbine blade inspection.

In a wind farm, wind turbines interact with each other due to the aerodynamic wakes created. Therefore, the local wind speed at each wind turbine in a wind farm is different. The software package WindPRO 2.7 [2] was used to determine the local wind speeds at each wind turbine location in the wind farm. The local wind speed was then inputted into the numerical model WindDRONE, and the energy and time required was predicted. This was done for every wind turbine location. The parameters investigated using this method included the wake model used, the undisturbed wind speed, the downwind inter-turbine spacing and the wind direction.

Results and Achievements

The four tests carried out investigated the different effects of the parameters mentioned previously. In each test, three cases were analysed. The range of the energy and time consumed to inspect the wind turbine blades of the entire wind farm for each test was calculated and represented in the column graph shown Figure1. From the results, as shown in Figure 1, it is evident that the parameter which has the largest influence on the energy consumption and inspection time of the drone is the undisturbed wind speed followed by the wind direction, the wake model and the downwind spacing.

The understanding of how the wind flow and wind farm layout parameters investigated in this study effect the energy consumption and inspection time is of utmost importance in the wind turbine industry. This knowledge enables the industry to plan a time and cost-effective inspection of the wind turbine blades in a wind farm.

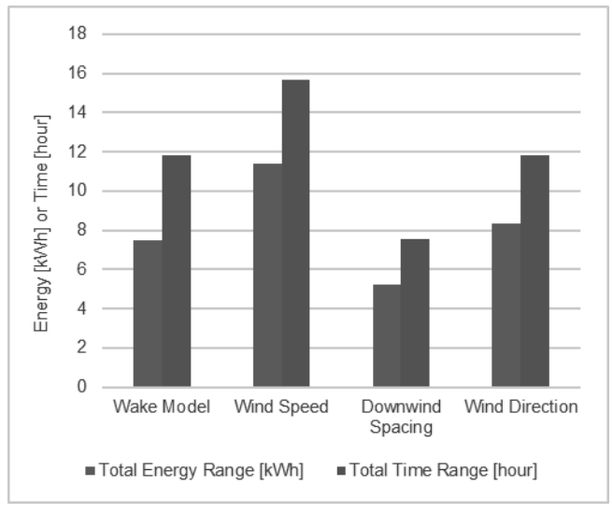


Figure 1: Column graph of the energy and time ranges predicted for each parameter

References

[1] MathWorks, “MATLAB R2015b”. [Online]. Available: https://www.mathworks.com/products/matlab.html

[2] EMD International A/S, “WindPRO”. [Online]. Available: https://www.emd.dk/windpro/

PIV Using Open Source Software and Common Photographic Equipment

Student: Mark Andreas Attard / Supervisor: Dr Ing. Christopher Micallef

Introduction

Particle Image Velocimetry (PIV) is an indirect full field quantitative flow measurement technique. This contrasts with other techniques such as hot wire or pitot where only a single point can be measured. PIV works by capturing sequential images of illuminated particles seeded in the flow under investigation which images are cross-correlated determining the distance between each set of particles. Knowing the time between one frame and the next, velocity is achieved.

Project Objectives

To build a PIV setup making use of an open source software readily available in the public domain and standard photographic equipment to determine a planar flow field around an object.

Project Methodologies

A laser setup [Figure 1] was built to illuminate the upper section of the aerofoil by a thin sheet of laser light which was diverged by a Powell Lens. Talc Powder, used as tracer particles, were seeded inside a wind tunnel containing an aerofoil and illuminated, recording their movement by a video camera at 200fps. Two sequential images were extracted at 5ms apart. These images were evaluated using PIVlab [1-3]. A mask was first applied in regions of no illumination. A filter was then applied to highlight the particles before analysing by a direct cross-correlation (DCC). After analysing, the image was calibrated and spurious vectors were removed and replaced with interpolated ones. Two plots were presented namely a streamline plot and a velocity magnitude colour map. [Figure 2]

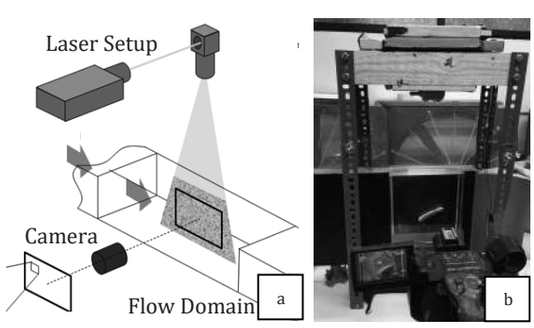


Figure 1: (a) Schematic diagram of the PIV setup [1] (b) The Setup used for this dissertation

Results and Achievements

Tests were carried out on six NACA 2412 aerofoil configurations at a freestream velocity of around 0.35ms^{-1}. Results were compared with visualisation carried out in a previous final year project [4] using smoke comb and atomised water.

The objectives of this dissertation were accomplished successfully by building a functioning PIV system. The results obtained exhibited a good general agreement with the streamlines generated by the smoke comb [4]. The flow structure and turbulence in the wake were clearly captured with more detailed streamline visualisation of the turbulent areas observed. Satisfactory results could also be observed when comparing the point of separation both in the streamline plot and the velocity magnitude colour map. [Figure 2]

References

[1] W. Thielicke, “The Flapping Flight of Birds: Analysis and Application”, Ph. D., University of Groningen, 2014
[2] W. Thielicke and E. Stamhuis, “PIVlab – Towards User-friendly, Affordable and Accurate Digital Particle Image Velocimetry in MATLAB”, Open Research Software, vol. 2, no. 1, 2014.
[3] W. Thielicke and E. Stamhuis, “PIVlab – Time-Resolved Digital Particle Image Velocimetry Tool for MATLAB (version: 1.41)”, 2014.
[4] G. Gauci, “Flow Visualisation of High-Lift Devices using Experimental and Numerical Techniques”, B.Eng.(Hons.) dissertation, Department of Mechanical Engineering, University of Malta, Msida, Malta, 2015

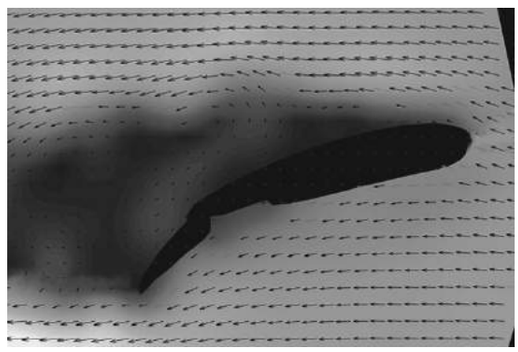


Figure 2: Velocity Magnitude Plot from PIV analysis of a Fowler Flap at 10°

Analysis of Steady State and Transient Vehicle Dynamic Handling Characteristics of a Production Car

Student: Mark Anthony Azzopardi / Supervisor: Prof. Ing. Mario Farrugia

Introduction

Vehicle dynamics is the major sector concerning the understanding of how vehicles function and how they react to external forces. It is a topic that relates every aspect of the vehicle with the surrounding environment and imposed conditions [1]. The handling characteristic of a vehicle can be described by two major metrics, these being the understeer gradient and roll gradient [2].

Project Objectives

The project objectives included the determination of understeer gradient, roll gradient and other pertinent measures observed in a production car. Moreover, the introduction of transient testing and simulation software were also among the project objectives.

Project Methodologies

The vehicle dynamic handling characteristics, such as the understeer gradient, roll gradient and other pertinent measures such as tyre slip angles and sideslip angles, were determined through a standardised steady state experiment. The execution of this experiment involves the car being driven around a constant radius circle for a variation of constant velocities.

The transient testing was carried out at a racetrack in Sicily. The obtained data was analysed to determine the vehicle and driver performance. These were compared to an optimal performance generated by a vehicle dynamics software.

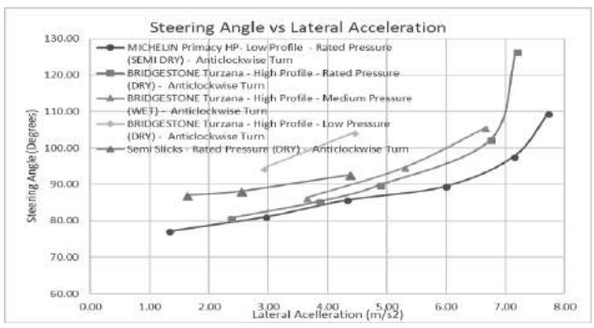


Figure 1: Collection of obtained anticlockwise curves during both test day

Results and Achievements

Figure 1 exhibits the results obtained for the understeer gradient. The curves obtained show that the production car has an understeer design. From these curves it was also concluded that the most important property during cornering is the tyre cornering stiffness. Moreover, tyre slip angles and side slip angles were determined. The results obtained were coherent to those presented in several literatures.

The roll gradient was also investigated. The curves obtained are coherent with those discussed in literature. Moreover, it was concluded that for reduced tyre pressures the vehicle undergoes higher roll which is undesirable with regards to vehicle handling. These results were then compared to results obtained through a vehicle dynamics software.

The results obtained through transient track testing were compared to the ideal performance obtained through a simulation software which can be observed in Figure 2. The testing was carried out using two different sets of tyres, road tyres and semi slick tyres. The results obtained showed the superior performance of the semi slick tyres both in straights and corners.

References

[1] Gillespie T.D., 'Fundamentals of Vehicle Dynamics' Society of Automotive Engineers, Warrendale, 1992.

[2] Milliken W.F., 'Race Car Vehicle Dynamics' Society of Automotive Engineers, Warrendale, 1995.

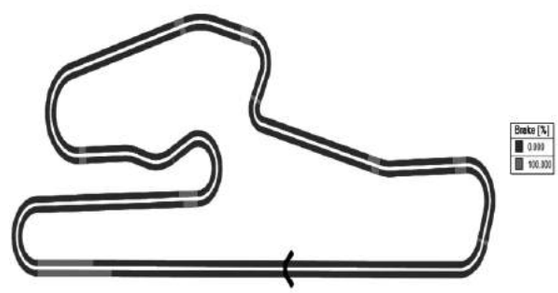


Figure 2: OptimumLap Track Map – Braking

Characterisation of External Flows Round an FSAE Car

Student: Jake Ayrton Bajada / Supervisor: Dr Simon Mizzi

Introduction

In motorsport it is well-known that by increasing the normal force acting on the tyres, higher lateral accelerations can be obtained, ultimately resulting in better vehicle performance [1]. This is the aim of aerodynamic packages, a common feature in the formula style FSAE competitions, in which the University of Malta Racing team (UoMR) participates.

Project Objectives

The primary scope of this dissertation was to improve on the first aerodynamic package design iteration by extracting more downforce through an optimised dual-element aerofoil configuration, by means of CFD analyses. Validation of the obtained results was to be done through on-track testing.

Project Methodologies

In order to evaluate the accuracy of the CFD analysis of two-element airfoils, the two-element airfoil used in NACA Report 573 was analysed in Fluent.
A Workbench set-up was used to carry out optimisation on a dual-element aerofoil configuration. The 2-D simulations consisted of evaluating the effect of 3 design parameters on the wing's performance. The front and rear wing were then modelled using Inventor and assembled with the rest of the vehicle. 3-D simulations were carried out following some geometry simplifications.
A constant radius test was used to validate the generated data by monitoring the measured lateral g while cornering.

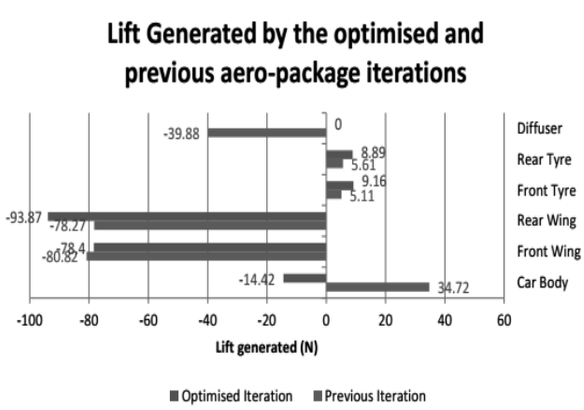


Figure 1: Optimised vs non-optimised 3-D results

Results and Achievements

The validation case showed that Spalart-Almaras provided lift coefficient values within 9% of the documented values. Hence the use of this inexpensive turbulence model for optimisation in 2-D was justified. Optimisation for the rear wing case showed that that the flap size should be minimized; the vertical separation has an optimal point that is neither too low nor too high, while the horizontal offset does not play a big role in generation of downforce. The 3-D results (Figure 1) showed an improvement in rear wing performance of 19.9% over the previous, non-optimised case. The front wing was not optimised fully for maximum downforce, improving flow over the rest of the vehicle body. In fact some downforce was generated rather than lift as in the previous iteration.
The constant radius test performed using a prototype aerodynamic package (Figure 2) showed a discrepancy of 29%, attributed to the difficulty in controlling this type of experiment. Hence, this method is not suitable for accurate evaluation of aerodynamic package performance.

References

[1] Katz J., 'Race Car Aerodynamics: Designing for Speed', Cambridge: Bentley Publishers,1995.

Figure 2: Prototype aerodynamic package

Solar Cooling

Student: Darrell Baldacchino / Supervisor: Prof. Ing. Robert Ghirlando

Introduction

Solar radiation can be exploited by means of solar collectors, to provide the necessary heat to the generator of a vapour absorption chiller. The Solar Cooling system in question was over-designed to enable operation during cloudy days when limited insolation is available. This led to the generation of excess thermal energy by the solar collectors during clear days, resulting in high vaporisation and pressurisation within the piping system.

Project Objectives

The objectives were to study an improvement to the system whereby the extra heat is either stored for later use or dissipated and to obtain new results and compare with the original system.

Project Methodologies

The Solar Cooling system found at the Wine Research Centre in Buskett was simulated with a computer model, using the software package TRNSYS. The individual components of the model namely, the chiller, the solar collectors, the dry fluid recooler and the thermal storage tanks were validated using real data from the system being modelled. Thus, data files representing actual weather data were generated. Finally, the system was tested using Meteonorm weather files. Two scenarios were taken into consideration; complete system without a thermal storage tank and complete system with the thermal storage tank included. The latter is shown in figure 1.

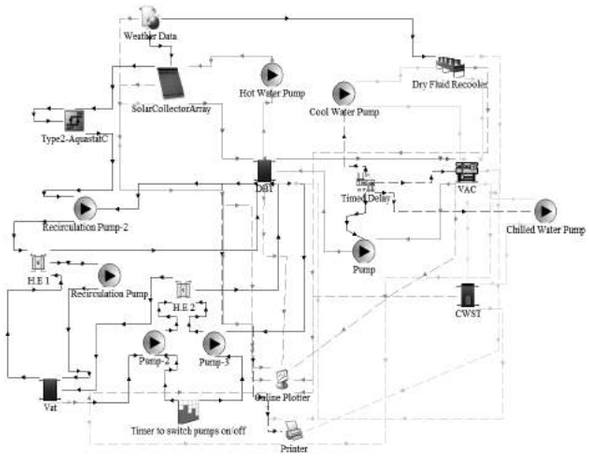


Figure 1: Solar Cooling system built using TRNSYS

Results and Achievements

The idea of incorporating one of the concrete vats found on site as a thermal energy storage to the Vapour Absorption System was chosen. The modelling of the original connections of the vat to the rest of the system had to be altered due to software limitations. This led to the introduction of two controllers instead of one.

Controller 1 calls the pump between the collectors and the thermal storage tank (vat) to switch on when a temperature of 95^0C is reached within the collectors. As a result, water exceeding 95^0C is pumped to the vat to be stored for later use.

On the other hand, controller 2, unlike controller 1 does not depend on temperatures to switch on and off. In fact, controller 2 was set to switch on the pump during night time and early in the morning when no solar energy is available. This was done so as to not lose the heat from the water since the small thermal storage tank, also known as the drain-back tank has a smaller capacity and higher thermal losses.

The graph for the 24-hour simulation run shown in figure 2 displays the temperature of the water leaving the collectors before and after the addition of the vat and optimisation of the original system. Prior to optimisation, the water temperature was exceedingly high, up to around 132^0C. However with the inclusion of the vat as a thermal storage and a flow rate of 0.15kg/s for the hot water pump, the temperature of the water does not exceed 100^0C.

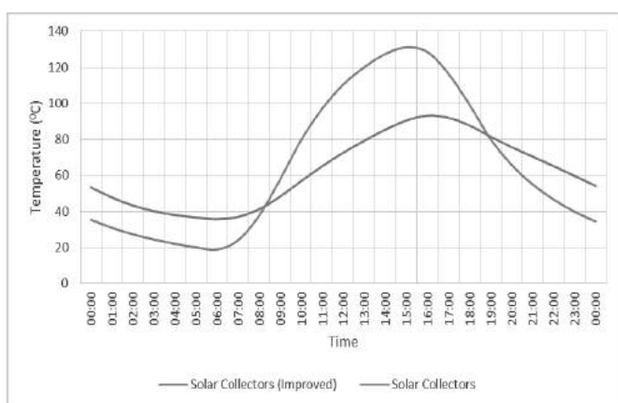


Figure 2: Graph of Temperature Vs time for the collectors

Preliminary Design of an Offshore Fish Farm Support Vessel.

Student: Sarah Baldacchino / Supervisor: Prof. Ing. Claire De Marco

Introduction

The aquaculture industry is growing rapidly, the expansion as well as other environmental issues, have given rise to the need for fish farms to move to offshore locations circa 12 nautical miles off coast. The project aims to create a preliminary design of a fish farm support vessel to be able to operate in offshore conditions.

Project Objectives

The overall objective is to produce a preliminary design of a general purpose workboat capable of journeying to a location 12 nautical mile offshore on a daily basis. The project aims to produce a general arrangement of the vessel tested for adequate stability and seakeeping ability according to existing maritime standards.

Project Methodologies

A comprehensive knowledge regarding fish farm support vessels was obtained prior to embarking on the design process. The primary functions of such a vessel include transportation and discharging of fish feed to the pans.
The first step in designing the vessel was to estimate the lightweight and deadweight components. The latter was achieved by using empirical formulas based on a survey of existing vessels.
The powering process was conducted by determining the total hull resistance at a service speed of 15 knot. The required engine power could then be calculated and the engine and propeller were sized accordingly.
The general arrangement was produced and two loadcases were designed mainly, the maximum loaded condition and the loaded arrival condition. The former relates to the vessel at the maximum displacement whilst the latter is equivalent to the maximum scenario without the payload. The reason behind the latter loadcase is that the fish feed would have been discharged off board before returning to shore.
Using the aforementioned loadcases, the vessel's stability was tested according to ISO 12217-1 [1] for operating conditions of Beaufort scale 8. Furthermore, the seakeeping ability was analysed in accordance with ISO 2631/3 [2].

Results and Achievements

The vessel's lightweight and deadweight were approximated as 87 and 20 tonne respectively. The required on-board tank capacities were based on a total crew of four members and a total voyage length of 24 hours to account for overnight stays.
Following a resistance analysis, the boat was fitted with a MAN Engines D2862 medium duty engine having an installed power of 1029 kilowatt and a fixed pitch propeller of 1 metre in diameter.
With the engine and propeller sized, a general arrangement was produced A three dimensional model of the support vessel can be seen in Figure 1.
Finally, the vessel was determined to be stable and having adequate seakeeping ability under weather conditions as specified by the relevant standards.

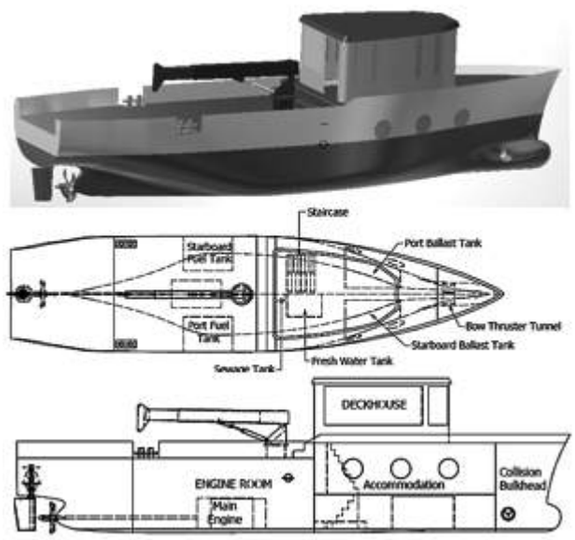


Figure 1: 'MV VELVET SEAS'

References

[1] International Organisation for Standardisation, 'ISO 12217-1: Stability and Buoyancy Assessment and Categorization of Non-sailing Boats of Hull Length Greater or Eqaul to 6 Metres', 2005.

[2] International Organisation for Standardisation, 'ISO 2631/3: Evaluation of human exposure to whole-bodv vibration'. 1985.

Development of a Robotic Teleoperation System

Student: Joshua Barbara / Supervisor: Prof. Ing. Michael A. Saliba / Co-Supervisor: Mr Donald Dalli

Introduction

The most dexterous robotic manipulators have similar shape and size to that of the human hand. The involvement of controlling a robot from a remote location not using direct implementation is known as teleoperation. Combining these properties would create an intuitive robotic control that is capable of carrying out human-like tasks.

Project Objectives

This primary objective is to achieve a fully functioning teleoperated hand system that also provides haptic feedback. Moreover, carry out some mechanical improvements, mount the hand on the Mitsubishi robot and develop a 3D tracking system.

Project Methodologies

The project was divided into two sections the glove and robotic hand section and the 3D tracking part. For the robotic hand part, the main focus was in bringing it back to operational conditions. For the glove system show in Figure 1, it had to be designed and build entirely from scratch. Once both systems were operating both were incorporated together in order for the user to be able in controlling the hand using a glove. For the 3D tracking part an IMU based system with gyroscopes, accelerometers and magnetometers. selected. The system works by integrating the provided acceleration twice in order to get the required displacement.

Results and Achievements

Once the whole system was up and runningit was assembled on the robotic arm as shoen in Figure 2, it was troubleshot and tested. Some major drawbacks started to emerge such as the actuating system being quite ineffective in certain positions, Moreover, when it comes to grasping heavy and bulky objects, the hand struggles in keeping a constant grip. This problem was fought back by introducing a haptic feedback since it works using FSRs and vibrating motors. For the dexterity test, the human outperformed the robotic hand. This is still a positive result since it shows that such a robot is capable of carrying out such a test under certain conditions and a benchmark time was established in order to be improved in the coming years.

For the 3D tracking section, the MPU9250 in combination with an Arduino Microcontroller were selected to be the base devices for this positioning system. After getting the theoretic background, this system was physically implemented. The roll and pitch acquisition techniques worked both in theory and in practice. Conversely, the yaw angle method was not precise enough mainly due to the calibration of the magnetometer or unstable hardware accuracies. For the position determination part, the system did not suffer from drift, but the positioning was not accurate due to the filtering and integration methods used. With the use of another calibration system and the use of a Madgwick filter, the yaw angle will work well. Also, if the integration and filtering methods are change the accuracy will improve.

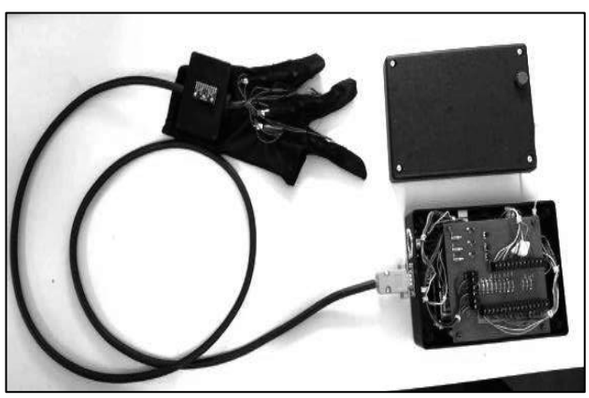


Figure 1: Data glove and its control system

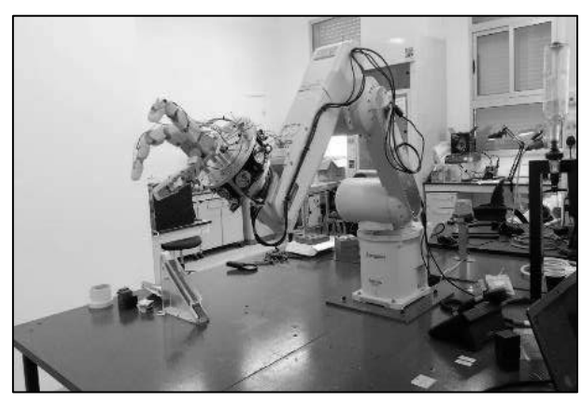


Figure 2: Final robotic arm and hand implementation

Characterisation of Small Craft FRP Laminate

Student: Jamie Bartolo / Supervisor: Prof. Claire De Marco

Introduction

The aim of the BS EN ISO 12215-5:2008 [1] standard is to achieve an overall structural strength that ensures the watertight and weathertight integrity of the craft. Researchers have performed characterisation tests on fibre reinforced plastic (FRP) composite laminates over a range of fibre mass fractions. The results obtained showed variations to the properties as given by the standard.

Project Objectives

The aim of the final year project is to:

- Build laminates consisting of a variety of fibre mass fractions by using different composite manufacturing techniques
- Characterisation testing regime of laminates with different fibre mass fractions
- Developing new analytical formulae governing laminate properties

Project Methodologies

For the design of the laminate, Mat 92 E-glass chopped strand mat (CSM) fibres were used as the reinforcement material. Two different types of CSM fibres were used; CSM300 and CSM450. Marine grade orthophthalic polyester, Reichhold POLYLITE® 440-M850 was used to act as the matrix. The aim of the laminate design was to obtain different fibre volume fractions, hence it was decided to have five different fibre volume fractions for both the CSM300 and the CSM450 fibres. All the laminates consisted of the same number of layers, since the properties of the fibre volume fractions were to be compared. In order to obtain a range of fibre volume fractions, two different fabrication methods were used; the hand lay-up method and the vacuum bagging technique. The hand lay-up method is used to obtain FRP laminates with small fibre volume fractions whilst the vacuum bagging technique is used to obtain larger fibre volume fractions. A characterization testing regime was carried out for laminates having different fibre volume fractions. Tensile, compression, flexural and shear tests were undertaken according to verified standards.

Results and Achievements

From the results obtained throughout the testing, it was clear that discrepancies occurred between the Standard predictions and the experimental results. Hence modifications have been made in order to improve the accuracy of the predicted results by the BS EN ISO 12215-5:2008 standard. Table C.4 a) in [1] presents the equations needed in order to predict properties for E-glass composites, according to the mass fibre fraction. From the results obtained, the CSM300 and the CSM450 fibres displayed minor variations in mechanical properties. However when considering experimental errors and the standard deviation of the results it can be concluded that the CSM300 and the CSM450 can follow the same prediction equations for all the mechanical properties. Hence the equations were modified by using a second order polynomial curve fitting exercise through the experimental results. Figure 1 shows a comparison between the new modified equation and the original standard equation for the ultimate tensile strength.

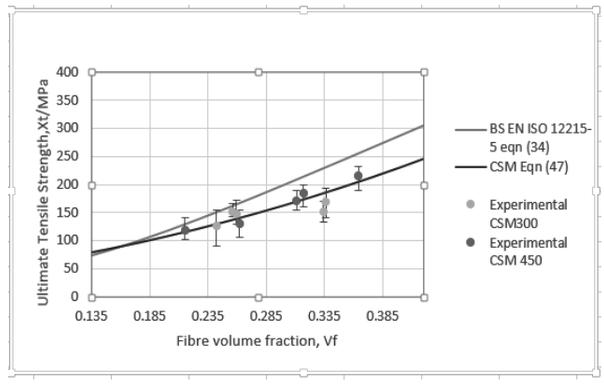


Figure 1: New Ultimate Tensile Strength prediction for CSM compared to the BS EN ISO 12215-5:2008 standard

References

[1] Small craft-Hull construction and Scantlings- Part 5: Design pressures for monohulls, design stresses, scantlings determination, ISO Standard 12215-5:2008

The Design, Build and Test of an Experiment on The Deformation of Truss Structures

Student: Rafel Bencini / Supervisor: Dr Ing. Pierluigi Mollicone

Introduction

The aim of this project was to bridge the gap between the theoretical side of the subject 'Mechanics of Materials' and the hands on approach an engineering student should gain from this subject. This project aimed at creating a fully functional experimental setup to understand the phenomena behind the deformation in truss structures. Through the course of this project an experimental setup was designed, built and tested so as to end up with a an apparatus that successfully portrayed the situation 2D truss structures undergo when loads are applied to them.

Project Objectives

- To create an experimental setup that would show a proper experimental representation of the deformation in truss structures
- To create an experimental setup that could be interchangeable and study different types of frameworks also equipped using different materials
- To create an experimental setup that accurately measures the results needed and is easy to use
- To create a comparison of the results obtained and use this comparison to draw out any conclusions
- To create a learning platform through which the student can understand the topic and through the use of lab reports grade the students on their understanding

Project Methodologies

Once the topic of the experimental setup to be constructed was chosen, the following step was to conduct a market research to obtain design ideas from professional educational engineering companies that construct similar apparatus that target the same topic. Through the ideas obtained from the market research, the components that would be needed to create a successful experiment were chosen and assessed and design ideas of these components were created. Through brainstorming methods and a morphological chart the best design for every component was then chosen.

Design calculations were then done on the designs chosen for the components so as to make sure that the components would withstand the loads to be applied onto to them. Once the calculations were approved, every component was manufactured and the final experimental assembly was created.

Results and Achievements

The experimental apparatus manufactured was then used to obtain a number of results regarding the deformation of four main industrial truss frameworks and compare these results together. This comparison was then used to analyse the performance of each framework mentioned and use the results to obtain conclusive data regarding each frameworks structural performance.

The deformations of the four frameworks obtained were then compared to theoretical and analytical calculations to see if the results obtained by the experimental apparatus constructed showed a correct representation and could be considered as successful. The results of this comparison showed that the experimental results fell into the 15% experimental error range when compared to the analytical results, deeming the experimental setup manufactured successful.

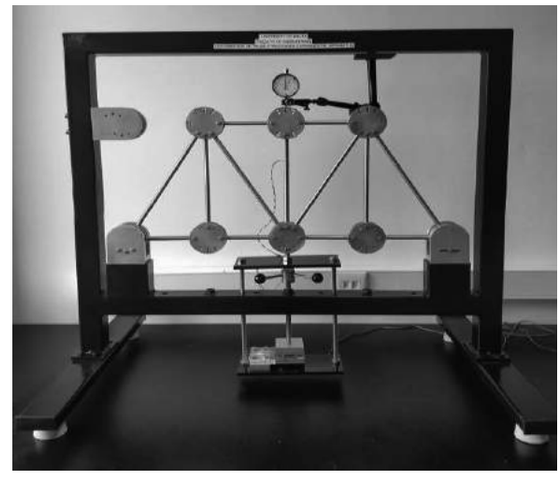


Figure 1: Final Experimental Apparatus regarding the 'Deformation of Truss Structures'

References

[1] R.C Hibbeler, Mechanics of Materials, Eighth Edition, Pearson Learning, 2012

[2] J.J. Connor, S. Faraji, Fundamentals of Structural Engineering, Springer International Publishing Switzerland 2016

Impact of Cooling Passages on Race Car Performance

Student: Ryan Bezzina / Supervisor: Dr Simon Mizzi

Introduction

In recent decades, motorsport has taken over the racing scene, with the primary area of improvement being aerodynamics. The cooling passage is one of many vehicle sections affecting the race car's performance. This project aims to shed light on the influential factors and testing techniques used to optimise cooling passage designs.

Project Objectives

The project basically involved using Computational Fluid Dynamics (CFD) software to study the factors essential to a successful cooling system. A validated simulation approach was found and used to analyse how to optimise a race car cooling system/passage.

Project Methodologies

The first step involved familiarizing one's self with the CFD software adopted for the project. A wind tunnel case study [1] analysing the heat transfer from a cylinder in axial turbulent flow was read thoroughly and implemented into the software. The intention being that of validating the simulation approach, to be able to implement it to the actual 3D cooling passage application.

The simulation approach was similarly applied to a concept 3D FSAE sidepod/cooling passage model using CFD. Vital factors including velocity, pressure and temperature fluctuations were observed.

Results and Achievements

After exhaustive research on the subject at hand [2], [3], it was found that the most important aspects would be high pressure and low velocity at passage inlet, followed by a large pressure drop in the radiator's region and finally low pressure and high velocity at passage outlet.

When implementing the validated simulation approach to the model, the 3D simulations managed to show just that. Besides that, the model was simulated at several radiator orientations, therefore increasing the amount of heat to be transferred. This was all done in such a way as to have no negative influence on the drag but a large improvement in cooling efficiency.

References

[1] Wiberg R. and Lior N., 'Heat transfer from a cylinder in axial turbulent flows' International Journal of Heat and Mass Transfer, 2005, Vol. 48, No. 8, pp.1505-1517

[2] Katz J., 'Race Car Aerodynamics. Designing for Speed' Bentley Publishers, Cambridge, 1995.

[3] Milliken W.F. and Milliken D.L., 'Race Car Vehicle Dynamics' Society of Automotive Engineers, Inc., Warrendale, USA, 1995.

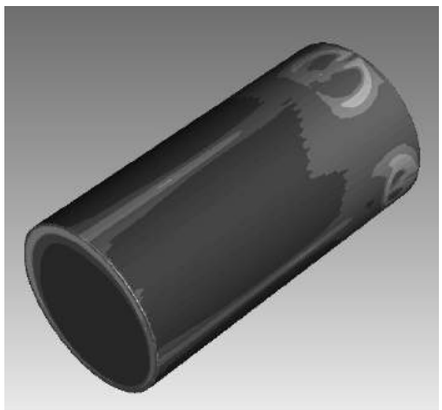


Figure 1: Cylinder Surface Temperature Variation

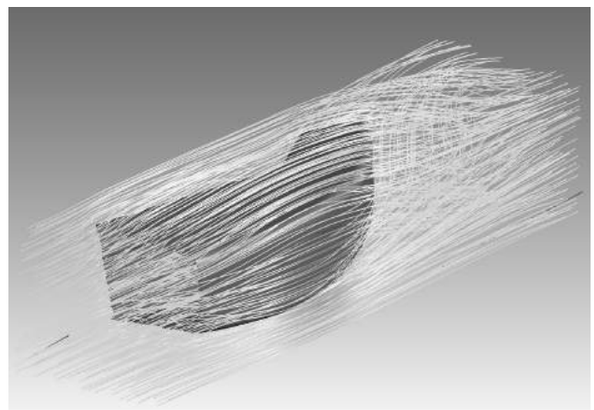


Figure 2: Velocity Streamlines for the FSAE Sidepod

Solar Assisted Air Conditioning

Student: Ylenia Victoria Bonello / Supervisor: Dr Ing. Christopher Micallef

Introduction

Air conditioning (AC), specifically cooling, has become more common due to the increased comfort demands and higher standard of living. This, however, has brought about a rise in greenhouse gas emissions. Novel technologies operated by renewable energy sources are constantly being developed to avoid this serious strain on the environment [1].

Project Objectives

This final year project investigates how an air conditioning system is affected when solar heat input is introduced to it. The objectives were to perform a literature review on the system built specifically for this project, and to test and analyse the efficiency of an experimental setup which simulates a solar assisted air conditioning unit.

Project Methodologies

The solar assisted air conditioning system consists of the same components of a normal AC unit, that is, the compressor, condenser, evaporator and a throttling device, with the incorporation of a water tank, which simulates the use of solar thermal collectors connected to a solar thermal storage tank. The water tank contains a coil through which the refrigerant passes, to allow heat transfer to occur. The water is heated up to simulate solar heat input, which in turn heats up the refrigerant inside the coil. The tank is situated just before the condenser, as shown in Figure 1.

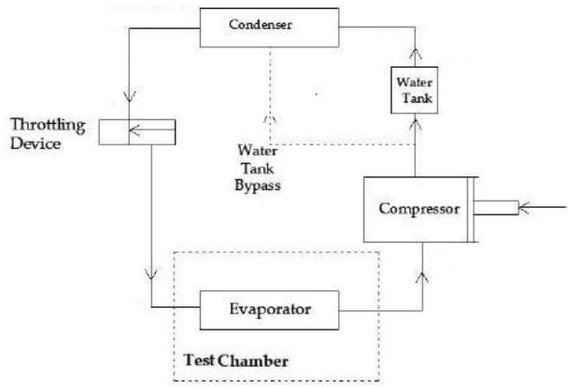


Figure 1: System Schematic

Results and Achievements

Testing was done for various water temperatures inside the tank, so as to observe how this would affect the system's performance. The Coefficient of Performance (COP) is a measure of an air conditioning system's performance. Various experiments were carried out to observe how different water tank temperatures would affect the COP. The experiments included a recording of the temperatures of all the components within the system, by means of thermocouples placed at various positions, which were then connected to a data logger. For the first experiment, the water tank was bypassed to allow the system to operate as a traditional AC system. The rest of experiments involved varying the water inside the tank and evaluating the COP for each test. The relationship between the water temperature and the corresponding COP is illustrated in Figure 2. From these results, it was concluded that as the water temperature increased, the system's performance decreased. However, the introduction of the water tank to the system was still of significance since at 25°C, the COP was much higher than that of a typical AC system.

References

[1] H. et al, ''An Overview of Solar Assisted Air-Conditioning System Application in Small Office Buildings," Proceedings of the 4th IASME/WSEAS International Conference on Energy & Environment, pp.244-251, 2009

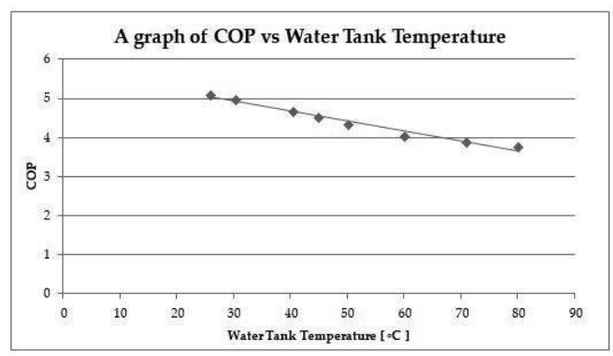


Figure 2: Variation of COP with Water Temperature

Transient thermal analysis (CFD) of MEMS devices processing

Student: Gabriel Borg / Supervisor: Dr Ing. Christopher Micallef

Introduction

MEMS devices are very small devices found in all of the electronics we daily use, making them more useful and compact. Most of these devices require a packaging system such as a metal can as a cover to protect any sensors that would be present in the device. The metal can is attached with the use of solder paste that is cured with a reflow process.

Project Objectives

The main aim of this project was to get a better understanding of the transient development of the temperature distribution in the component using both experimental results and CFD simulations.

Project Methodologies

The temperature results were obtained from a reflow oven using the thermocouples that were attached to the substrate seen in Figure 1.
With this information gathered from the experimental runs, a 2D and 3D CFD simulations were designed.
To validate the simulations, the results obtained experimentally were compared with the results obtained from the simulations. From the results obtained, a difference between the top and bottom surface temperatures was evident. The edge effect was also present in both the experimental results and in the 3D simulation.

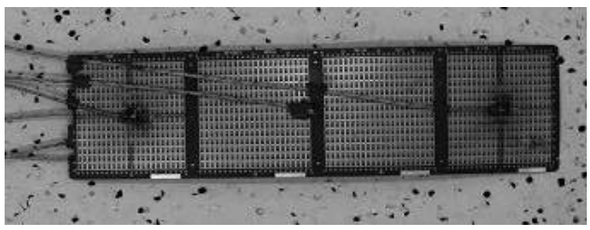


Figure 1: The jig used to record the temperatures that the substrate was undergoing throughout the whole process. Another 3 thermocouples were attached to the bottom surface of the substrate in the same locations as the top thermocouples

Results and Achievements

From the results obtained, 2 main issues were established from the reflow process:

1. The Mesh Belt:

Since the bottom surface of the substrate was in contact with the mesh belt throughout the whole process and since the mesh belt is a conductor, it was found that the bottom surface of the substrate was heating up and cooling down faster than the top surface of the substrate. This was also proved by analysing the CFD simulation and finding out that without the mesh belt the top and bottom surface temperatures of the substrate were very similar to each other.

2. Edge Effect:

From the results obtained both experimentally and from the CFD simulation, it was concluded that the edge effect was present during the reflow process mainly due to the geometry of the substrate. Due to the edge effect, many devices located near the edge of the substrate were cooling down at a much faster rate than predicted and due to the faster rate of cooling, the solder paste was undergoing thermal shocks which were followed by cracks in the solder making the solder joint weak. This difference in temperature can be seen in Figure 2 where the edges of the substrate are light blue whereas the centre of the substrate is green showing that the centre of the substrate on entering the cooling zone has a higher temperature than the edges of the substrate.

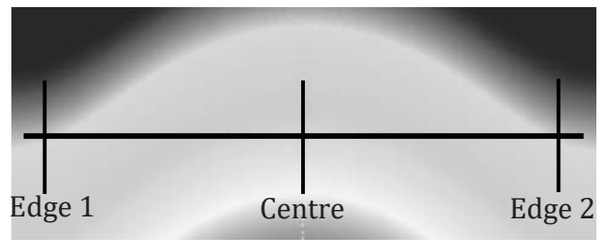


Figure 2: The temperature contour plot of the middle section of the substrate showing the difference in temperature between the edges and the centre of the substrate

Improvement of a Robotic Supermarket Checkout System

Student: Matthew Brincat / Supervisor: Prof. Ing. Michael A. Saliba

Introduction

A robotic checkout system is currently being developed at the University of Malta. Before the robotic checkout can be introduced to the market, a number of improvements are required to make it more desirable and suitable for supermarket owners. The robotic checkout makes use of a SCARA robot, a machine vision system and a conveyor belt for operation.

Project Objectives

The main objectives for the dissertation were to create a computer aided design model for the finalised robotic checkout as would it appear in its final layout, as well as to improve general issues with the current prototype.

Project Methodologies

The main improvements highlighted throughout the dissertation focused mainly on the safety and security requirements of the robotic checkout, the addition of a reject and box replenishment system, and a solution to the drifting issue present with the conveyor belt.

A design process for the improvements was carried out by first identifying the requirements posed by supermarket owners, who make up the target market for the robotic checkout. A number of conceptual solutions were drawn up, with the ones most suited for the requirements being chosen using a decision matrix.

The solutions were then designed in Autodesk Inventor using existing technologies and equipment to improve the ease of assembly and maintenance for the system whilst also aiming to keep costs low and realistic to the supermarket environment.

The safety requirements were derived from a risk assessment and modelled to conform to existing ISO Standards, such as ISO 12100:2010 (Safety of Machinery).[1] The security layout was modelled to make use of radio frequency tags as theft indicators, whilst utilising existing systems such as barcode scanners and electronic gates to further reduce the likelihood of theft.

Results and Achievements

The final layout for the robotic checkout, seen in Figure 1 below, was drawn up in detail using Autodesk Inventor. The dimensions and distances applied were comparable to existing supermarket layouts, with the values being retrieved from architectural drawings of two different Maltese supermarkets.

The final system conforms as much as possible to the requirements posed by supermarket owners who specified that a supermarket checkout must be low in cost and small in size for them to consider investing in it.

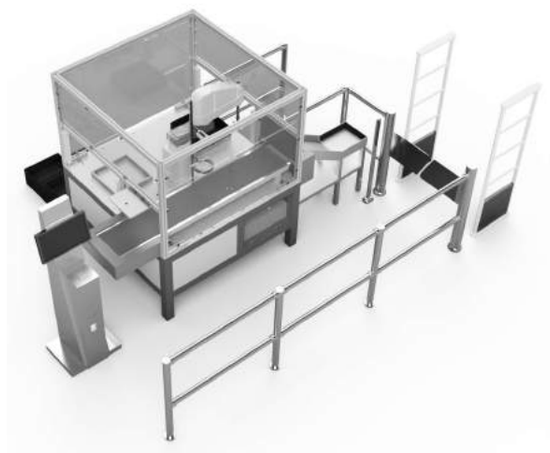


Figure 1: CAD Model for the Robotic Supermarket Checkout

References

[1] *Safety of Machinery – General Principles for Design – Risk Assessment & Risk Reduction,* EN ISO Standard 12100, 2010.

Winter Heat Pump Dissipation Through Well

Student: Malcolm Bugeja / Supervisor: Prof. Ing. Mario Farrugia

Introduction

Ground-coupled heat pumps make use of the constant temperature of the earth's surface to provide heating or cooling. The performance of such systems depends on the temperature of the geothermal couple, which can be groundwater, surface-water or the ground itself. The aims of this dissertation was to analyse, by in situ testing, the effects of changes in source temperature on the performance of a heat pump, coupled to a well, while operating in heating mode.

Project Objectives

The objectives of this project were to analyse the performance of the system while operating in winter mode and observe the changes in coefficient of performance with changing well-water temperature. The recovery history of the well-water temperature was also observed to assess the performance of the well as a geothermal coupling.

Project Methodologies

Temperature data was collected during both the time in which the heat pump was in-operation and the time it was switched off allowing the well-water temperature to recover. Other values collected during the experiments included: the flow rate of water; the compressor induction and delivery pressures (of refrigerant); and the electrical power consumed by the heat pump. The data was collected with the aim of analysing the performance of the heat pump system during its operation in heating mode, while that collected during nonoperational periods was used to analyse the recovery history.

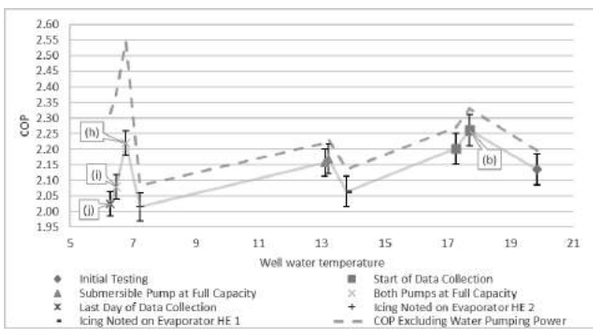


Figure 1: COP values calculated using the total power input, including the water pumping power

Results and Achievements

The well-coupled heat pump system was operated for the two months of January and February (of 2018) for which temperature, pressure and power consumption data was collected to analyse the system's performance. During these two months the well-water was cooled from 18 to 6.1°C consuming a total of 2520kW of energy for over 400hrs of operation.

During the period of operation, icing was noted to be forming on the heat exchanger in two occasions, namely at well water temperature of 13.2 and 6.8°C. This demanded an increase in water flowrate in the evaporator heat exchanger, which was used as the source of the heat pump system. These cases were identified as being major points of interest and the data collected during these tests, the day before and that after were used for the performance analysis.

For the performance analysis the system's COP was calculated and plotted against the well-water temperature (see Figure 1). This plot shows both the effect of decreasing source temperature and increasing water flowrate through the evaporator heat exchanger during the history of operation of the well-coupled ground source heat pump.

Finally, temperature recovery history of the well was observed. A suitable trend was identified for the plot recovering from 6°C up to 15°C. It was also noted that in the first two days the temperature recovered by 1°C but the full 9°C recovery took a total of 60days (See Figure 2).

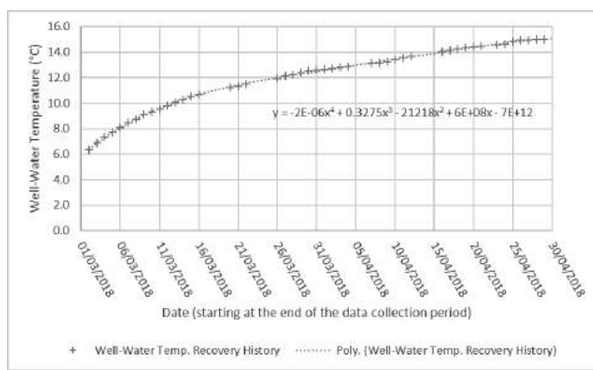


Figure 2: Recovery history after the end of data collection period, duration of recovery of approximately 60 days

Integrating Compressed Air Energy Storage into Floating Offshore Wind Farms

Student: George Cauchi / Supervisor: Prof. Tonio Sant / Co-Supervisor: Dr Ing. Robert N Farrugia

Introduction

Offshore wind farms offer numerous advantages, but these are still hindered by a few major challenges, with the most notable challenge being the need to even out the power fluctuations in wind energy generation. Energy storage can be a real solution to this problem with which large levels of penetration of renewable energy can be achieved.

Project Objectives

The project aims to investigate the performance of a Compressed Air Energy Storage (CAES) concept when used to even out power fluctuations, and to investigate its energy storage capacity requirements for different conditions occurring within a wind farm.

Project Methodologies

Several conceptual designs of an offshore floating wind farm with integrated CAES at each floating support structure were created in WindPRO, a software specifically designed for wind energy projects. The time series power output from each wind turbine within the designed wind farms were simulated, using real measured meteorological data. Three different wake models were used to estimate the wake losses within the designed wind farms.

The state of charge of the energy storage systems at different positions within the wind farm was modelled from knowledge of the simulated time series power output. Computational procedures created in Matlab were used to obtain the state of charge (SOC) time series of the storage system. From these SOC time series, the required energy storage capacity of the storage system was estimated with the use of data analysis tools such as cumulative density functions and histograms. Several test cases were devised to investigate how estimates for the required energy storage capacity for a wind farm are influenced by the wake model used, turbine position, turbine spacing and different averaging times.

Lastly, the influence that the size of the CAES and different thermodynamic processes have on the thermodynamic properties of the compressed air were investigated using numerical simulations.

Results and Achievements

The modelling performed in Matlab showed that the CAES concept can effectively convert an intermittent power output signal into a stepped signal with a reasonable energy storage capacity. The results obtained from the simulations showed that turbine position, the wake model used and inter-turbine spacing have a marginal influence on the required storage capacity. Meanwhile, it was determined that the averaging time on which the stepped signal is based has a significant influence on the required storage capacity.

The thermodynamic modelling performed in Matlab revealed that the CAES system exhibits best efficiency and energy density when it behaves adiabatically, and the attained air pressures and temperatures were also highest for the adiabatic process. Moreover, it was found that the air pressure and temperature increase significantly when smaller external chamber volumes are used.

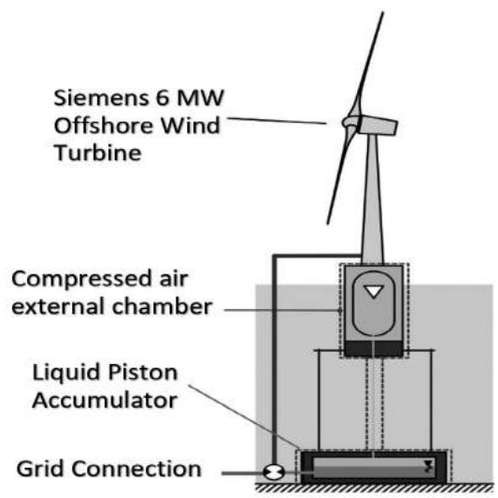


Figure 1: CAES integrated into Offshore Wind Turbine [1] (modified)

References

[1] D. Buhagiar, T. Sant, "Journal of Energy Storage," *Modelling Of A Novel Hydro-Pneumatic Accumulator For Large-Scale Offshore Energy Storage Applications,* vol. 14, no. 2, pp. 283 - 294, 2017.

PhotoStress Experimental Technique

Student: Michael Coppini / Supervisor: Dr Ing. Pierluigi Mollicone

Introduction

Today's industry dictates that components and structural members must be as efficient and structurally sound as possible. This is done by analysing stress distributions in components and structural members under load using computer modelling. This can be verified by alternative methods such as the PhotoStress Experimental Technique.

Project Objectives

This dissertation is aimed at building up knowledge on the PhotoStress Experimental Technique, reviewing the current equipment and setting it up to be easily used by students and researchers alike. Benchmark tests were also carried out and discussed.

Project Methodologies

The PhotoStress Experimental technique relies on the principles of polarisation and birefringence. Polarisation is used to orient incident light onto a particular plane, which in turn allows the operator to determine the direction of the principal stresses in the component or structural member and therefore determine the magnitudes of these stresses.

Birefringence is the ability that some materials have to alter their optical properties when put under stress. This is essential for the stresses in the component or structural member to be analysed based on the colour fringes induced in the PhotoStress coating. [1,2,3]

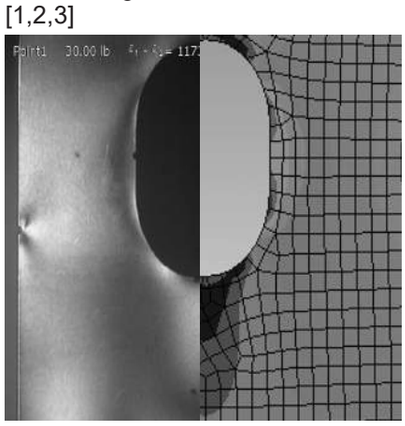


Figure 1: PhotoStress (left) and FEA (right)

Results and Achievements

The results obtained from the PhotoStress tests were compared to FEA results for the 2D specimens and to analytical solutions for the 3D specimen. These results were precise however not always accurate. Despite this, trend lines followed the same paths for all test methods. The average percentage error for a 2D bend test specimen was 7.4% whilst that of a 3D specimen was 18.9% when compared to FEA and analytical solutions.

The PhotoStress Experimental Technique was found to produce more realistic results than FEA, taking into account the imperfections in a material. The technique is fairly straightforward and stress analysis may be carried out on site. A hybrid of PhotoStress-FEA is recommended for accurate stress analysis.

References

[1] 'Introduction to Stress Analysis by the PhotoStress® Method', Vishaypg.com, 2011.

[2] K. Ramesh and G. Lewis, "Digital Photoelasticity: Advanced Techniques and Applications", Applied Mechanics Reviews, vol. 55, no. 4, p. B69, 2002.

[3] D. Pye, Polarised light in science and nature. Bristol: Institute of physics publ., 2001.

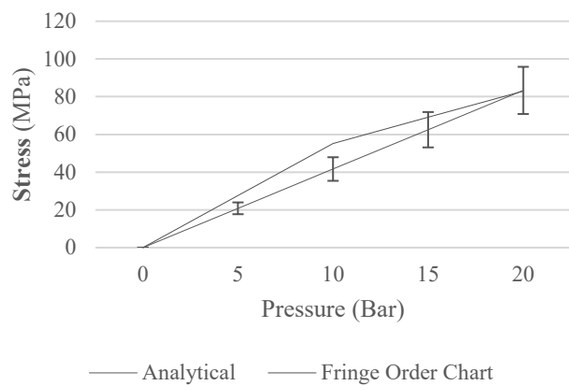


Figure 2: Graph of Stress vs. Pressure for 3D specimen

Modelling of a Hybrid Floating Wind, Energy Storage and Desalination Unit

Student: Charise Cutajar / Supervisor: Prof. Ing. Tonio Sant / Co-Supervisor: Dr Ing. Daniel Buhagiar

Introduction

With a continuously growing demand for fresh water, water resources are increasingly being stressed making desalination an ever-growing requirement. A novel system is being proposed which comprises of an offshore wind-powered desalination unit. A hydro-pneumatic energy storage is also integrated with the system to mitigate the supply-demand mismatch and provide a stabilising upthrust to the floating structure.

Project Objectives

The main objective of this project was to develop a computational model to simulate the performance of the system when subject to different wind conditions. Based on preliminary simulation results, an adequate sizing of the main components was also established.

Project Methodologies

Following a literature review to identify emerging concepts and technologies within the context of this project, a conceptual design of the system was developed. This consisted of an offshore wind turbine-driven hydraulic pump pressurising the intake seawater to be stored in a liquid-piston accumulator. The latter in turn supplies a pressurised flow to a Reverse Osmosis (RO) desalination unit to produce potable water whilst recovering some of the energy in due operation.

Next, a mathematical model was derived and later adapted to a computational model in MATLAB®. The latter model was first verified and validated accordingly. This was then used to carry out a parametric analysis and investigate the behaviour of the system when subject to different conditions. The simulation results were then extracted and analysed.

Results and Achievements

Simulation results have generated smoother yield outputs from the desalination unit as compared to the intermittent input signal of the wind. However, this was only possible through the implementation of a flow control strategy from the storage to the desalination unit.

It was also established that the 5 MW wind turbine integrated with a 6.5 MWh hydro-pneumatic storage, has the potential to power a medium-scaled RO unit producing over 32, 000 m^3 of fresh water every day. The RO unit would consume on average 4.4 kWh/m^3 of permeate water produced, with 30% of the energy supplied being recovered back to the system. Furthermore, a 900 m^2 floating platform is required to accommodate all the necessary components for RO integration.

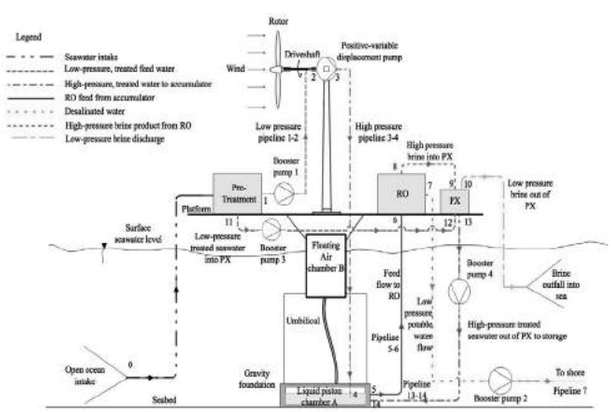


Figure 1: The proposed hybrid floating wind, energy storage and desalination unit

Fluid Flow Measurements in Radial Rotating Channels

Student: Joseph Degabriele / Supervisor: Dr Ing. Christopher Micallef

Introduction

Rotating cooling channels are utilised in numerous engineering applications most notably in electrical machines. While measuring fluid velocity inside a stationery duct is relatively easy, measurement of fluid velocities inside rotating ducts is much more complex.

Project Objectives

The two main objectives of this project were to investigate fluid flow in the radial direction of a rotating elbow setup which have thus far proved to be unsuccessful. The knowledge gained on the rotating elbow will then be applied to a generator which had radial cooling channels machined on its stacks.

Project Methodologies

The instrumentation used to measure air flow velocities in the rotating elbow and in the alternator was hot wire anemometry. This measurement technique is most ideally used in measuring instantaneous changes in the flow velocities such as those found in a rotating duct.

A bridge circuit working on the principle of Constant Temperature Anemometry was used and the necessary hot wire probes used for testing were constructed. A calibration procedure was carried out for each of the hot wire probes by inserting them inside a wind tunnel having a known flow velocity.

Results and Achievements

Flow measurements in the rotating elbow were carried out in three different positions: radial, axial and at the duct entry. The flow measurements extracted from the rotating elbow suggest that there is a decrease in flow velocity as the flow progresses from the entry region of the duct to the radial position.

Results obtained for the alternator setup have shown that with an increase in the rotating frequency, air flow as well as the turbulence intensities increase considerably. The results obtained for both setups are very encouraging and further research to gain further insights into secondary flow development is planned

References

[Journal:]
[1] Barrow, H., 1969. A Survey in Fluid Flow and Heat Transfer in Rotating Ducts.

[Conference:]
[2] C. Micallef, J.Degabriele, D.Camilleri, 2018. Fluid flow measurement in rotor ventilation ducts. *Conference Paper PEMD 2018*.

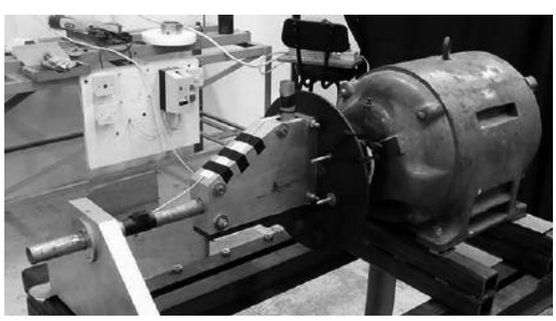


Figure 1: Rotating Elbow Setup

Figure 2: Alternator Setup

Vapour Absorption Cooling Utilising Waste Heat from an IC Engine

Student: Luke Deguara / Supervisor: Prof. Ing. Robert Ghirlando

Introduction

Professional fishermen require a cold room below the deck of the fishing vessel in order to preserve the freshness of their catch. Present onboard refrigeration technologies rely on the vapour compression system which require electrical energy to drive the compressors which compress the refrigerant. Such systems have been found to consume about 50% of the total electrical energy generated on board the fishing vessel [1].

The vapour absorption system is an alternative technology which relies on heat that can be obtained from the engine exhaust and jacket water streams as the main energy source. The integration of such a system would result in lower energy and fuel consumption, which results in lower pollution [2], [3].

Project Objectives

- Conducting a literature survey to obtain information regarding current onboard refrigeration technologies, with particular attention to Maltese and Sicilian vessels.
- Modelling an absorption refrigeration system on board a fishing vessel using TRNSYS software.

Project Methodologies

Two computer models were developed to simulate an onboard absorption refrigeration system. One model represents a system obtaining heat from the engine jacket water (shown in Figure 1) while the other system obtains heat from the engine exhaust stream. TRNSYS software was used to model both transient systems. The software is based on components which accept inputs from the user, and through mathematical equations, the software processes this data and gives outputs accordingly.

The models were based on a fishing vessel from the Italian fishing fleet having a rated engine output power of 195 kW and a necessary cooling load of 5 – 10 kW [2]. The models were tested under varying working conditions in order to analyse their performance throughout four months of the year (February, May, August and November). This was done by varying the parameters and inputs to certain components of the simulations. Some variations include the engine output power, fluid flow rates, heat exchanger effectiveness and cooling load.

Results and Achievements

The results obtained indicate that the simulations work under certain working conditions. Thus, it is possible to integrate an absorption refrigeration system on a fishing vessel with the previously-mentioned specifications, by obtaining heat either from the jacket water or the exhaust stream.

In certain cases, the results obtained from the simulations were impractical. This leads to the conclusion that the simulations have their limitations, some of which arise from limitations of the software itself, which do not reflect all the practical considerations of the system.

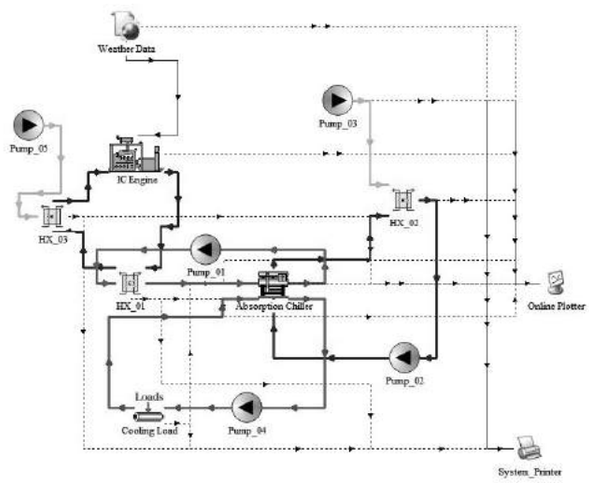


Figure 1: Model of an Absorption Refrigeration System Obtaining Heat from the IC Engine Jacket Water Stream Developed in TRNSYS

References

[1] V. Ruiz, "Analysis of existing refrigeration plants onboard fishing vessels and improvement possibilities", in *Second International Symposium on Fishing Vessel Energy Efficiency, May 22-24, 2012, Vigo, Spain*.

[2] V. Palomba, M. Aprile, M. Motta and S. Vasta, "Study of sorption systems for application on low-emission fishing vessels", *Energy*, vol. 134, pp. 554-565, Sep. 2017.

[3] A. Ouadha and Y. El-Gotni, "Integration of an Ammonia-water Absorption Refrigeration System with a Marine Diesel Engine: A Thermodynamic Study", in *The 3rd International Conference on Sustainable Energy Information Technology, Jun 25-28, 2013, Halifax Nova Scotia, Canada*, Elsevier B.V., 2013, pp. 754-761.

Analytical/Experimental Studies of Finger Motion

Student: Yasmine Elsadi / Supervisor: Prof. Ing. Michael A. Saliba

Introduction

Dexterity is an important factor desired for every anthropomorphic robotic and prosthetic hand. Previous studies conducted at the University of Malta show that with minimal anthropomorphic conditions, where only the thumb together with the index and middle fingers are allowed to move, 84% manual dexterity is achieved [1].

Project Objectives

The focus of this project was to analyse the motion of multiple finger joints under these minimal conditions whilst executing everyday tasks and statistically extract hand postural synergies through Principal Component Analysis which is a dimensionality reduction technique.

Project Methodologies

First an experimental setup was designed and built consisting of an instrumental data glove with embedded resistive sensors placed on proper anatomical locations, and connected to a PC based data acquisition device which also powered the system. The degrees of freedom (DOFs) being investigated were the flexion/extension of the metacarpophalangeal and proximal interphalangeal joints of the index and middle fingers and thumb, the abduction/adduction between the index and middle fingers, and the abduction/adduction together with the rotation of the thumb.

Repeatability and reliability tests were then carried out to ensure the validity of such system. This data glove system was then used in a number of experimental procedures composed of a number of grasping and manipulation tasks, mimicking everyday tasks, carried out by a total of five participants. Data was continuously logged and later extracted were it was filtered and converted to finger joint angles.

Grouping all the data for all five participants into a matrix, Principal Component Analysis using a statistical package was then performed to evaluate the existent postural synergy between the joints by extracting patterns of covariation in the form of principal components.

Results and Achievements

The first three principal components accounted for 64.4% of the total variance in the original data. It was thus verified that a few principal components could account for a large variety of different grasps. Further analysis put light on the existent strong correlations between the extracted principal components and anatomical groups of both intrinsic and extrinsic muscles. Therefore, these components could serve as a representation of the synergies present between the finger joints.

These components may therefore be used as input variables for the actuation control of an under-actuated anthropomorphic robotic, such as the UMMAR Hand II [2], or prosthetic hand where an algorithm consisting of these three principal components could potentially move a total of nine DOFs.

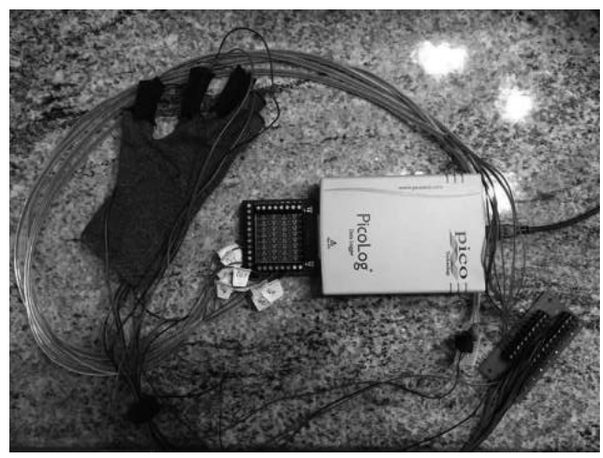


Figure 1: The Data Glove System

References

[1] M. A. SALIBA, A. CHETCUTI, and M. J. FARRUGIA, “Towards the Rationalization of Anthropomorphic Robot Hand Design: Extracting Knowledge from Constrained Human Manual Dexterity Testing,” Int. J. Humanoid Robot., 2013, vol. 10, no. 02, p. 1350001.

[2] D. Dalli and M. A. Saliba, “The university of Malta minimal anthropomorphic robot (UM-MAR) Hand II,” IEEE/ASME Int. Conf. Adv. Intell. Mechatronics, AIM, vol. 2016–Septe, pp. 371–376.

Separating and Throttling Calorimeter

Student: Samuel Farrugia / Supervisor: Prof. Ing. Robert Ghirlando

Introduction

Over the years steam has been used in a variety of industries. Some of the applications of steam are heating of products or areas in plants, households or factories. Steam is also used as a means to drive turbines which are in turn used in electrical power stations. These are only a small portion of the uses of steam.

Project Objectives

The objective behind this project is to design and implement the necessary peripherals required to be able to operate the separating and throttling calorimeter. The final setup should be fully operational and usable for relevant thermodynamics lab sessions.

Project Methodologies

The setup design procedure comprises of a structured analysis where the main focus was to analyse the conditions of the steam required for the throttling process to occur completely. Figure 1 shows the schematic diagram of the final setup.

The throttling process was chosen to be the start point of the design process since the throttling process would require an almost dry saturated steam. Also, the pressure of steam entering the throttling process needs to have a certain value for it to be turned to superheat when passing through the orifice. After analysing the required data, a rollback system was undertaken, where the approach was taken in the direction starting from the orifice and ending at the boiler. Finally, after designing the process up to the throttling process, the condenser was sized based on the assumed condition of superheated steam.

Other analyses which were done on the setup were: testing of the flow coefficient of the orifice present in the throttling process, the standby heat loss of the boiler and the conversion factor of the condensate level glass to the mass of water collected. The experimental testing was carried out to determine whether the setup is performing as designed and also to determine the parameters for which it can be operated.

Results and Achievements

Results from testing proved to be compliant with the theoretical assumptions taken during the design process. During all the testing sessions, a high degree of test repeatability and consistency was achieved with minimal deviation of readings during each session. Steam condensate formation in piping, although minimal, proved to be a cause of error in determining the steam quality produced by the boiler.

The final setup proved to be applicable for steam pressures ranging from 2-5 bar gauge. The average steam dryness fraction achieved was that of around 0.77.

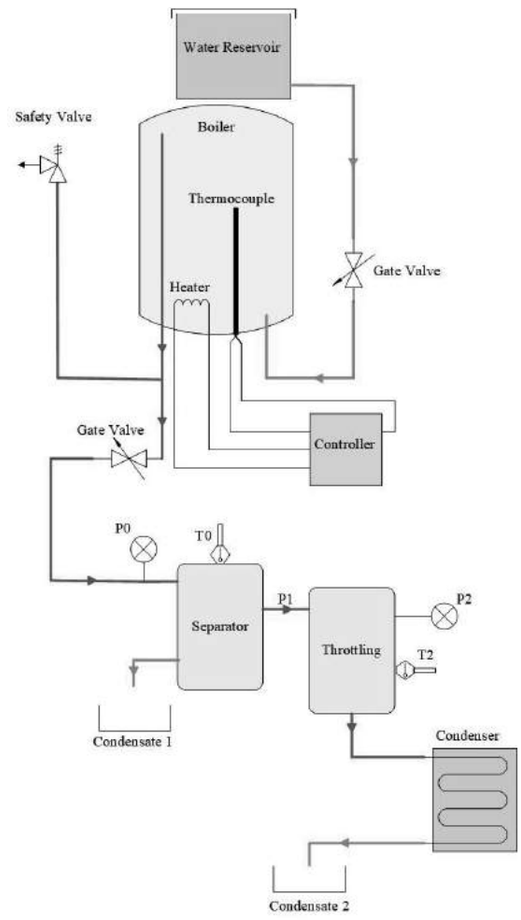


Figure 1: Schematic diagram of testing setup

Preliminary Design and CFD Analysis of a Wind Tunnel

Student: Thomas Farrugia / Supervisor: Dr Ing. Christopher Micallef

Introduction

The Faculty of Engineering has initiated a study into the plausibility of building a closed loop wind tunnel situated inside the University of Malta. This wind tunnel will aim to provide a test section of 1m by 1m by 1m at a flow speed of 30 meters per second for testing the effect of fluid flow on prototype models and the resulting stresses as well as to aid in their dynamic design.

Project Objectives

The purpose of this study was to design, test and determine the cost of a proposed closed loop wind tunnel to be built in the Department of Mechanical Engineering.

Project Methodologies

The study was initiated by selection of an appropriate fan series. Using this, a design was drafted around this series and the losses in the tunnel were calculated using empirical equations from literature. The losses were used to select the fan model parameters required. This was followed by a CAD rendering as seen in **Figure 1** in order to extract the required part and assembly drawings. After design was finalised, the tunnel was remodelled using CFD software in order to simulate the flow through the tunnel and ensure that it reached the required performance characteristics. Once the performance analysis of the wind tunnel was completed, a selection process was initiated to select the optimum materials to be used to construct the wind tunnel. To finish off, the material cost of the wind tunnel was deduced.

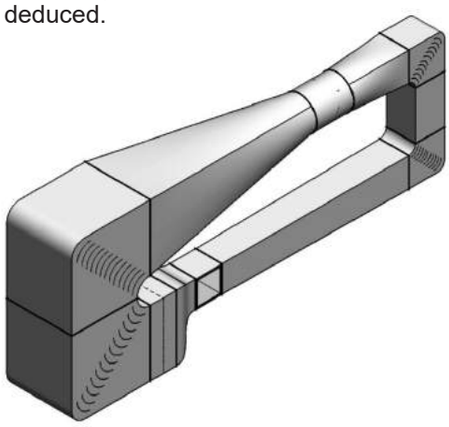


Figure 1: CAD Rendering of Wind Tunnel Design

Results and Achievements

The computational model was meshed to ensure that the required mesh metric parameters were reached. This mesh was unable to be solved using the technology available at the time so a coarser mesh was used. The validity of the results using this coarser mesh was evaluated using four mesh tests. These tests showed that the results were able to give a good indication of the real life conditions expected in the wind tunnel.

Following this, the results were analysed using pressure, velocity and turbulence intensity contours and x-y plots through the Test section which showed that the tunnel reached the required flow parameters. A velocity streamline was also exported. From this it was determined that the tunnel reached high quality flow and can be seen in **Figure 2**. The values of pressure losses calculated using empirical equations from literature as well as those from the computation simulation were found to be very similar suggesting that the design is optimal for such a wind tunnel.

Finally, following material selection, the cost of the wind tunnel materials that was computed was deemed to be satisfactory for a wind tunnel of this size and flow speed. When performing a comparison to the price of other wind tunnels offered by third party companies, it was found that the wind tunnel designed came at a lower cost due to the lack of profit margin required.

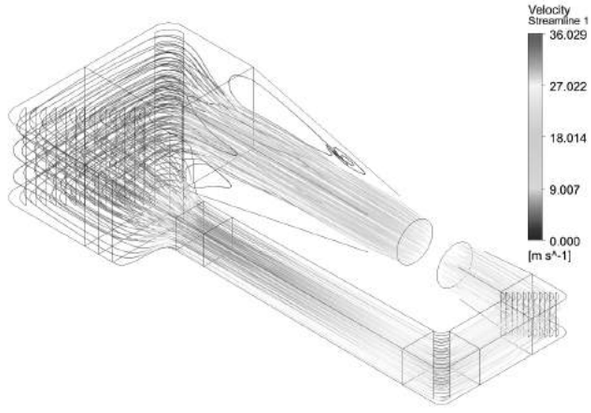


Figure 2: Velocity Streamline of the Wind Tunnel Flow

Composite Pressure Vessels

Student: Anthea Fenech / Supervisor: Prof. Ing. Martin Muscat

Introduction

The interest in composite materials has increased globally because of their structural efficiency and their high strength- and stiffness- to weight ratios, giving them an advantage over other conventional materials. However, when it comes to assessing their failure mechanisms, some might agree that finding failure analysis is a tedious process.

Project Objectives

To use AS4D/9310, a carbon- epoxy material [1] in order to conduct buckling and limit load analyses on a composite cylindrical pressure vessel, by means of the finite element method. Tests in this project will be conducted using different failure criteria in order to identify the mode of failure, and when possible, results extracted from Ansys APDL 18.2 will be compared with the values achieved using design by rule methods.

Project Methodologies

Using the finite element software [2] for both buckling and limit load analysis, the failure mechanisms were studied for different properties of the composite pressure vessel. In both cases, the failure mechanisms were primarily analysed on a simple model, and then, the same approach was implemented on the actual pressure vessel model, as seen in Figure 2.

For both cases, the failure mechanisms were identified using two failure criteria, the first being the Tsai-Wu criterion [3], which identified the location of failure, as shown in Figure 1, and the second being the Hashin criterion [4], which identified the mode of failure at the previously determined failure region.

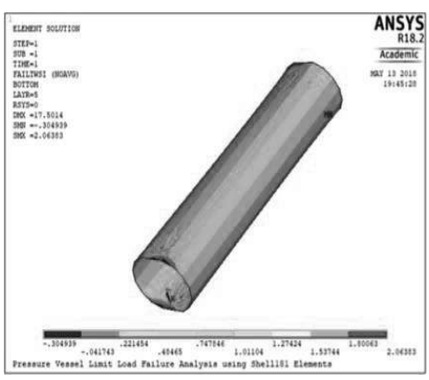


Figure 1: Elemental contour plot of cylindrical pressure vessel reaching first ply failure using the Tsai-Wu failure criterion

Results and Achievements

After conducting tests on models with different geometrical properties, according to the results obtained through buckling analysis, the best design properties for a pressure vessel were obtained for a model consisting of 10 laminas with fibres which are oriented anti-symmetrically at $[-5°/5°]$ when the aspect ratio was of 1:8 (diameter: length). In each case, before reaching the buckling load, the model was tested to ensure that before this point, it didn't reach first ply failure, and in addition, further studies were done to identify the Eigen mode at which this would occur. Finally, the model with the best geometrical properties was once again tested, this time including initial imperfections, which consisted of deformations to the initial perfect model, before buckling, in order to obtain the variation of load versus displacement of the model from the unloaded to the post-buckled state.

As for limit load analysis, a smaller combination of properties was assessed. The best outcome which resulted from the model was that of five laminas, of which fibres were oriented anti-symmetrically at $[-15°/15°]$. Once having identified the location of failure, through the Hashin criterion, the matrix was proven to reach tensile failure first, which led to the degradation of mechanical properties of the entire lamina for the analysis of failure progression using the Tserpes-II model.

References

[1] Barbero E., Finite element analysis of composite materials, 1st ed. Boca Raton: CRC Press, 2008, p.7

[2] Mechanical ANSYS APDL 18.2. SAS IP,Inc, 2017

[3] Garnich M., Akula V., "Review for degradation models for progressive failure analysis of fibre reinforced polymer composites", Applied mechanics reviews, vol. 62, pp. 2-27, 2009.

[4] Paris F, A study of failure criteria of fibrous composite materials' NASA, 2011 Vol. 210661, pp 30-32

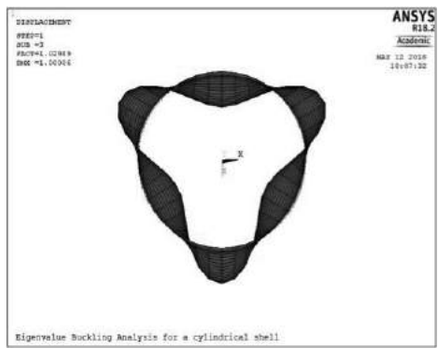


Figure 2: Top view of a buckled cylindrical pressure vessel

Analysing the Free Yaw Behaviour of a Prototype Multi-Bladed Micro Wind Turbine

Student: Carl Galea / Supervisor: Prof. Ing. Tonio Sant / Co-Supervisor: Dr Ing. Cedric Caruana

Introduction

This project is a continuation of a larger project with the aim to develop a prototype multi-bladed wind turbine. The wind turbine is installed at the Għammieri Government Farm and during operation, wind gusts can easily cause the rotor to generate more power than the rated value of the generator. This requires the development of a system to regulate the power output of the wind turbine at high wind speeds.

Project Objectives

The main objective of this project was to analyse the effect of tail position on the yaw error and power output of the wind turbine. A secondary objective was to create a yaw model to predict the yaw behaviour under steady and turbulent wind conditions at different tail angles.

Project Methodologies

The aerodynamic thrust on the rotor was modelled using the C_T-λ relationship derived in a previous project using free wake modelling. The force on the tail vane was modelled using a Computational Fluid Dynamics simulation. The yaw behavior was modelled using an explicit time-marching technique which was implemented in MATLAB. The yaw model was tested both for an operating turbine and a parked rotor. The predictions of the yaw model were then compared to data collected from the prototype. Turbulent wind data was generated by TurbSim, using the one-minute averages recorded on-site as reference values.

Figure 1: The prototype wind turbine

Results and Achievements

Data analysis showed that as the tail angle was increased, the power output reduced. This showed that this method can be used to regulate the power output and protect the generator.

The variability of yaw position in turbulent wind speeds as predicted by the yaw model showed good agreement with on-site measurements. The yaw error was slightly underpredicted, mostly when the tail was fully open. The discrepancy in yaw error between the model predictions and on-site measurements was larger when the turbine was operating. This suggests that the discrepancy was due to the fact that the rotor wake was neglected. If a model for the rotor wake is included in the model in the future, the predictions at low tail angles can be improved.

The yaw model may be used in the future to develop an active control system that regulates the power output by adjusting the angle of the tail.

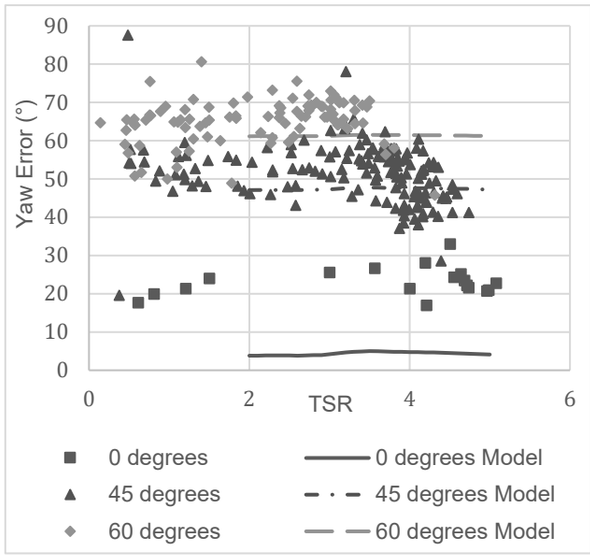


Figure 2: A graph of yaw error vs wind speed

Analysis of Green Composites in Maritime Use

Student: Nathan Gatt / Supervisor: Prof. Ing. Claire De Marco

Introduction

Fibre reinforced composites are finding increasing use in engineering applications in recent years. However, the rising concern towards the environment has led to an increasing interest about composites consisting of natural-organic materials. Such composites usually referred to as “green”, can find numerous industrial applications.

Project Objectives

Review current state of affairs in green composite development. Outline the relevant theory used to design the panels and theory associated with the prediction of the mechanical properties of the fabricated panels. Test fabricated composites in order to compare the properties of conventional glass fibre reinforced composites and the more sustainable natural flax composite. Compare the theoretical results with experimental results obtained through testing.

Project Methodologies

E-glass fibres with polyester resin are compared with a bio-based epoxy resin reinforced with natural flax. Marine panels are designed according to BS EN ISO 12215-5:2008 [1] and tested for the tensile and flexural properties according to the respective standards. Experimental values obtained are verified using the rule of mixtures and the classical laminate theory. Failure mechanisms are investigated by viewing test specimens under a scanning electron microscope (SEM).

Results and Achievements

Higher tensile mechanical properties from the E-glass specimens were recorded and such an outcome was as expected due to the higher experimental fibre volume fractions achieved in the E-glass specimens. Once again, the glass fibre reinforced specimen resulted in higher flexure values. Theoretical predictions revealed higher mechanical properties for both laminates with a percentage difference of 24% and 28% between the average experimental tensile moduli and the theoretical prediction for the glass and flax specimens respectively. For the flexural moduli, a difference of 26% and 22% between the average experimental values and predicted theoretical values for the glass specimens and natural flax specimens respectively was recorded. Upon viewing randomly selected specimens under a scanning electron microscope (SEM) it was concluded that both types of composites experienced similar failure mechanisms with flax specimens showing slightly better fibre/matrix adhesion. Crucial properties of natural flax, including moisture absorption and hydrophilic characteristics present many challenges when designing green composites for marine applications.

References

[Standard:]
[1] Small Craft – Hull Construction and Scantlings – Part 5: Design pressures for monohulls, design stresses, scantling determination., ISO Standard 12215-5-2008.

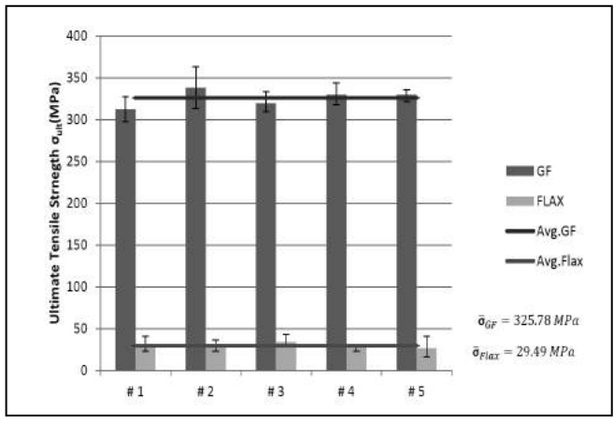


Figure 1: Ultimate tensile strengths of both panels

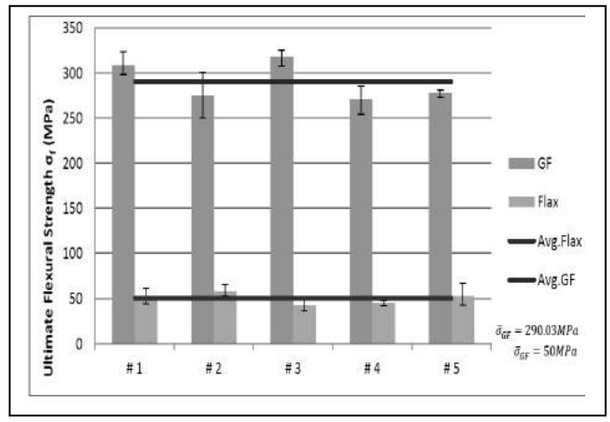


Figure 2: Ultimate flexural strengths of both panels

Design, Build and Test Apparatus to Characterise Marine Laminates

Student: Gilbert Gauci / Supervisor: Prof. Claire De Marco

Introduction

Composites are gaining popularity and are being used in structural elements. Complete failure of such structural elements can be caused by a propagation of an interlaminar crack. The interlaminar fracture toughness, G (kJ/m^2) is an important property to be known in the design process as it describes the work needed to increase the delaminated area by one unit.

Project Objectives

To design and build a mixed mode bending (MMB) apparatus and glass fibre reinforced polymer composite in the form of a double cantilever beam (DCB). To test the MMB apparatus by finding the interlaminar fracture toughness of the manufactured composite at various mixed mode I/II ratios.

Project Methodologies

The MMB apparatus was redesigned from the proposed ASTM D6671 [1] standard by subdividing parts into smaller components and replacing certain parts with already available bought off-the-shelf products (as can be seen in figure 1). The redesign reduced the machining time and cost.

The DCB specimen was manufactured using the hand layup method and an artificial crack was done by the insertion of an over-head projector sheet during the manufacturing process.

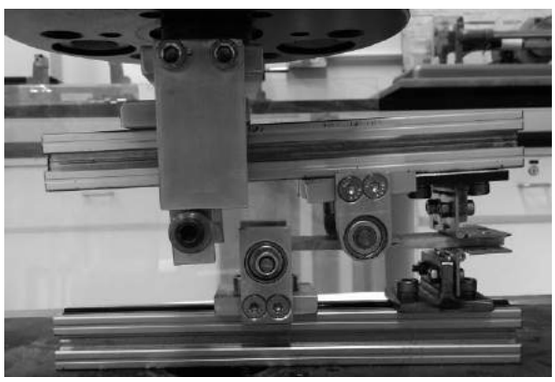


Figure 1: The manufactured MMB apparatus test setup

The specimen was loaded using a constant displacement load machine and from the outputted load – displacement graph, the respective fracture toughness at a certain mixed mode I/II ratio was found.

The results were validated by comparing the obtained fracture toughness values to the results obtained from another renowned graphical method.

Lever weight corrections were applied to the results obtained from the MMB apparatus due to premature loading.

Results and Achievements

The load – displacement graphs obtained for each mode mixture were analysed and calculations took place on the resulted values from the graph in order to get the respective fracture toughness.

From the calculations carried out, it was observed that the fracture toughness increased as the mode mixture increased as can be seen in figure 2), thus implying that in the design stage, it is better to encourage cracking in mode II than in mode I as it requires around 40% more energy to propagate the crack.

References

[1] ASTM Standard D6671, 'Mixed Mode I-Mode II Interlaminar Fracture Toughness of Unidirectional Fibre Reinforced Polymer Matrix Composites', 2006

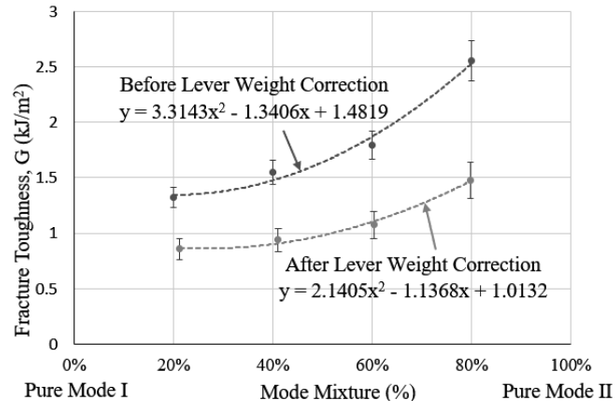


Figure 2: The variation of the fracture toughness with mode mixture

Designing Structures Using GFRP Pultruded Sections

Student: Josef Neil Gerada / Supervisor: Prof. Martin Muscat

Introduction

The increased use of liquified petroleum gas, delivered in pressurised tanks, together with the changing architecture within the Maltese islands has presented new problems concerning distribution and handling of such tanks. This thesis studies the possibility of using a manually powered hoist to lift these heavy payloads up a number of storeys.

Project Objectives

The focus of this project is about the use of pultruded glass fibre reinforced plastics (GFRP) to act as the load bearing members of the proposed hoist. Advantages of weight reduction and resistance to degradation can be exploited to design a hoist which can be easily assembled by a single person and withstand environmental effects.

Project Methodologies

A three-point bend test was conducted to confirm the material properties specified by the manufacturer, in particular the effective flexural modulus in the axial direction. Using this information, a finite element model was constructed and verified to replicate the three-point bend test.
Codes of practice and other regulations applicable in the European Union were analysed and the relevant amplification factors and load combinations were highlighted so that the hoist is designed according to these standards.

Figure 1: Finite element analysis to investigate deflections of main members

Results and Achievements

By applying the appropriate standards and design guidelines related to pultruded GFRP, a detailed model of how the hoist should be fabricated was created. This ensured that limit states cannot be exceeded under the chosen load combinations thereby guaranteeing the safety of the structure.

A 3-D model of the proposed design was created and based on this, the physical model was fabricated and assembled successfully. In under thirty-five minutes a capable person can assemble and erect this hoist by using the supplied components and two wrenches. Following this, a payload of 25 kilograms could be hoisted effortlessly by the manual winch included in the design.

A test was carried out on the assembled hoist where deflections were measured as a load acting on the structure was increased. It was found that there exists a difference between these results and those obtained through finite element analysis. Multiple explanations were given to account for these differences, namely these were shock loading and creep effects.

Figure 2: Three-dimensional virtual view of the hoist built with GFRP Pultruded Sections

Application of Shape Memory Alloy actuator in Cosmetic Packaging

Student: Neil Magro / Supervisor: Prof. Ing. Michael Saliba

Introduction

Shape Memory Alloys (SMAs) show a unique characteristic whereby the material is able to deform at room temperature but returns to its original shape and size once it is heated.[1] This project was carried out in collaboration with Toly Ltd., where the clip mechanism of a make-up compact case was redesigned to include a SMA mechanism with the potential of replacing conventional methods of actuation.

Project Objectives

This project included academic and industrial objectives, whereby a literature review was to be provided so as to give a background of the subject, and further generate a concept for a compact SMA actuator. Furthermore, a prototype of the potential application was to be provided.

Project Methodologies

A design process was followed in this project whereby after background research was carried out, the required specifications were listed and engineering requirements were identified. Conceptual Designs were then generated and analysed against the required criteria. Different test pieces were then designed and 3D printed so as to integrate the SMA in the most efficient way. A cycle test was then performed on the final test piece in order to test its fatigue. The main issue with the chosen design was that the SMA was easily overheated, therefore a timing circuit was set up, which could be later integrated as part of the SMA mechanism in the future. The compact was then designed to include the mechanism and was finally 3D printed

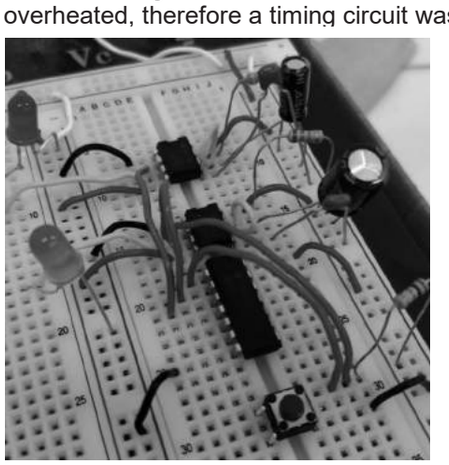


Figure 1: Timing Circuit on breadboard

Results and Achievements

The final clip mechanism was able to run for 1256 cycles. All electronic circuits were setup on a breadboard whereby they both performed their required function. The final prototype in this project consisted of a battery in order to heat up the SMA wire, and a tactile switch to toggle the mechanism to function. The next step in this project would be to integrate the timing circuit into the compact, which would require the case to increase in size. The timing circuit will be printed on a PCB using Surface Mount Devices (SMD's).

References

[1] D. Lagoudas, Shape Memory Alloys Modeling and Engineering Applications. New York, USA: Springer Science+Business Media, 2008.

Figure 2: Final 3D printed prototype

Further Experimentation on the Free-Piston Engine

Student: Ian Mangion / Supervisor: Prof. Robert Ghirlando

Introduction

Free Piston Engines have recently resurfaced as possible candidates at replacing conventional engine technology with a more efficient design for generating electricity. Having less components and moving parts than a traditional engine, a Free Piston Engine is expected to have lower energy losses through frictional heating and therefore higher fuel efficiency.

Project Objectives

The Free Piston Engine at the University of Malta has not yet run self-sufficiently. The aim of this thesis is to further experiment on the Free Piston Engine to reach or approach a state at which the engine runs self sufficiently.

Project Methodologies

The starting mechanism contained a restriction to the air flow used to oscillate the piston assembly. This resulted in the engine moving slowly when being driven by this mechanism. To increase the speed of the engine during starting, the air was rerouted through the compressor ports.

The setup that detects that the piston assembly has reached a travelling extremity was not sturdy and was not capable of accurately sensing the limit of travel at different speeds. A complete redesign of the mechanical aspect of the sensing mechanism was undertaken to create a stronger and more reliable setup.

The spark system did not offer any means of adjusting the spark timing as it used the same signal from the travel extremities sensing mechanism to time the spark. A new system that determines when the spark is generated had to be designed from scratch. The new system generates a spark at a particular in-cylinder pressure rather than a particular piston position. To do this two Glow Plugs with Pressure Sensor were used to obtain an analogue voltage signal which corresponds to the in-cylinder pressure. The circuit would then use the in-cylinder pressure signal and compare it to a reference voltage and generate a spark when the pressure signal reaches the reference voltage.

Since the Glow Plugs with Pressure Sensor have not been used before at the University of Malta, their response needed to be learned. An experimental setup was used to learn more about the response of these sensors as well as to calibrate each of the sensors used.

The amount of fuel that is needed at different engine speeds and air intake was calculated. This was carried out for the stoichiometric air to fuel ratio and a look-up table was constructed for future reference.

Results and Achievements

The engine was tested with the new modifications to test their reliability and effectiveness. The modifications to the starting mechanism increases the engine speed during starting by 33.5% from 2.27 Hz to 3.03Hz. The spark timing and delivery system was reliable, and a spark and combustion were obtained at every cycle with a controllable spark timing. However, the engine is still away from running self sufficiently. A problem that was noticed was that the exhaust was being trapped in the cylinder and further work is still needed to improve scavenging.

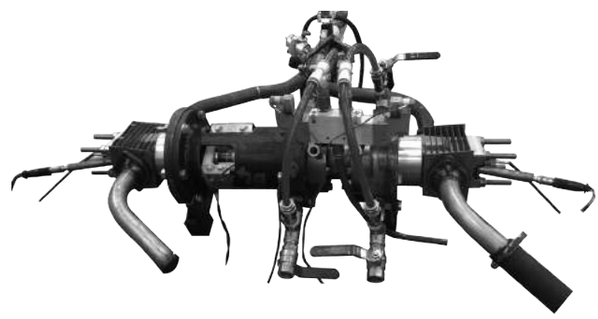


Figure 1: The Free Piston Engine at the University of Malta

Analysis of Green Composites for Mechanical Structural Components

Student: Aaron Meilak / Supervisor: Prof. Ing. Martin Muscat

Introduction

Natural fibre composites (NFCs), which are polymers reinforced with natural fibres, have the potential to be used in a range of industries. High strength and low weight makes them a potential substitute to glass fibre reinforced plastics (GFRP). Moreover these NFCs have some beneficial characteristics such as having a lower environmental impact than synthetic composites, being biodegradable and being inherently renewable.

Project Objectives

The main goals of this dissertation, are the analysis of the strength and environmental impact assessment comparison of green, aramid and glass fibre reinforced composites. Moreover, other objectives include survey on commercially available green composite constituents and sample preparation and mechanical testing.

Project Methodologies

Test plates for fibre reinforced composites were fabricated using two techniques: Hand layup and Vacuum bagging. Testing of laminates was carried out in order to determine the mechanical properties of green composites. Three different types of laminate panels were produced, to produce panels with different thicknesses.

Four different testing procedure were done to measure different material properties, namely tensile testing, compressive testing, shear testing and flexural testing.

LCA is a tool particularly useful for environmental impact analysis and is used to evaluate how a product or material, the composite material in our case, potentially affects ecosystems from its start, to its end-of-life. LCA is globally endorsed by ISO committees, to analyse a product from an environmental point of view. It is a standardized, holistic and a scientifically recognized methodology. LCA allows the systematic quantitative assessment of products in the form of human toxicity, resource consumption and environmental impact.

Results and Achievements

With regards to tensile modulus, flax fibres and glass fibres are quite similar hence flax fibres, can be of a substitute to glass fibres when only the Young's modulus is of importance. Moreover, the results for ultimate tensile strength of flax fibres were significantly lower amongst glass and aramid fibres. With regards to shear modulus, flax fibres and aramid fibres are quite similar hence flax fibres, can be of a substitute to aramid fibres when only the shear modulus is of importance.

Environmental impact of flax fibre manufacturing is much lower when compared with glass fibre production. Moreover, flax reinforced composites parts prove to have less weight thus contributing to a lower fuel utilization and consequently less emissions during the component use phase.

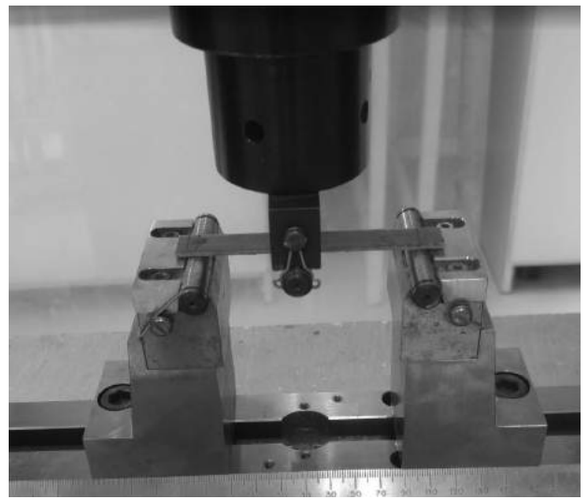


Figure 1: Flexural testing of flax fibre reinforced composites

Aerodynamic Modelling of the Magnus Effect for Maritime Propulsion

Student: Dylan Mercieca / Supervisor: Dr Ing. Simon Mizzi

Introduction

Freight transport is by far the mostly used mode of goods transportation in the world. However each year, the rates of CO_2 emissions due to this transportation mode is increasing drastically. Due to this, environmental regulations urge the need for environmental friendly means of propulsion. One technique which makes use of wind as a source of renewable energy is called the Flettner rotor, which consists of a tall rotating cylinder, which when in contact with the wind, manages to create a thrust force due to a phenomenon called the Magnus effect.

Project Objectives

The main objectives of this project were to create a 2D numerical model of a Flettner rotor to investigate the thrust generated by the Magnus Effect, and then to calculate the possible net power generated by one Flettner rotor for different wind conditions.

Project Methodologies

Computational Fluid Dynamics (CFD) is the process of numerically solving the laws of physics which govern the motion of a fluid. The Navier-Stokes (N-S) equations govern this motion by solving the three fundamental governing equations; the conservation of mass, conservation of momentum and conservation of energy.

In this project, ANSYS was used to create and investigate a 2D model in which flow passes past a rotating cylinder. The software works by dividing the area around the cylinder (domain) into multiple, very fine cells, and then solving the N-S equations for each cell.

The results of this software were given in terms of lift and drag coefficients, which were then used to generate the thrust forward created by the cylinder. The magnitude of these coefficients greatly depend on a parameter known as the rotation rate (α), which is the ratio of the circumferential velocity of the cylinder to free-stream velocity (wind). Due to this, the study investigated rotation rates of $2 \leq \alpha \leq 5$.

The results were then used in a set of equations in order to calculate the net power generated by a Flettner rotor for different wind and ship conditions.

Results and Achievements

The results obtained from the ANSYS software showed that the generated lift was perpendicular to the direction of the flow, while the drag was generated in the same direction of the flow. It was also concluded that with increasing α, both lift and drag coefficient increased linearly which resulted in a higher power output. However, an increase in α also resulted in an increase in the power input required to rotate the cylinder.

A series of regression analyses were conducted in order to try and achieve a relationship between the net power and the independent variables present, which are the rotation rate, ship speed, wind speed and wind angle. From this analysis, it was concluded that:

- The maximum net power was being generated for winds coming from the sides of the ship ($60^o \leq \beta \leq 120^o$). At these angles, a higher rotation rate resulted in higher net power. In fact, the highest value of net power generated by 1 Flettner rotor was equivalent to 877.40kW, and was generated at an angle of 88^o for $\alpha = 5$.
- At very low angles ($0^o \leq \beta \leq 5^o$), the net power was negative for any ship operating conditions – the rotors should be turned off.
- An increase in the ship and/or wind speeds resulted in a higher overall net power generation.

Figure 1: The first ever Flettner rotor, built in 1924

An Experimental Method for measuring the Total Hemispherical Emissivity for the ASTREA project

Student: Luke Mercieca / Supervisor: Dr Ing. Pierluigi Mollicone / Co-Supervisor: Prof. Mario Farrugia

Introduction

The Astrionics research group of the University of Malta, ASTREA, is currently pursuing its first space venture. An assembly of research students, academics, supporting engineers and other contributors are engineering the pico-satellite, UoMBSat – 1. A $5 \times 5 \times 5\ cm$ cube satellite, launched into space to study effects of the Ionosphere on radio components.

Project Objectives

The aim of this dissertation was to study the radiative surface properties of the copper foil surface of the PCB. This required the development of a vacuum chamber test setup and a measurement technique was adopted to find the total hemispherical emissivity of the copper surface.

Project Methodologies

An experimental setup within a testing vacuum chamber was designed. This involved two samples of the PCB copper laminates suspended at a small distance from each other, $\approx 10\ mm$, and monitoring temperatures using different thermocouples. Heat transfer theory was then used to develop a thermal network of the system to be solved analytically. [1] Moreover, a thermal imaging technique was adopted and using a standard method given by the FLIR E60 series, the emissivity of the surface was measured. [2]

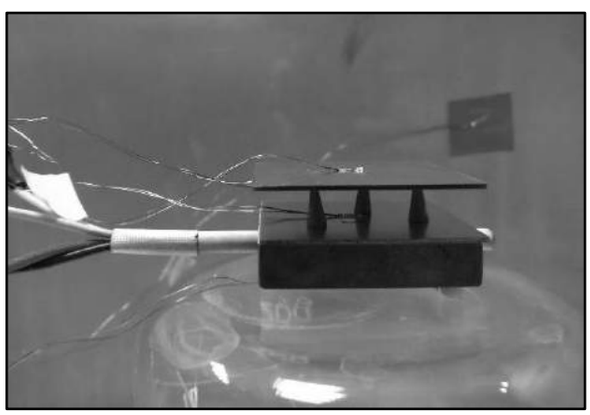


Figure 1: Experimental Setup within Vacuum Chamber

Results and Achievements

The emissivity of a material and the respective radiative properties are highly influenced by the conditions in which the surface is in. This can depend on the surface finish and amount of oxidization, contamination etc… The experimental setup was used to measure the emissivity of an oxidised copper surface. The DE104 laminate resulted in a total hemispherical emissivity of ≈ 0.42.

The thermographic approach was also used to measure the emissivity and also to study the effects of the surface finish, measuring the emissivity of a polished sample and an oxidised sample. A considerable difference was noted, whereby the oxidised copper specimen yielded a total hemispherical emissivity of ≈ 0.5, whilst the same specimen undergone a treatment of brushing and polishing, yielded a total hemispherical emissivity of ≈ 0.08.

References

[Book:]
[1] Incropera F. and David P. D., Fundamentals of heat and mass transfer, 7th ed. Hoboken, NJ: John Wiley, 2007.

[Book:]
[2] Williams T., “Thermal imaging cameras”. Boca Raton: CRC Press, 2009.

Figure 2: Thermal Imaging Setup using FLIR E60

Preliminary Design of a Sailing Yacht

Student: Bernard Mifsud / Supervisor: Prof. Ing. Claire De Marco

Introduction

A sailing yacht is a wonderful piece of engineering design that depends on a balance of forces between air and sea. There are various areas on a sailing yacht that are to be of interest to engineers, namely the external structures including the rig, keel, rudder and hull as well as the internal arrangements and on-board power unit. Achieving the desired balance between performance, aesthetics and comfort depends on the designer's ability to overcome the complexities involved in achieving the correct balance between all the components and arrangements of the sailing yacht.

Project Objectives

The aim of the project was to develop a preliminary design of a sailing yacht whereby the final design characteristics are to meet the demands of a potential client.

Project Methodologies

The initial design requirements were established whereby a sailing cruiser that is to sail between Malta, Sicily, Italy and Tunisia, which will accommodate eight persons was to be designed. A conceptual design was developed, having based the initial exterior and interior designs as well as the auxiliary power unit and component masses on the results of market research analysis and data from already existing sailing yachts. The conceptual design model was developed and iteratively improved by implementing Bentley® System's naval architecture design and analysis software, Maxsurf Enterprise Suit [1], until the design requirements had been achieved. At the end of the iterative improvement process the preliminary design sailing yacht was obtained. The sailing yacht was designed in accordance to the regulations provided by the Malta Commercial Yacht Code [2]. A preliminary assessment of the yacht's hull was made in terms of the hull's hydrostatic data. Additional preliminary assessments of yacht's helm balance and stiffness were made by determining the yacht's lead value and the Dellenbaugh angle respectively. The stability of the yacht was checked to ensure that the design complied with the BS EN 12217:2-2002 [3] stability criteria. The yacht's engine power requirement was determined after having computed the yacht's resistance from the Delft Systematic Yacht Hull Series. The yacht's performance for a variety of wind speeds and angles was also analysed by making use of a Velocity Prediction Program.

Results and Achievements

A sailing yacht was designed to accommodate eight persons. The general arrangement drawings and lines plans of the design were generated, such as the plan view of the design seen in Figure 1. The hull assessment provided the yacht's optimal sailing velocity. The design's sailing performance proved to be satisfactory in a variety of wind conditions whereby the yacht provides the adequate range to travel between the specified countries. The sailing yacht's helm balance was satisfactory and thereby ensuring that the yacht will require little input at the helm to travel in the required direction. The yacht was also determined to be tender which offers a comfortable sailing experience to the occupants. The design also passed the stability criteria provided by BS EN 12217:2-2002 [3]. The yacht's auxiliary engine's power rating was also finalised for the design.

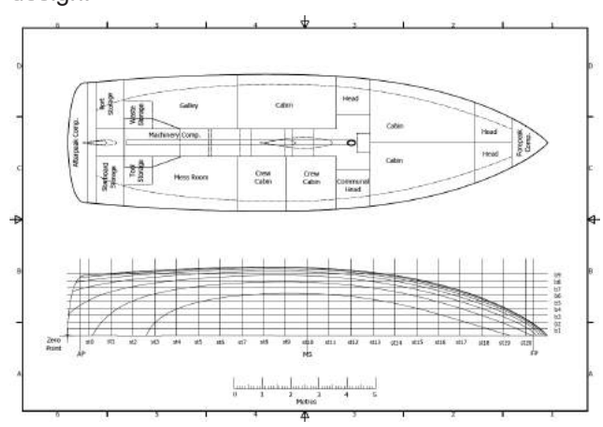


Figure 1: Plan view general arrangement and lines plan of the preliminary sailing yacht design

References

[1] Maxsurf Enterprise Suit v21.10.00.39, Bentley Systems.

[2] Transport Malta, "Malta Commercial Yacht Code," 2015.

[3] "BS EN ISO 12217-2:2002 Small Craft – Stability and buoyancy assessment and categorization," International Standards Organisation, 2002.

Experimental Analysis of Degassing and Regassing of R410a and R32 Refrigerants

Student: Andrea-Ivan Migneco / Supervisor: Prof. Ing. Mario Farrugia

Introduction

Under the new European F-Gas regulations [1] introduced in 2015, refrigerants which have a high Global Warming Potential (GWP) such as R410a will be banned for use in residential air conditioning applications by 2025. As a result, R32 was identified as a suitable replacement since its GWP is approximately one third of R410a. A common issue which still persists even on modern air conditioning systems is refrigerant leakage, which results in the inefficient operation of the system. This issue in conjunction with the use of R410a and R32 refrigerant was investigated.

Project Objectives

The main objectives of this project were to compare and contrast the performance of a refrigeration circuit running on R410a and R32 refrigerant at different refrigerant charge levels and compressor speeds. The various charge levels emulate the gas leaks, hence, the experiments were initially carried out with a full charge of 1000g and gradual, slow degassing followed. Regassing was also done in gradual steps, to emulate the recharging process which HVAC technicians carry out after fixing a leak.

Project Methodologies

A setup previously utilised by Eric Vella [2] was used to carry out the investigation. After performing necessary repairs and getting the setup back into working order, the relevant experiments utilising R410a and R32 refrigerant were performed. Various set points at different compressor speeds and refrigerant charge levels were used for the investigation. The goal of each experiment was to obtain several readings which relate to the performance of the system while maintaining the water temperatures in the evaporator and condenser constant at 20°C and 35°C respectively. The necessary readings were taken once the water temperatures (in the condenser and evaporator reservoirs) and the refrigerant temperatures (at the inlet and outlet of the condenser and evaporator) reached steady state. After obtaining the relevant pressures and temperatures, the vapour-compression cycle was plotted on a *p-h* diagram, gathering the necessary enthalpy values for system performance calculations.

Results and Achievements

When comparing the investigations carried out and the results obtained for R410a and R32, it was observed that R410a performed better at a higher refrigerant charge, while R32 was slightly superior when the system was running at lower refrigerant charge level. Nonetheless, the difference in the values obtained between the two were slight. Therefore, it results that R32 is an ideal candidate to replace R410a due to similar performance characteristics with the benefit of having a lower GWP.

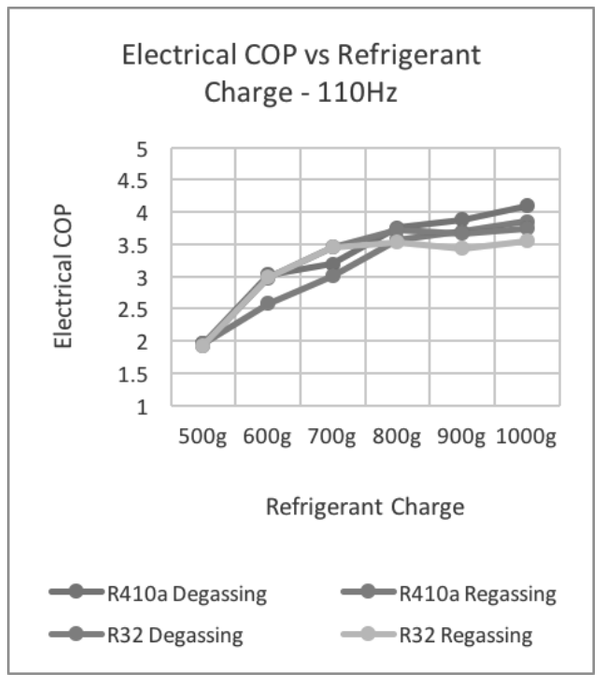


Figure 1: Comparison Graph of Electrical COP against Refrigerant Charge at 110Hz

References

[1] Regulation (EU) No. 517/2014 of the European Parliament and of the Council of 16 April 2014 on Fluorinated Greenhouse Gases and repealing Regulation (EC) No. 842/2006, The European Parliament and the Council of the European Union, 2014

[2] E. Vella, “Investigation of Variable Expansion Device in Air Conditioning”, B.Eng. (Hons.), Mechanical Engineering, University of Malta, Msida, 2011

Design, Build and Test of a Mechanics of Materials Experiment

Student: Reuben Mizzi / Supervisor: Dr Ing. Pierluigi Mollicone

Introduction

The project is based on the Mechanics of Materials study-unit which is taught through theoretical approaches and teaching aids such as laboratory practical experiments. Students tend to better grasp the theoretical background of a subject when exposed to practical examples, thus the project aims at expanding the usability of a torsion experimental setup which was built in a previous project [1].

Project Objectives

To improve the current torsion experimental setup in the Structural Mechanics Laboratory at the Department of Mechanical Engineering by expanding its usability, adding new features and increasing user friendliness.

Project Methodologies

The design process started by conducting a market research in which useful apparatus features were targeted. This was followed by the design of an initial concept after setting constraints such as budget and manufacturing capabilities. A detailed design included structural calculations to ensure the stability of the concept before manufacturing and purchasing all the necessary components. Finally, the experimental setup was assembled as shown in Figure 1 and tested using various size test specimens which provided results that could be compared to analytical calculations.

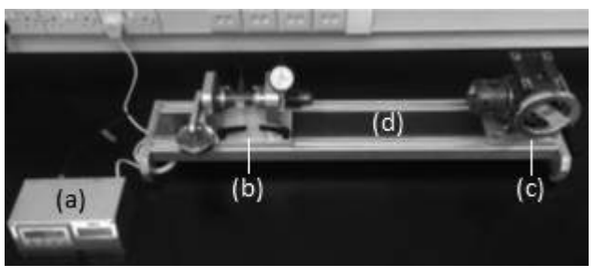


Figure 1: Assembled experimental setup, including; (a) Display unit for torque and angle, (b) Torque sensing unit, (c) Torque applicator/reduction gearbox, (d) Sliding base structure

Results and Achievements

Figure 2 shows one of the plots for torque applied against the angle of twist produced for one of the specimens which were subjected to five tests each. From the data points obtained, the experimental setup was confirmed in its ability to provide highly repeatable data which was further backed up by analytical calculations.

The project was successful in the designing, building and testing of a laboratory apparatus setup which provides accurate data and is easy to operate. Furthermore, the apparatus possesses most of the features offered by apparatuses from manufacturers specialising in laboratory equipment at a much smaller cost.

References

[1] Apap P., 'Design, Build and Test of a Torsion experiment' Bachelor of Engineering (Hons.), 2017, University of Malta.

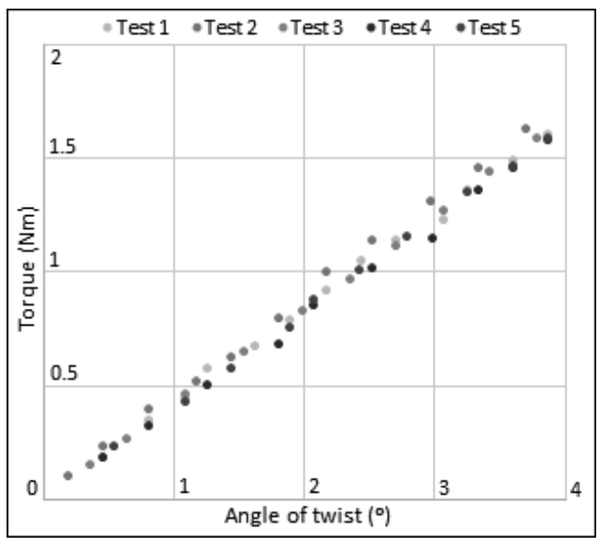


Figure 2: Plot of Torque applied (Nm) against Angle of twist (°) for five tests on one specimen

Waste to Energy

Student: Andrea Portelli / Supervisor: Prof. Robert Ghirlando

Introduction

Biogas is produced when organic matter decomposes in the absence of oxygen. It is a mixture of methane and carbon dioxide, the former of which can be used to generate heat or electricity. To increase the calorific value of the gas, carbon dioxide along with impurities are filtered by passing the gas over adsorbent pellets in a tube at a raised pressure.

Project Objectives

The aim of this dissertation was to explain the discrepancy in carbon dioxide (CO_2) filtration between two mineral adsorbents (or zeolites). Zeolite APG (Chinese) adsorbed 25% of the CO_2 while zeolites NaMSXK/BFK (German) adsorbed 99%.[1]

Project Methodologies

A sample from each zeolite was analysed. An optical microscope was used to get a general idea of the mineral surface at low magnification. A scanning electron microscope (SEM) was used to obtain high magnification topography images.

Energy-dispersive spectroscopy (EDS) was used to obtain a quantitative analysis with regards to the elemental composition of each zeolite.

Lastly, X-ray Diffraction (XRD) was used to analyse the phase of the samples, obtain information about their chemical formula and crystal structure.

Results and Achievements

The results obtained by previous students were analysed and the discrepancy in carbon dioxide filtration was investigated.

The optical microscope images showed that the samples contain numerous impurities, such as iron oxide. The SEM images resulted in a stark difference with regards to surface area and crystalline topography. The zeolite APG had a low surface area with scattered crystalline particles on the surface. The zeolites NaMSXK and BFK were both covered with crystalline particles. The difference between the two was also investigated as although they are identical, the former has what is called a binder. This was identified to contain calcium and magnesium and covers the surface of the zeolite like a web, leading to a slightly less effective open pore system.

The elemental analysis (EDS) confirmed and identified all the impurities observed in the optical images. The XRD results showed that both samples were crystalline, however it was found that the zeolite APG has a different crystal structure which results in smaller pore openings.

This makes the zeolite APG unsuitable for carbon dioxide adsorbtion, thus explaining the difference in performance.

References

[1] D. Frendo, Waste to Energy, B.Eng. (Hons.) Malta: University of Malta, 2017

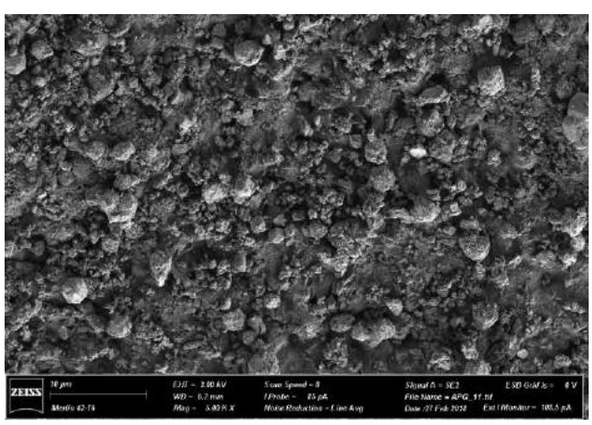


Figure 1: SEM image of zeolite APG (CHN)

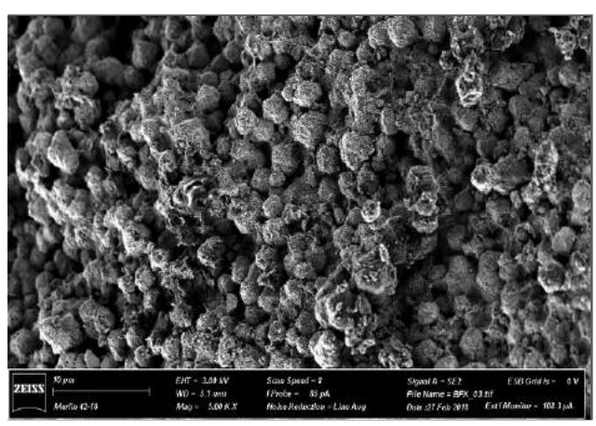


Figure 2: SEM image of zeolite NaMSXK (GER)

Pneumatic Conveying of Granular Substances

Student: Amy Rapa / Supervisor: Prof. Ing. Tonio Sant / Co-Supervisor: Dr Ing. Christopher Micallef

Introduction

In pneumatic conveying, one of the major drawbacks is the degradation of the granular material. Various factors contribute to this degradation, including pipeline geometry, dimensions, material being conveyed, and pressure [1]. In this Final Year Project, the particle degradation of sugar at Foster Clark Products Ltd. was studied.

Project Objectives

The main objectives of this final year project were to test samples after being passed through a pneumatic conveying system, that was modified to monitor and measure various parameters that affect conveying, using different Solids Loading Ratios (SLRs). The SLR is the ratio of the mass flow rate of sugar to mass flow rate of air present in the pipeline [2].

Project Methodologies

In order to vary the SLR, six sets of parameters were used. The mass flow rate of the air was varied by using two blower settings – 100% and 80% capacity, while the mass flow rate of sugar was varied by setting the screw feeder at 25%, 50% and 75%. During the test runs, the dynamic and static pressure were recorded to analyse the pressure drops along the pipeline. Five test runs were carried out for each set of parameters, and a sample was taken after every test run. The samples were then tested using sieve analysis to obtain a histogram such as the one shown in Figure 1. Finally, the results from each set of parameters were averaged and compared.

Results and Achievements

The range of SLRs tested during this project was from 0.484 to 3.993. As shown in Figure 2, increasing the SLR, resulted in a reduction in particle degradation. For the same screw feeder rates, an increase in degradation was observed when increasing the blower capacity from 80% to 100%. This is consistent with the hypotheses that a reduction in SLR results in increased particle degradation. The added mass flow rate of air, gives more space within the pipeline for the sugar particles to move, increasing the probability of a collision with the walls of the pipe, that is one of the factors that gives rise to particle degradation [3]. The experimental setup used provided reliable and repeatable readings. This was mainly due to the fact that the experiments were carried out on the actual line at Foster Clark Products Ltd. Furthermore, by increasing the SLR, the conveying time required to transfer a batch is reduced, increasing production capacity.

References

[1] D. Mills, 'Pneumatic Conveying Design Guide', Second ed. Burlington: Elsevier Butterworth-Heinemann, 2004.

[2] D. Mills, M. G. Jones, and V. K. Agarwal, 'Handbook of Pneumatic Conveying Engineering'. New York: Marcel Dekker, Inc., 2004.

[3] F. Wuertele, "Classification of Pneumatic Conveying Systems Part II: Material Conveying Phase," *Powder and Bulk Engineering,* 1989.

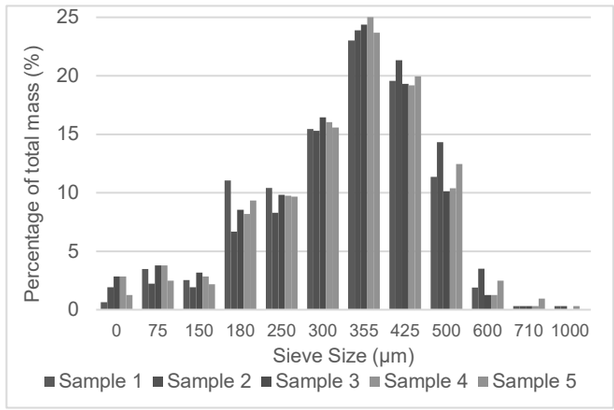


Figure 1: Particle Size Histogram for 100% blower capacity and 25% screw feeder capacity

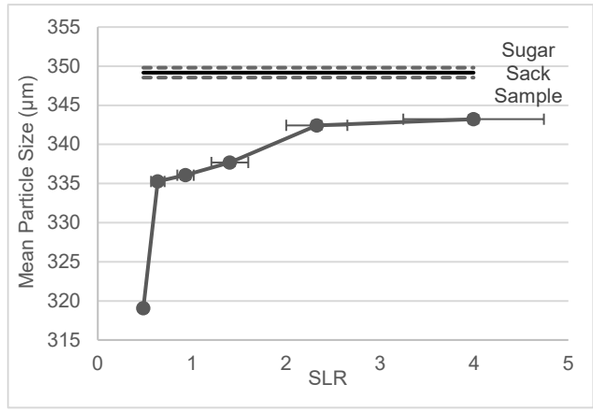


Figure 2: Particle Size versus SLR compared to sample from sack

Dynamometer Testing Improvements for the Common Rail Diesel Engine

Student: Christian Saliba / Supervisor: Prof. Ing. Mario Farrugia

Introduction

Diesel engines possess features including reliability, durability and high efficiency making them the most desired engines for light and heavy duty vehicles. To determine engine performance, engine testing is carried out using a dynamometer which converts the rotating mechanical energy from the loaded output shaft to thermal or electrical energy. [1]

Project Objectives

- Replacement of engine and gearbox since the tip of a glow plug was broken in the previous project and fell into the cylinder during engine testing;
- Development of a physical setup for exhaust smoke opacity measurements;
- Clutch locking to pressure plate to avoid clutch slippage and eliminate the difference between engine and dynamometer speeds;
- Elimination of gearbox oil leaks;
- Conversion from the variable frequency drive (VFD) to a valve-controlled system to eliminate torque signal noise during data acquisition.

Project Methodologies

An optical smoke detector was tested but was not suitable for exhaust opacity measurements. A transmissive optical sensor was then tested with diesel engine exhaust. The clutch was locked to the pressure plate using M4 and M5 bolts. The seal plate in Figure 1 was manufactured to cover the back plane of the gearbox. Due to the operating principle of the VFD, noise was being caused to the torque signal. The valve-controlled system was applied to eliminate this noise.

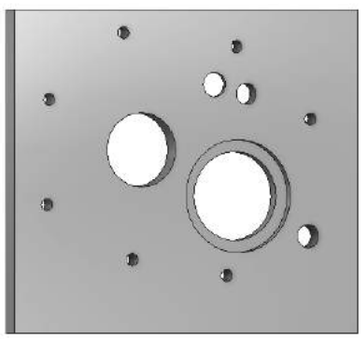


Figure 1: Seal Plate

Results and Achievements

The engine and gearbox replacement involved the installation of fuel tank and fuel pump, manufacturing of a new gearbox mounting frame and drive shaft coupling, and also the modification of the dynamometer bed left front mounting leg. The transmissive optical sensor proved to be utilisable for exhaust opacity measurements. The change in proportional analogue output required was achieved with a variation in smoke intensity.

The locking of the clutch to the pressure plate was in itself achieved. However, the unexpected shaft failure could not be easily explained. This might be because of the metal fatigue due to the second hand nature of the main shaft which was probably amplified by minor and unmeasurable misalignment. The seal plate was very effective because the oil leaks were eliminated.

From the tests conducted by the valve-controlled system, the engine was controlled properly and a reduction of the torque noise signal was obtained. Engine testing was successfully performed to verify the mechanical integrity of the engine. Three set points at different throttle position (TPS) were tested. Graphs were plotted for various parameters including the torque curve illustrated in Figure 2.

References

[1] Isenstadt A., German J., 'Diesel Engines', International Council on Clean Transportation (ICCT), USA, 2017

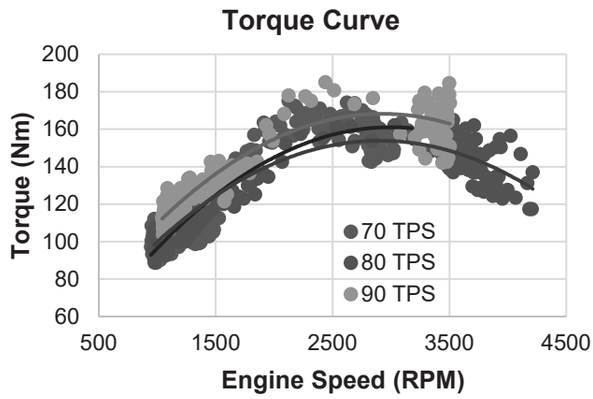


Figure 2: Graph of Torque (Nm) against Engine Speed (RPM)

Laboratory Testing of Scaled Rudders for Cavitation

Student: Christopher Saliba / Supervisor: Dr Simon Mizzi

Introduction

Cavitation is an undesirable phenomenon often encountered in the maritime industry wherein the vaporisation of water occurs as the local pressure surrounding a lifting surface decreases to a value below the vaporisation pressure of water. The reduction in pressure experienced is a result of the high velocity of fluid flow induced on the surface. The volume of vapour that develops is referred to as cavitation.

Project Objectives

The aim of this project was to modify the previous setup [1] in such a way that a much greater flowrate would be achieved in order to be able to enlarge the test section along with the hydrofoils being tested as well as obtaining more accurate results by modifying the pressure measuring technique. The inception of cavitation over three different hydrofoil profiles would be investigated through experimental testing. Testing was carried out at three different angles of attack for each profile in order to analyse the effect that different angles of attack have on the inception of cavitation.

Project Methodologies

Hydrofoil shapes that resemble those used in actual maritime applications were chosen for this experiment, such as the NACA 0020 section which is appropriate for use in rudders or keels due to its symmetric nature, providing equal lift on both sides.

Furthermore, the HSVA MP 71-20 section was chosen since its profile resists the inception of cavitation, allowing us to investigate the importance of hydrofoil shape. Finally, the NACA 63-215 section was chosen in order for us to investigate the effects that a cambered profile have on the inception of cavitation.

Results and Achievements

Using the manufactured setup, measurements for the pressure differential between two locations on the surface of the hydrofoil could be obtained via pressure tappings on the same surface. A comparison of the experimental results and theoretical results obtained using XFoil was carried out in order to ensure validation.

As can be seen in Figure 1 below, validation of results was achieved as the experimental and theoretical values obtained were very similar.

A significant amount of attached-sheet cavitation can be observed on the leading edge of the HSVA MP 71-20 hydrofoil at an angle of attack of 20° in Figure 2 below.

References

[1] Jacqueline Mifsud, "Cavitation in Maritime Control Surfaces," University of Malta, Msida, B.Eng. Dissertation 2017.

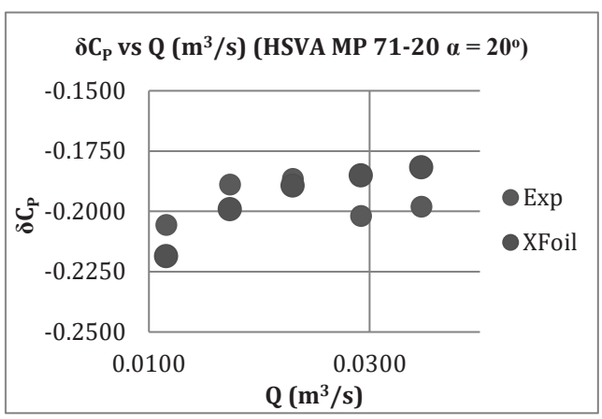


Figure 1: δC_P vs Q (m^3/s) Experimental vs XFoil (HSVA MP 71-20 α = 20°)

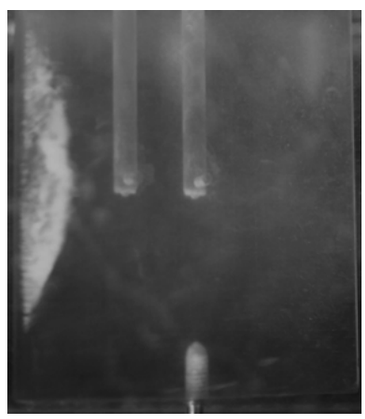


Figure 2: Cavitation on HSVA MP 71-20 (α = 20°)

Structural Analysis of a Composite GFRP Wind Turbine Nacelle

Student: Liam Sammut / Supervisor: Prof. Ing. Martin Muscat

Introduction

The Maltese landscape is scattered with various Chicago type wind pumps which were previously used to pump water from the water table for irrigation purposes. These structures have become neglected due to advancements in technology. This knowledge led to the design and construction of a modern electric wind turbine, shown in Figure 1, having the same overall appearance of a traditional Chicago wind pump.

Project Objectives

To build upon previous work already carried out on the existing prototype and to design a composite finite element model for the wind turbine nacelle to carry out a stress analysis on the structure and check whether it operates safely.

Project Methodologies

The design load conditions were identified from [1] and the extreme load cases were applied to the FE model to analyse the stresses induced by the nacelle structure. Pultruded fibreglass specimens were prepared for material testing following standards [2] and [3] to verify the true material properties of the nacelle frame. In addition, partial safety factors were applied to the material properties of each material used for the nacelle and the extreme load cases in order to obtain the allowable stress on the nacelle structure. The stresses acting on the nacelle were then compared to the allowable stress of each material to ensure that the nacelle operates safely.

Figure 1: Current prototype installed at the Government experimental Farm in Ghammieri

Results and Achievements

Satisfactory results were achieved, whereby the stresses induced by the nacelle were accepted for each load case. The maximum stress always occurred at the connection between the flat plates and the bearing housing. Load cases 1A and 1B, which occur when the wind turbine is yawing at a maximum rate producing a gyroscopic moment loading and torque on the shaft, produced the largest stresses on the nacelle as seen in the Figure 2 below.

Load case 2, which occurs when the wind turbine is in the parked condition facing the wind with a maximum thrust loading on the shaft, posed no threat to the design since the code allowable stress was not exceeded. An alteration to the design was proposed which reduced the stresses acting on the steel plate and chopped strand mat fibreglass plate due to the bearing housing by around 40 per cent and 100 per cent respectively for load cases 1A and 1B.

References

[1] BS EN61400-2:2006, Wind turbines- Part 2: Design requirements for small wind turbines, Malta Standards Authority, 2006

[2] BS EN ISO527, Plastics. Determination of tensile properties, United Kingdom, 1996

[3] ASTM D5379M, Standard Test Method for Shear Properties of Composite Materials by the V-notched Beam Method, United States, 1998

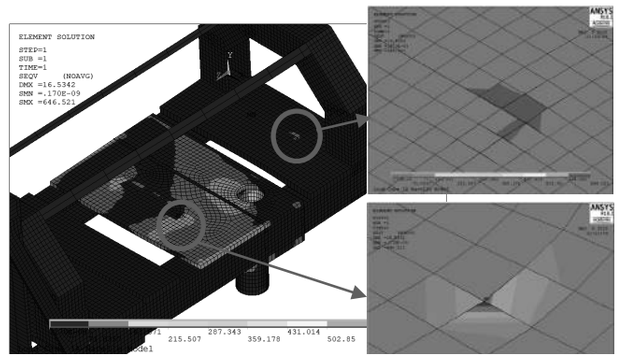


Figure 2: Contour plot of the von Mises stress (MPa) on the nacelle for Load Case 1A

Control Improvements on the Turbocharger Hot Gas Test Stand

Student: Luke Spiteri / Supervisor: Prof. Ing. Mario Farrugia

Introduction

The performance of the turbocharger is affected by its two main components; the turbine and compressor the operating characteristics of which are illustrated on the turbine and compressor maps respectively. For the past three years a turbocharger hot gas test stand which allows the measurement of a turbocharger's performance has been under development.

Project Objectives

The focus of this project was to improve the test stand setup in terms of safety requirements, enhance the control system capability by installing a mass airflow and a compressor outlet pressure ratio control systems and develop a feedforward control system.

Project Methodologies

The test stand safety level was improved primarily by making it capable to be operated from a remote area to increase the safety measures taken during testing procedures.
The inverter frequency control was automated so that the turbine inlet mass airflow variation could be controlled electronically. A photocoupler analogue circuit was utilised for this inverter control connection. The turbine inlet mass airflow variation was adjustable through LabVIEW software by using a PID controller. An electronic throttle body was also installed at the compressor outlet to increase the test stand autonomy by enabling automatic compressor pressure ratio control.

A feedforward control system was developed to increase the performance of the control system. A feedforward controller uses feedforward variables and a model, so it can adjust the control before the controlled variable deviates from its setpoint. [1] A feedforward controller uses a model to deduce the required buffer tank pressure to achieve the required temperature setpoint. Furthermore it has a number of feedforward variables (mainly the turbine inlet mass airflow) to deduce any variations in the temperature output.

Results and Achievements

A cascade-alone, feedforward-alone and a feedforward-cascade control systems were developed and their performances was compared together with the same testing matrix. When a feedforward-cascade control system was assigned an improvement in the turbine inlet temperature control was noticed (see Figure 1). The major improvement was noticed when a step change in the inlet mass airflow was inputted since a cascade control system could not notice such variation but since the parameter is chosen as a feedforward variable and inputted in the feedforward model (see Figure 2), a faster correction could be possible.

References

[1] [Marlin T.], 'Process Control' McGraw Hill, Boston MA, 1999.

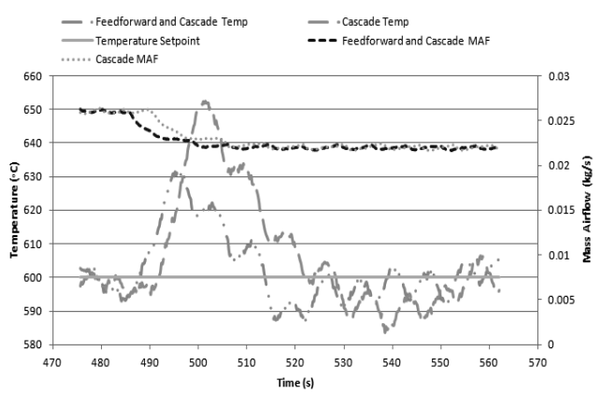


Figure 1: Feedforward-Cascade and Cascade Inlet Temperature (Step Decrease in the Mass Airflow)

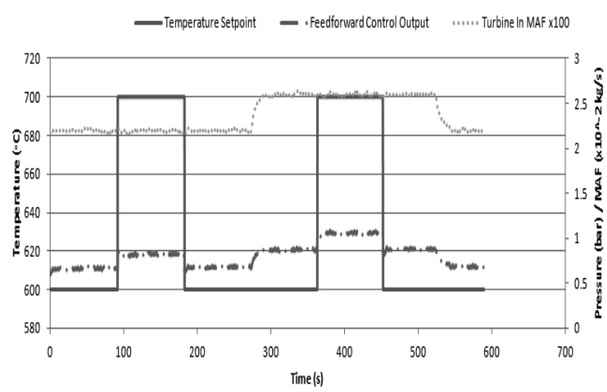


Figure 2: Feedforward Control Output (with the mass airflow and turbine inlet temperature variation)

Emulation of Vehicle Crash on Electronic Control Unit

Student: Miguel Tabone / Supervisor: Prof. Ing. Mario Farrugia

Introduction

Malta leads the line of road deaths amongst all EU countries. As a result of this alarming situation, the scope of this dissertation focuses on exploiting and analyzing the capabilities of a powerful tool whose application is still dawning in our islands, in light to improve vehicle and road safety while minimizing the number of road injuries and deaths.

Project Objectives

An EDR equipped vehicle was procured and by providing a novel approach to simulate a vehicle crash within a confined laboratory space and without necessitating the expenses related to full-scale vehicle collision, the EDR capabilities were accessed.

Project Methodologies

A vehicle of the same make, model and year listed in the Bosch CDR Coverage Guide [1], being a 2007 Toyota Auris, was procured. Its electrical harness, ECUs and other vehicle parts were retrieved and set up in the laboratory.

By applying the simple pendulum motion principles, an impactor that was securely attached to a string was displaced from equilibrium and then released from rest at predetermined potential energy. On event-by-event basis, when the impactor strikes the ACM at an acceleration that exceeds a specified threshold, intentional EDR events of different nature and severities are created.

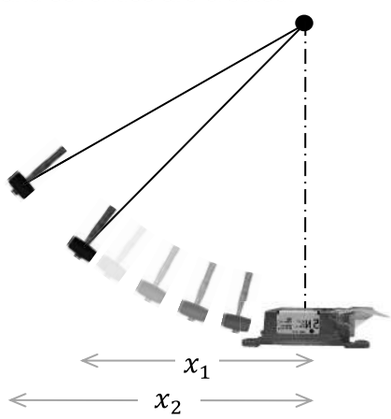


Figure 1: Striking the ACM to replicate a real-life vehicle collision and record a minor event

Results and Achievements

Four electrical circuits, one for each wheel speed sensor, were emulated to replicate the communication signal transferred between the same sensors and the rest of the electrical harness.

An Arduino program sketch being responsible to inject the accelerating and decelerating wheel speeds in a controlled fashion was generated.

The ABS system was integrated and activated during rapid accelerations and decelerations. For this reason, the ABS hydraulic pump had its outlet ports looped providing a closed line for restoring, dumping and holding of the hydraulic fluid's pressure.

By deliberately not connecting the airbags and pretensioners as these may be extremely dangerous, dummy resistors were used to simulate the presence of the live deployable devices to reduce further the vehicle faults.

Both pre and post-crash data were successfully recorded, extracted and interpreted through the application of Bosch CDR tool following the events created for the respective impact test combinations and correlated well with the imposed speeds and impacts.

References

[1] A. Huber, 'Bosch Coverage Guide CDR Version 16.5' asDARTS Inh., Germany, 2017.

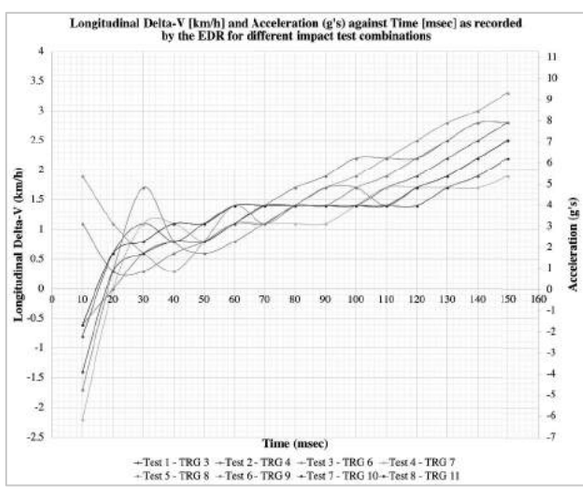


Figure 2: A graph for the data recorded by the EDR when the ACM is subjected to impacts of different nature and severity

Pilot Study on an Air Mattress Overlay Pressure Variation

Student: Nicole Vassallo / Supervisor: Dr Ing. Zdenka Sant / Co-Supervisor: Prof. Tonio Sant

Introduction

Pressure ulcers (PUs) are areas of damaged skin on bony areas of the body which cause pain and discomfort to those suffering from them, these mainly being bedridden patients. To counter PUs, alternating pressure air mattress (APAM) overlays have been developed to alternately relieve the prolonged pressure which causes PUs to occur.

Project Objectives

The aims of this study were to familiarise oneself with the working mechanism of such an overlay and to study if a relationship between the pressure variation of the said APAM overlay and the mass applied onto the overlay can be established.

Project Methodologies

Preliminary tests were carried out to familiarise oneself with the operating mechanism of the APAM overlay. Here, the time taken for the overlay to deflate an internal air pressure interval of $30\ kPa$ from maximum inflation was recorded for different masses. The overlay was placed on rigid surfaces and the masses were set on a firm plate covering the active area of the overlay, as shown in *Figure 1*.

These tests showed promising results, hence the methodology was modified appropriately. The same setup was kept, that is, the overlay was still placed on rigid surfaces and the masses set on firm plates, data but a data logger was introduced in order to digitalise the data-recording process and reduce human error. The entire deflation of the overlay was now recorded (pressure versus time) and capacitor theory was used for analysis of the pressure decay variation.

A focused calibration test was preformed and a calibration graph was established. Less focused tests were carried out, where the plate area on which the masses were applied and the overlay insert channel in use were varied. The results obtained were compared to the calibration graph.

Two final sets of tests were performed where the overlay was set on a non-rigid surface and the loads were applied directly onto the overlay. Both results were compared to those of the calibration (*Figure 2*).

Figure 1: Setup of the equipment

Results and Achievements

A downward trend was observed from the results when the overlay was supported by a rigid surface and the loads were applied onto a firm plate, irrespective of the area of the plate. This downward trend was not maintained when the overlay was placed upon a conforming surface and the masses were set directly onto the overlay, as shown in *Figure 2*.

In conclusion, it can be said that the conformance of the support surface and the mode of application of the masses onto the overlay considerably affect the pressure variation characteristics along the deflation cycle of the overlay.

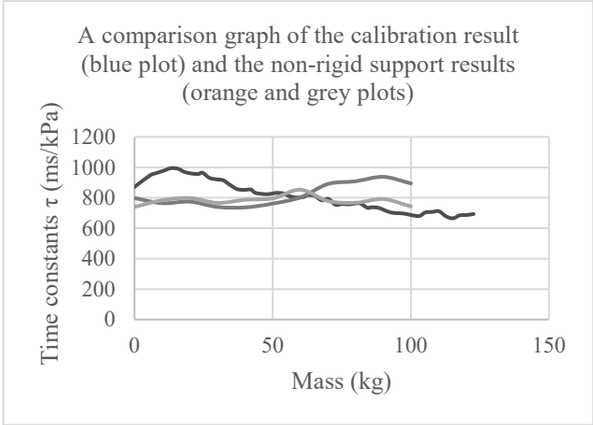


Figure 2: Non-rigid support comparison graph

Design of a Towfish Using GFRP

Student: Adrian Xiberras / Supervisor: Prof. Martin Muscat

Introduction

Monitoring and scanning for pollution in the sea is very important in order to preserve the marine environment. Surveillance of the sea can be achieved using a marine vessel known as a towfish. The towfish is towed behind a ship and is controlled by a crew member on board the ship itself. A towfish that is manufactured from GFRP will achieve a reduction in mass when compared to the same design but made of steel. When operating in the same conditions, the GFRP towfish will therefore contribute to better handling during a mission than the steel design.

Project Objectives

The aims of this project were to review the previous designs within the department, as well as, to review the available codes of standards for pressure vessel using GFRP. Additionally, the towfish will be redesigned by making use of the same geometrical features as in the previous steel design [1] and produce required workshop drawings.

Project Methodologies

The towfish designed from GFRP was to be manufactured using a hand layup method. First, experimental tests were carried out to determine the Tensile Young's modulus of the CSM laminate as to prove that the material was as stipulated within Code of Standard ASTM D 3039-00 [2]. Five specimens were cut out from a laminate at different orientations to prove that the material has the same tensile Young's Modulus in different direction and achieve repeated readings. Strain gauges were then fitted in the middle, at the front and back of each specimen as to compute the strain and bending of the specimen during loading. After attaining the Tensile Young's Modulus of the material from the experimentation, strains and stresses were plotted, and the Young's modulus was computed linearly from the graph. A design by rule (DBR) method was then carried out following the recommendations stipulated by the Code of Standard BS EN 13121-3:2008+A1:2010 [3] to determine the thickness of the four main components of the towfish, using critical buckling equations. An analysis was carried out on the main cylindrical shell, hemispherical head, conical tail and the cylindrical arms shown in Figure 1 as component number 1, 4, 3 and 8 respectively, since the code [3] could only compute the thickness of such standard geometries. After, computing the thickness of each component mentioned, the mass for each component was then calculated and compared to that of the steel design.

Results and Achievements

The thickness of the four components were computed and the thickest section resulted to be the main cylinder, as the cylinder is the most susceptible component to buckling. Reduction of the mass achieved when compared to the previous steel design were deemed to be satisfactory, with a total reduction of 9.63kg.

New features were added to the existing design, such as dowels that where introduced to the flange face to make the correct alignment of the main components easier, as well as to hold the gasket in place until flanges are assembled together. Additionally, a part was added to every flange assembly to connect it with the GFRP components.

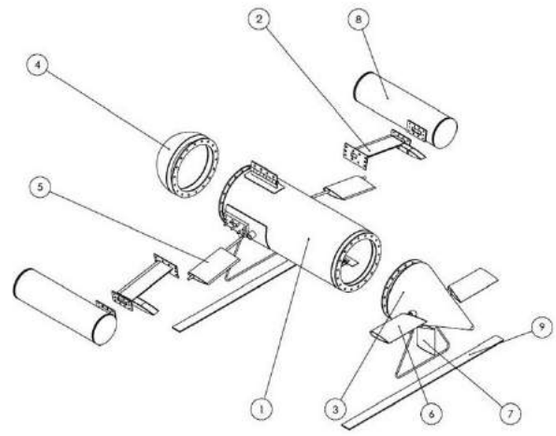


Figure 1: Towfish Components [1]

References

[1] M. F. G. S. Dr Martin Muscat, "BioDiValue Project Towfish Design Report Version 3," Italia - Malta, 2013.

[2] "Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials," ASTM International.

[3] "GRP tanks and vessels for use above ground Part 3: Design and workmanship," 2010.

The Influence of Cavitation on the Hydrodynamic Performance of a Rudder Profile

Student: Damian Xuereb / Supervisor: Dr Simon Mizzi

Introduction

Cavitation is a physical phenomenon which can be described as the appearance of vapor cavities in an initially homogenous liquid medium. Cavitation is a longstanding issue in hydrodynamics which occurs when the local pressure on a control surfaces falls below the vaporization pressure. The phenomenon causes a drop in profile performance together with material degradation. [1]

Project Objectives

Due consideration is given to cavitation to predict and mitigate its effects. The main aim of the project is to employ numerical techniques to characterize the influence of cavitation on the performance of a rudder profile.

Project Methodologies

A simulation was performed characterising a commonly used rudder profile (NACA0015) in freestream at a non-cavitating condition. The simulation was conducted using various turbulence models and the lift and drag coefficient obtained by each model was compared to the coefficients computed by the 2D panel code XFOIL.

Cavitating flow over the NACA66(MOD) profile was then simulated using the Full Cavitation Model, developed by Singhal et al. [2], and the pressure distribution curves predicted by Fluent were compared to experimental data. The validation experiment was first conducted at a cavitation number of 0.84 using various turbulence models. Various cavitation numbers were then simulated at multiple angles of attack $(4° \text{ and } 6°)$ and compared to experimental data.

An automated system was generated using ANSYS Workbench to investigate the influence of cavitation on the lift and drag generated by a hydrofoil. A range of hydrofoils pertaining to the NACA00 series were investigated over a range of operating conditions. After which a regression analysis was performed on the data attained to mathematically characterise the relations present between cavitation and hydrodynamic performance.

Results and Achievements

The ideal setup, in terms of computational time and accuracy, to model a 2D hydrofoil in freestream was identified. In general, a good agreement was achieved between FLUENT and XFOIL using various turbulence models.

The results obtained from the validation process clearly outline the ability of the Full Cavitation Model to predict the influence of cavitation on the hydrodynamic performance of a hydrofoil.

The main relations identified, between cavitation and performance, throughout this study were; a decrease in cavitation number yields a decrease in lift; the drag coefficient increases with a decrease in cavitation number and the overall efficiency of the rudder (lift to drag coefficient) decreases with a decrease in cavitation number.

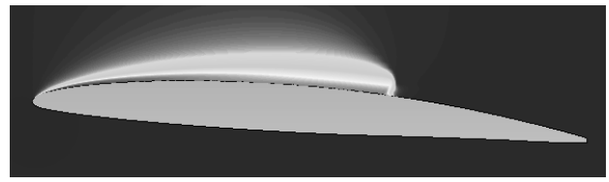


Figure 1: Simulation of cavitation on a NACA66(MOD) profile at $\sigma = 0.84$ and $\alpha = 4°$

References

[1] Franc JP., Michel JM, 'Fundamentals of Cavitation' Fluid Mechanics and Its Applications Vol. 76 No 1.

[2] Singhal.AK, Li.H,; Athavale.MM, Jiang.Y, 'Mathematical Basis and Validation of the full Cavitation Model' Journal of Fluids Engineering, Vol. 124, pp. 617-624

Analysis of Tubular Welded Frames

Student: Jeremy Zerafa / Supervisor: Dr Ing. Pierluigi Mollicone

Introduction

Finite Element Analyses (FEA) aids in the evaluation of new designs that may include structures in complex configurations, such as tubular welded frames. Simulating a model in a finite element program such as ANSYS APDL or ANSYS Workbench, offers structural modelling of such frames by various element types. For a simulation to be considered reliable, the results obtained must be validated against thorough experimental investigations.

Project Objectives

To review previous work conducted on five stress relieved tubular welded frames and attempt a further validation of the FEA modelling using the supplied material properties. To investigate the phenomena of strain hardening that leads to shakedown, and to model and analyse the tubular welded square frame using beam, shell and solid elements in ANSYS APDL and ANSYS Workbench.

Project Methodologies

To further investigate the phenomena of strain hardening, the frames were loaded using load steps in both the experimental investigation and the FEA modelling. A total of 6 experiments were conducted on each square specimen to obtain sound data for an experimental validation, whilst 10 simulations were modelled using the aforementioned elements.

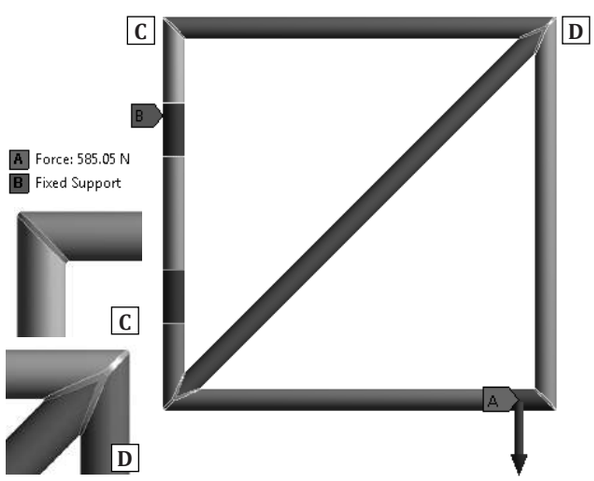


Figure 1: Tubular Welded Frame – Solid modelling including welds

The simulations included a comparison of the linear isotropic hardening model and the bilinear kinematic hardening model. Using solid elements, the actual welds were modelled at the connections of the hollow tubes as can be seen in Figure 1. Two simulations included the modelling of bimaterial properties, where the global tubes of the frame were assigned with the non-welded material properties, whilst the joints that represented the welds were assigned with the welded material properties. All FEA elements were compared and a validation was carried out.

Results and Achievements

For the beam, solid and shell elements respectively, the percentage errors for the bending stiffnesses were equal to -239.23%, -322.54% and -450.99%, whereas the percentage errors for the maximum deflections undergone were equal to 68.55%, 76.61% and 82.26%. The supplied material properties and dimensions were recalculated due to the high discrepancies, although the new parameters found had no effect such errors. These errors were attributed to the clamping mechanisms that are believed to induce high stresses when fastened. Strain hardening was occurring only in the experimental investigation, whereas in all simulations, the yield stress was not exceeded by the equal force applied. It was concluded that the induced stresses at the fixed supports are exceeding the yield stress of the frame at a certain load applied. Such stresses were not modelled, thus the bending stiffnesses and maximum deflections undergone in the simulation were incomparable as can be seen in Figure 2.

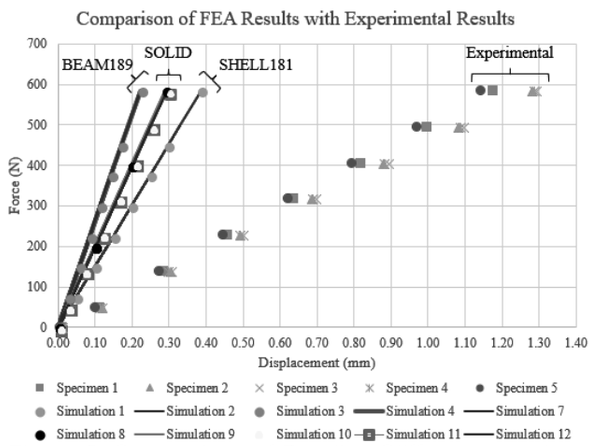


Figure 2: Comparison of Bending Stiffnesses and Maximum deflection undergone by all results

Laser Shock Peening of Austempered Ductile Iron

Student: Amy Abdilla / Supervisor: Dr Ing. Ann Zammit

Introduction

Austempered ductile iron (ADI) is a type of ductile cast iron that has been subjected to an isothermal heat treatment with the aim of improving the toughness and the wear and fatigue resistance. In fact, ADI possesses a combination of excellent properties such as good tensile strength and ductility, which makes it renowned in the automotive industry.
Further improvement of the surface properties of ADI can be performed by means of cold processes such as laser shock peening [1]. Laser shock peening is a process variant of the conventional shot peening process whereby compressive stresses are induced in the surface of components by means of a pulsating laser beam. This process aims at improving the fatigue life, wear resistance and corrosion resistance of metallic materials [2].

Project Objectives

The aim of this project was to understand the science behind the LSP process and to determine a suitable range of process parameters that can be used to obtain better surface properties on ADI.

Project Methodologies

Austempering heat treatment was initially carried out on ductile iron alloyed with copper and nickel to obtain ADI. Following austempering, an ausferrite matrix was obtained consisting of high carbon austenite and acicular ferrite. The LSP process was then performed on the ADI with different process parameters mainly different laser power densities, laser energies, pulse time, beam shapes and beam areas were used. Moreover, a water- confined ablation, similar to the one in Figure 1 was used. Water was used as the transparent overlay and an aluminium coating and black tape were used as the absorbent coating.
Optical microscopy, scanning electron microscopy, hardness tests, profilometry tests and 3D scanning were performed to analyse the surface characteristics and properties attained by LSP and compared them to those pertaining to the as-austempered ductile iron.
Moreover, the incremental hole-drilling technique was used to measure the compressive residual stresses generated by LSP on ADI. These measurements were carried out on ADI samples treated with a single and double impact so as to compare the values attained with different laser impacts.

Results and Achievements

No phase transformation from austenite to martensite was observed and the surface hardness of ADI following LSP revealed no changes. However, an increase in hardness was observed in the sub-surface of the LSP-ed specimens. In fact, for ADI treated with a high laser power density, a 7% increase in hardness was attained. Moreover, the affected depths after LSP were of around 1.45 mm. Furthermore, the surface roughness measured on the LSP-ed ADI was found to be much higher than the as-austempered DI and this was attributed to the surface undulations formed during the LSP process.
The residual compressive stresses obtained for laser shock peened ADI were found to be both higher in magnitude and have a deeper effect that those obtained by SP. In fact, the compressive stresses generated by LSP where found to be 50% greater in magnitude and 70% deeper than the compressive stresses generated by SP.
The results obtained in this project reveal that LSP is beneficial to improve the mechanical properties of ADI.

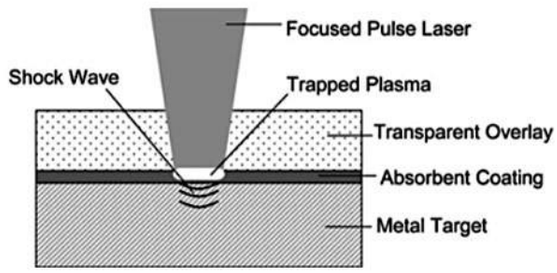


Figure 1: Schematic diagram of the LSP process [2]

References

[1] Zhang J., 'Microstructure and mechanical properties of austempered ductile iron with different strength grades]' [Materials Letters, 2014 Vol. 119, pp.47-50

[2] Montross C. S., Wei T., Ye L. Clark G. and Mai Y., 'Laser Shock process and its effects on microstructure and properties of metal alloys: a review' International Journal of Fatigue, 2002, No. 24, pp.1021-1036

Cr-C Coatings for Medical Implants: Structure, Properties and Performance

Student: Dylan Abela / Supervisor: Dr Ing. Bertram Mallia

Introduction

The need for orthopaedic implants is continuously on the rise. According to the American Joint Replacement Registry, in 2015, there was a 102 % [1] increase in the number of joint arthroplasty procedures, compared to 2014 [1]. Austenitic stainless steels are used in this application due to their good corrosion properties and their lower cost when compared to other metallic biomaterials such as titanium and cobalt based alloys. However, more than 90 % [2] of failures in orthopaedic implants made from austenitic stainless steel are due to leaching of metal ions and localised corrosion in the taper section, together with the effect of tribocorrosion between bearing surfaces.

PVD is used to deposit coatings, to try and inhibit these problems. Cr-C coatings possess a combination of high hardness, toughness and adhesion and good corrosion resistance [3]. Corrosion due to wear is the principal material loss mechanism in such systems [3].

Project Objectives

The aim of this dissertation is to analyse the effect of heat treatments of magnetron sputtered Cr-C hard coatings deposited on 316LVM stainless steel. The properties, structure and electrochemical behaviour will be analysed following heat treatments at different temperatures to study the effect of the microstructure on their properties and performance.

Project Methodologies

Heat treatments of magnetron sputtered Cr-C coated 316LVM were conducted using a tube furnace in 95%$N_2$5%H_2 for 1 hour holding time at 400 and 600 °C. The structure of the coating before and after heat-treatment was analysed by using X-ray diffraction. Nano-indentation, nano-scratching, microhardness tests, fractured specimen analysis and Rockwell C tests were conducted to investigate the adhesion and hardness of the coatings. Also, potentiodynamic polarization tests were performed to investigate the effect of corrosion in a body simulating fluid (Ringer's Solution) at 37 °C to simulate the human environment.

Results and Achievements

The as-deposited Cr-C coating comprises of fine crystallites with the possible presence of an amorphous phase. Whereas coatings heat-treated at 400 °C displayed the same XRD pattern as the as-deposited one, indicating no change in structure, when the temperature was raised to 600 °C, the coating transformed to a multiphase crystalline material (Cr + $Cr_{23}C_6$). There was an increase in hardness compared to U/T 316LVM (4.6 ± 0.5 GPa vs. 23.5 ± 1.7 GPa in Cr-C HT600). Also, all coatings showed good adhesion and ductile behaviour. Figure 1 shows an SEM image of the Rockwell C indentation obtained for Cr-C AD, showing good adhesion. Finally, good corrosion resistance was exhibited by the coating and its heat-treated counterparts, with the best being for Cr-C AD, making them viable for further research in this field.

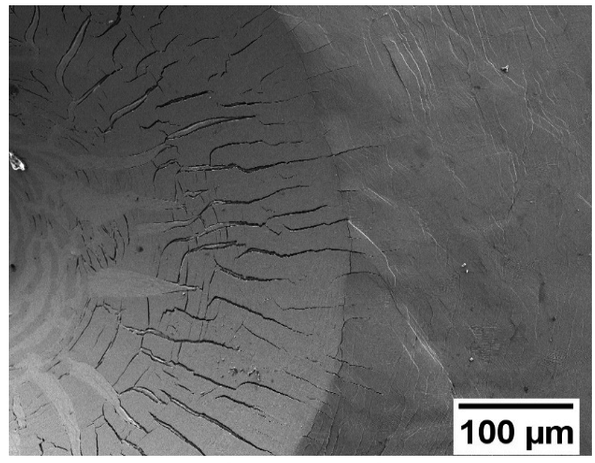


Figure 1: Rockwell C indentation for as-deposited Cr-C

References

[1] American Joint Replacement Registry, "Third AJRR Annual Report on Hip and Knee Arthroplasty Data," American Joint Replacement Registry, Rosemont, 2016.
[2] D. C. Hansen, "Metal Corrosion in the Human Body: The Ultimate Bio-Corrosion Scenario," Interface, vol. 1, pp. 31-34, 2008.
[3] D. K. Merl, P. Panjan, M. Cekada and M. Macek, "The corrosion behaviour of Cr-(C,N) PVD hard coatings deposited on various substrates," Electrochim. Acta, vol. 49, pp. 1527-1533, 2004.

Shot Peening of Austempered Ductile Iron for the Automotive Industry

Student: Warren Abela / Supervisor: Dr Ing. Ann Zammit / Co-Supervisor: Dr Ing. Glenn Cassar

Introduction

The microstructure of austempered ductile iron (ADI) is made up of graphite nodules dispersed in a metallic ferrous matrix - Figure 1. This structure provides the material with excellent fatigue performance [1]. Along with its good machinability, this makes ADI a front runner in automotive applications involving cyclic loading, such as power transmission gears and crank shafts [1,2]. The fatigue life of ADI may be further improved through a surface treatment called shot peening.

Project Objectives

The aim of this research is to determine whether shot peening, and duplex shot peening of ADI, can be a suitable surface engineering technique to enhance the fatigue performance of the as-austempered material. This involves characterisation of surface and near-surface regions along with mechanical testing of as-austempered and shot peened specimens.

Project Methodologies

ADI was produced by subjecting the as-cast ductile iron to an austempering heat treatment. This involves two stages; firstly a two hour hold in an electric furnace at 900℃, followed by an hour and a half in a salt bath kept at 360°C. Following this, the specimens are allowed to cool down in air back to room temperature. This brings about changes in the microstructure which improve the mechanical properties relative to the as-cast condition.

ADI hourglass-type specimens were then subjected to a shot peening treatment. This process employs compressed air to blast the surface of the specimens with small spherical media called shots (ø 0.84 mm). Another variant of this treatment, referred to as duplex shot peening, was also applied on another batch of specimens. This is similar to the aforementioned treatment but entails an additional peening stage using smaller shots (ø 0.28 mm).

This study involved the use of various characterisation techniques including microscopy, hardness testing, profilometry, diffractometry, and residual stress measurement, in order to analyse the changes brought about by the heat treatment and shot peening process on the as-cast material. This was complemented by mechanical testing in order to assess the benefits on fatigue performance of ADI brought about via shot peening.

Results and Achievements

Rotating bending fatigue testing revealed that shot peening was successful in increasing the fatigue strength of ADI by approximately 70%. This was attributed to compressive residual stresses induced in the surface layers of the material, through work hardening of the ferrite phase, and a strain-induced transformation of austenite into martensite. Moreover, duplex shot peening was successful in reducing the roughness of the peened specimens and increasing the magnitude of the compressive residual stresses in the surface layers, which lead to improvement in fatigue performance of ADI. This study also revealed that at high stress levels, duplex shot peening brought about an improvement in fatigue life of around 140% relative to conventionally shot peened ADI, albeit resulting in the same fatigue strength.

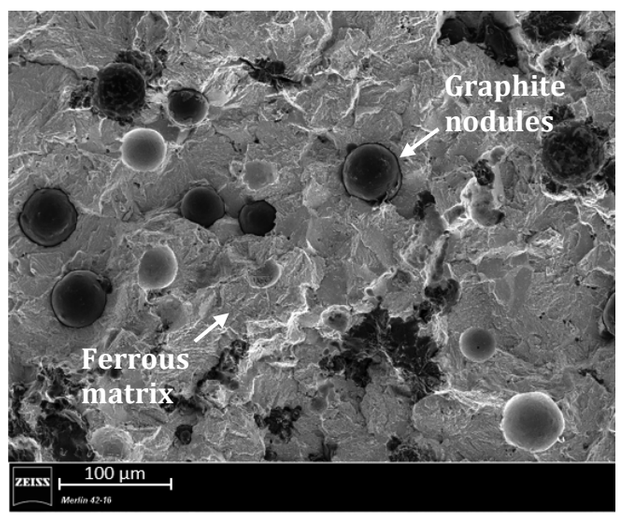


Figure 1: Fracture surface of ADI, displaying graphite nodules dispersed in a metallic ferrous matrix

References

[1] Zammit A., Mhaede M., Grech M., et al., 'Influence of shot peening on the fatigue life of Cu–Ni austempered ductile iron' Materials Science and Engineering A, 2012, Vol. 545, pp. 78-85.

[2] Keough J. and Hayrynen K., 'Automotive Applications of Austempered Ductile Iron (ADI): A Critical Review' SAE World Conference, 2000.

CoCrMo(C) coatings for medical implants Structure, Properties and Performance

Student: Andrea Borg / Supervisor: Dr Ing. Bertram Mallia

Introduction

Surface engineering techniques are gaining popularity in the biomedical industry [1], as they offer the possibility of improving the life-time and performance of the implant whilst still retaining the bulk properties of the metallic substrate. From previous works [2], which focused on the testing of as-deposited Co-Cr-Mo-(C) s-phase coatings against corrosion wear showed several strengths and limitations. The strengths of such coatings included high toughness and high corrosion resistance, however the limitations included poor Type I resistance during tribocorrosion testing [2]. The scope of this research was to follow the findings found in previous works and heat treat the coatings so as to better assess how the change in structure and mechanical properties may affect their performance

Project Objectives

The main aim of this research was to evaluate the properties and corrosion characteristics of the 316LVM substrate, as-deposited Co-Cr-Mo (C) s-phase coated 316LVM [designated as: Co-Cr-Mo-(C)-AD] and also study the effect of heat treatment on the structure, properties and performance [designated as: Co-Cr-Mo-(C)-HT400 and Co-Cr-Mo-(C)-HT600].

Project Methodologies

CoCrMo(C) s-phase coatings deposited on 316LVM substrates via magnetron sputtering at Boride Services Ltd. (UK) were studied. The coatings were subjected to two heat treatments at 400°C and 600°C for one hour. The structure of the coatings under the different conditions was examined using X-Ray Diffraction (XRD), profilometry and fracture cross section analysis. The hardness and deformation mechanisms were examined using nano-indentation, nano-scratch and Rockwell C tests. The static corrosion resistance was electrochemically tested using a three-electrode setup. Full strength Ringer's Solution was utilized as the test electrolyte. The Scanning Electron Microscope (SEM), Light Optical Microscope (LOM) and Energy Dispersive Spectroscopy (EDS) were utilised for further

Results and Achievements

Results obtained showed that the coating has an overall higher hardness then the bare substrate, and the hardness increases with the increase in the heat treatment temperatures.

The Co-Cr-Mo-(C)-AD sample (15.0 ± 0.6 GPa) experienced an increase in hardness when heat treated at 600°C (20.4 ± 0.6 GPa). This was due to the emergence of chromium carbides in the coating itself as identified using XRD analysis. With higher hardness, higher brittleness was displayed in scars, however no delamination was recorded following scratch tests. When tested for localised corrosion resistance, the as-deposited coating sample showed an improved resistance. Co-Cr-Mo-(C)-HT400, showed the best static corrosion results overall. Co-Cr-Mo-(C)-HT600 showed a deterioration in localised corrosion resistance. This is due to the fact that a probable chromium depletion was experienced due to the carbide formation. The potentiodynamic results can be better observed in Figure 1. From the results obtained, it was shown that the heat treatment at 600°C became harder but displayed metastable pitting events during corrosion testing. Further investigation on the possibility of heat treating the samples at 400°C should be considered and more research should be carried out on the possibility of finding an optimum treatment in which the coating still retains its thermal stability.

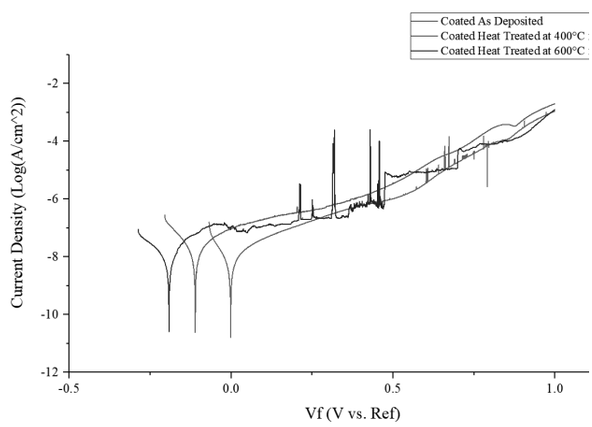


Figure 1: Potentiodynamic polarisation curves obtained in Full Strength Ringer's Solution at 37±1°C

References

[1] N. Thomsen, A. Fischer-Cripps and M. Swain, "Crack formation mechanisms during micro and macro indentation of diamond-like carbon coatings on elastic–plastic substrates", *Thin Solid Films*, vol. 332, no. 1-2, pp. 180-184, 1998

[2] R. Chetcuti, "Tribocorrosion Response of Duplex S/Cr(N) and Cr(N)/S coatings on Implant Grade 316LVM," University of Malta, Malta, 2016.

Residual Stress Measurement of Shot Peened Automotive Gears

Student: Jamie Borg / Supervisor: Dr Ing. Ann Zammit / Co-Supervisor: Dr Ing. Glenn Cassar

Introduction

During operation, gears undergo cyclic tensile and compressive stresses particularly at their root making them susceptible to fatigue failure. Shot peening induces a case hardened layer to protect gears from fatigue failure. A compressively stressed layer is the result of this surface treatment. In addition, Austempered Ductile Iron (ADI) provides several advantages as a gear material. It is a relatively cheap material and has mechanical properties that rival commonly used steels.

Project Objectives

- Produce a literature survey on surface stresses of shot peened ADI.
- Setup and carry out austempering heat treatments and shot peening surface treatments.
- Obtain stress measurements of shot peened ADI using laboratory based diffractometry and synchrotron diffraction.

Project Methodologies

ADI flat coupons and gears were austempered at 360°C for 1 hour 30 minutes, and at 260°C for 4 hours. Surface hardness, optical microscopy, and XRD phase analysis were carried out for the as-ADI coupons. As for shot peening, an optimisation process was carried out to identify which shot size, from S70 (~0.3 mm) and S110 (~0.5 mm), gives the optimum balance between high surface and subsurface hardness, and the lowest surface roughness possible. The effect of shot type on duplex shot peening was also tested.

Hardness profiles and surface roughness data were generated to determine the final shot type choice. For both single and duplex peening, the S110 shot type gave the best results. Single and duplex shot peening were then carried out on all gears and coupons. Stress measurement via X-ray diffraction was performed on the flat coupons, and synchrotron diffraction was also carried out on both the gears and coupons to check whether the residual stresses on coupons were comparable with the stresses on the gears.

Results and Achievements

For the shot peened gears austempered at 360°C, synchrotron diffraction residual stress-depth profiles reveals that the compressive residual stress layer for single peened specimens, is much deeper in the flat coupons than it is in the gears' teeth roots. This suggests that the effect of shot peening on an unobstructed flat coupon, is not replicated on the more complex gear tooth root geometry. This results in underpeening at the gear tooth roots. This is shown in Figure 1. Synchrotron diffraction patterns are also representative of the fact that duplex peening has in fact suppressed the said problem. The second shot peening treatment with the S110 shots is seen to overcome the underpeening of the initial S330 peening treatment. This resulted in the gear tooth root and the flat coupon having very similar surface and subsurface compressive residual stress values, at similar depths below the shot peened surface. This is portrayed in Figure 2.

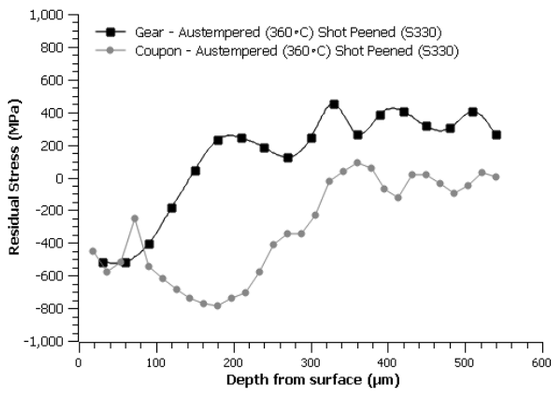


Figure 1: Residual Stress / Depth using single peening (S330)

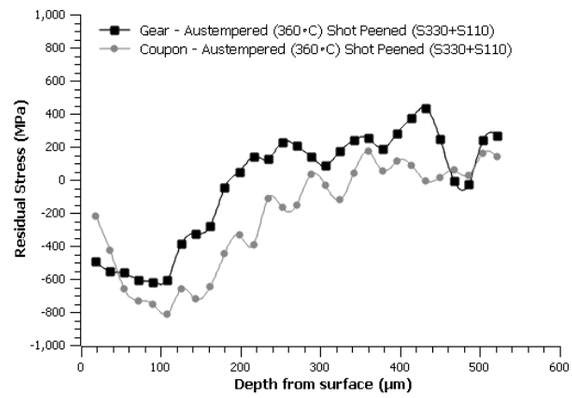


Figure 2: Residual Stress / Depth using duplex peening (S330 + S110)

Duplex Stainless Steel for the Petrochemical Industry

Student: Kyrie Marie Cachia / Supervisor: Dr Ing. Joseph Buhagiar

Introduction

Duplex stainless steels have a dual-phase microstructure consisting of both ferrite and austenite, possessing excellent strength, toughness and corrosion resistance [1]. As a result of these extraordinary properties, duplex stainless steels are widely used in the petrochemical industry, in particular in the desalination of crude oil, a water-washing operation involving the removal of water and corrosive salts from the crude oil [2], where a higher hardness and better corrosion resistance is required.

Project Objectives

The aim of this study was to harden duplex stainless steel 2205 by low temperature carburising, for the application of desalination of crude oil in the petrochemical industry. The principle objective was surface characterisation and degradation testing of the carburised duplex stainless steel 2205.

Project Methodologies

In this work, a duplex stainless steel 2205 was subjected to a low temperature carburizing process known as Kolsterising® which is proprietary to Bodycote Specialist Technologies GmbH (Landsberg, Germany). During this process, the samples were exposed to temperatures lower than 500°C and high carbon potentials for a number of days.

The effect of Kolsterising® on duplex stainless steel 2205 was investigated. Material characterisation was done through optical microscopy, Scanning Electron Microscopy, X-Ray Diffraction analysis (XRD), Glow-discharge optical emission spectroscopy (GDOES), microhardness testing and surface and cross-section Nano-indentation hardness tests. Potentiodynamic tests were performed to observe the corrosion response of the untreated and carburised duplex stainless steel 2205 when exposed to conditions similar to those in desalination of crude oil processes.

Results and Achievements

XRD analysis showed that after low temperature carburizing carbon S-phase formed from the austenitic phases, whilst Hägg Carbides (χ-Fe_5C_2), iron carbides (Fe_3C) and a phase thought to be expanded ferrite were present in minor quantities in the ferritic regions. Cross-section microstructural analysis of an etched carburised specimen revealed a bright, white, unetched carburised layer thicker on the austenite than on the ferrite.

Surface microhardness of the carburised specimen was five times harder than that of the untreated, with an average of 1361 ± 280 $HV_{0.025}$, with the ferritic phase of the carburised specimen being around 523 ± 188 $HV_{0.025}$ harder than the austenitic phase, potentially a result of carbide precipitation.

Cross-section Nano-indentation hardness tests and GDOES results show that the hardness is dependent upon the carbon content, which is maximum at the surface and decreases with depth to the core of the carburised specimen, as observed in Figure 1.

Potentiodynamic testing in acidified 5% NaCl solution (pH 4) at 45 ± 1°C revealed that both the untreated and carburised specimens do not suffer from any type of corrosion attack.

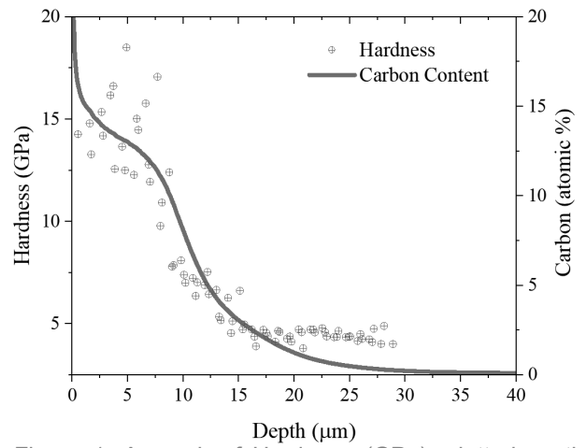


Figure 1: A graph of Hardness (GPa), plotted on the primary y-axis, and Carbon (atomic %), plotted on the secondary y-axis, against depth (μm)

References

[1] J.R. Davis, *Stainless Steels*. ASM Speciality Handbook, United States, ASM International, 1994.

[2] M.F. McGuire, *Duplex Stainless Steels*, in *Stainless Steels for Design Engineers*, United States of America, ASM International, 2008

Synthesis of Nano-Structured Carbon: Graphene

Student: Graziella Fenech / Supervisor: Ms Anthea A. Anastasi / Co-Supervisor: Dr Ing. Glenn Cassar

Introduction

Graphene, a single layer of carbon atoms resembling a honeycomb in structure, has evoked a lot of interest in the scientific community [1]. In fact, after its first appearance in 2004, extensive research has been dedicated to this nanostructured carbon allotrope, including a variety of synthesis techniques, which revealed its exceptional mechanical, electrical, optical, and thermal properties, propelling graphene towards the frontline of material research [2].

Project Objectives

This work contributes towards a more streamlined method of synthesising graphene for laboratory research, with the use of simple and fast characterisation techniques to identify potentially single-layer or few-layer graphene. Experimentation with the deposition of graphene on different silicon-based substrates aims at facilitating the integration of graphene in future applications, such as flexible touch screens, medical processes including cancer treatment, as well as for electric circuits, allowing the charging of smartphones in seconds.

Project Methodologies

Graphene was synthesised by cleaving graphite until only a few or a single layer of graphene was left. The process of producing thinner graphitic flakes was realised using two transfer media: adhesive tape, and a polydimethylsiloxane (PDMS) stamp. In both cases, two pieces of the same transfer medium were successively pressed against each other with the graphitic flakes in between, and peeled off to cleave the graphite into thinner flakes. The thin flakes were then deposited on different substrates by placing the transfer medium loaded with the flakes in contact with the substrate. A MATLAB code was developed to compare the flakes deposited on the substrates by using the different transfer media.

Different substrates including the use of two different hydrophobic sol gel coatings applied on silicon wafers were used to study the dependence of the flakes on the hydrophobicity and roughness of the substrate. Flakes were also deposited on a substrate having fabricated micropores. Characterisation of the flakes was carried out using an optical microscope, a scanning electron microscope (SEM), and an atomic force microscope, allowing for a holistic analysis.

Results and Achievements

It was found that the change in flake colour relative to the substrate can be attributed to a change in flake thickness, irrespective of the underlying substrate, as can be observed from Figure 1. The visualisation of the deposited flakes is also highly dependent on the SEM settings employed, such as the detectors and accelerating voltages used. The results obtained conclude that while SEM-EsB imaging allows for a thickness-based distinction between flakes, SEM-InLens imaging facilitates detection of even the thinnest of flakes. Furthermore, when measuring the thickness of the flakes via atomic force microscopy, discrepancies were noted among different measurements of the same flake. While tip-sample interaction during AFM imaging is one plausible explanation, another theory is the diffusion of liquid-phase water beneath the flakes.

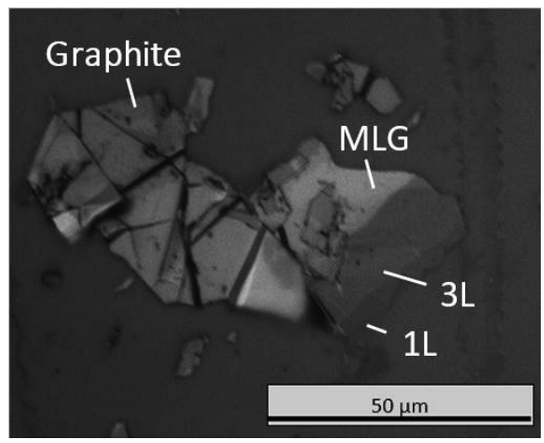


Figure 1: An optical micrograph of a flake having a gradual change in colour, as a result of a gradual increase in thickness, with areas of 1 layer (1L), 3 layers (3L), multilayer graphene (MLG), and graphite marked on the respective areas

References

[1] Pollard B., 'Growing Graphene via Chemical Vapor Deposition,' Ph.D. Thesis, Department of Physics, Pomona College, Claremont, 2011.

[2] Zhang Y. and Pan C., 'Measurements of mechanical properties and number of layers of graphene from nano-indentation,' Diamond and Related Materials, vol. 24, pp. 1-5, 2012.

Investigating the Structure and Properties of Carbide Layers Deposited on Tool Steel Produced by Transferred Arc Treatment

Student: Kenneth Galea / Supervisor: Dr Ing. Stephen Abela

Introduction

Tool steels are vital to almost every engineering application due of their considerable high hardness and wear resistance. At present, low alloy steels are facing serious competition due to the increasing demanding tooling requirements and required longer productive runs. To satisfy such demanding requirements, these steels require a "makeover".

Surface engineering technologies are often applied on tool steels that require high hardness and heightened wear resistance. The use of surface enhancements such as Nitriding followed by, PVD or CVD coatings, will provide vastly superior properties than those of untreated steel, however; these modifications are performed at high temperature. [1] Such technologies are thus not applicable to low alloy steels.

Project Objectives

This study is aimed at understanding the physical and tribological properties of carbides grown in the surface of heat treated low alloy tool steel, using an innovative Transferred Arc surface modification process at atmospheric conditions.

Project Methodologies

Samples were completely submerged, leaving a thin layer of oil at the surface. The tip of the electrode was set at a height of 4mm from the surface of the sample. The arc generated, was used to decompose the oil sitting on the surface of the sample and release its activated constituents. The released C and Si can thus diffuse in the molten sample surface and form compounds with the alloying elements within. Different treatment conditions were carried out using an automated experimental setup.

Various surface characterization techniques like X-Ray Diffraction, Energy Dispersive Spectroscopy, and Scanning Electron Microscope, were used to measure the enrichment in the carbon and silicon content in the surface of the samples, and to identify which new phases of carbides formed using this surface enhancement process.

The mechanical property of the treated samples was studied using nanoindentation tests. The thicknesses of the treated layers developed were also measured for each processing condition used. Tribology tests were performed using a pin on disc tribometer to compare the wear performance of the modified surface layers. For this series of investigations, ZrO_2 counter surface was used.

Results and Achievements

Increasing the treatment intensity resulted in higher concentrations of carbon, and eventually thicker surface layers of hard carbides. This improved the wear performance. The rough surface layers generated by the treatment yielded higher wear rates than those with a smooth finish and reduced some of the process benefits, but only during the running in period i.e. first 1 µm of wear. In fact, by increasing the overlapping of the arcs and reducing the roughness of the carbide layer resulted in wear depths that are hardly identified by surface profilometry, Figure 1. This treatment can thus provide a cheap and reliable solution to tackle wear problems, for low alloy steels without altering their bulk properties or shape.

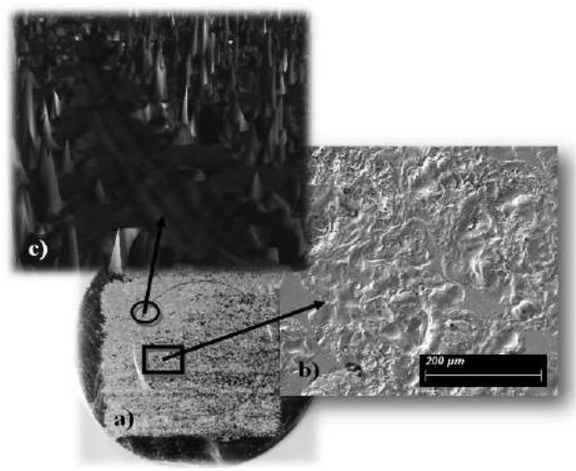


Figure 1: a) A monolithic treated layer with a feed rate of 10 mm/min and step size of 0.1 mm, b) SEM image of treated area and c) 3D profilometry scan demonstrating the respective wear track

References

[1] H. R. Hartmut Frey, "Chemical Vapour Deposition CVD," in *Handbook of Thin-Film Technology*, Berlin, Springer, 2015, pp. 225-253.

Study of High-Temperature Nano-Indentation of Light Metal Alloys

Student: Darrell Gauci / Supervisor: Dr Ing. Glenn Cassar / Co-Supervisor: Ms Anthea Agius Anastasi

Introduction

Since its inception, instrumented nanoindentation has played a pivotal role in the study of nanoscale behavior since it allows the testing of extremely small volumes of material. The use of high-temperature nanoindentation allows us to study nanoscale behavior at high temperature relevant to important applications which may trigger deformation and/or failure mechanisms not typically observed at lower temperatures.

Project Objectives

The aim of this project was to study high temperature nanoindentation and the associated thermal drift phenomenon, such that a reliable methodology can be formulated to mitigate it and successfully characterize the hardness, elastic modulus, and creep exponent of Ti-6Al-4V and Ti-15Mo at temperatures of up to 400 °C.

Project Methodologies

Nanoindentation experiments were initially performed on a reference fused silica sample to assess the use of heated and unheated indenter tips. This was followed by experiments to determine an optimal temperature matching procedure and whether a PID control set at the target temperature should be employed for the indenter. Thermal equilibrium between the sample and indenter tip was thus accomplished by independently heating the sample and the indenter tip and subsequently monitoring their temperature in real time. The formulated indentation procedure consisted of a pre-contact hold of 120 seconds, followed by a pre- and post-indentation thermal stabilization periods of 120 seconds each, in conjunction with a dwell period at maximum load of 30 seconds to permit viscoelastic relaxation within the specimen material, which is extended to 300 seconds to characterize creep.

Ti-6Al-4V and Ti-15Mo were analyzed using the newly formulated high temperature nanoindentation methodology to measure their hardness, elastic modulus, and creep exponent at room temperature, and at 100, 200, 300, and 400 °C to identify any temperature dependencies of any of these material properties. Low loads of 5 mN were also used at 100 and 400 °C to measure any depth dependency of hardness and elastic modulus.

Results and Achievements

Results from preliminary experiments suggest that the adopted procedure should involve the use of a power-locked heated indenter tip, coupled with temperature matching using thermocouple tuning and real time temperature monitoring following contact between the indenter and the sample. This procedure results in thermal drift rates comparable to room temperature in all subsequent experiments. Through this procedure, significant depth and temperature dependencies for hardness and elastic modulus values were found in both Ti-6Al-4V and Ti-15Mo. Creep exponent values do not change significantly with temperature for both alloys, however the variance can increase appreciably.

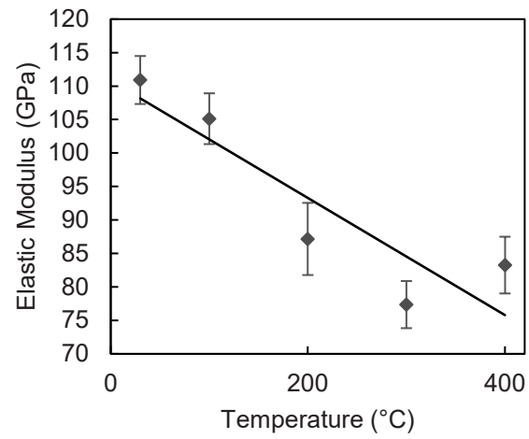


Figure 1: Temperature dependence of elastic modulus of Ti-6Al-4V

Biodegradable Scaffolds of Fe-Mn-Ag Alloy for Orthopaedic Applications

Student: Sandra Murillo / Supervisor: Dr Ing. Joseph Buhagiar / Co-Supervisor: Ing. Marcela Múnera

Introduction

Fe-Mn alloys have a potential use as biodegradable metallic scaffolds for orthopaedical applications due to their non-magnetic and good mechanical properties. [1] On the other hand they are limited due to a slow degradation rate [2]. In this project, the replication method combined with powder metallurgy was used to create biodegradable Fe-Mn-Ag scaffolds with improved mechanical properties and a controlled degradation rate.

Project Objectives

The main aim of this project is to develop scaffold of Iron-Manganese-Silver using the replication technique combined with powder metallurgy.
- Characterize the Fe-Mn-Ag alloy sintered scaffolds.
- Analyze the correlation between the phases formed, porosity, and corrosion response of the sintered scaffolds.

Project Methodology

Planetary Ball milling (Fritsch Pulverisette-6) was conducted on elemental powders of Iron and Manganese using hardened stainless-steel balls to obtain an Fe-30Mn and an Fe35Mn alloyed powder. This powder was then blended with silver powder together with ethanol and Polyvinyl alcohol (PVA) to obtain a slurry.
Reticulated polyurethane sponges with 45 pores per inch (Articoli Resine Espansi S.r.l) supplied in cylinder form was loaded with slurry and transferred to a tube furnace (Nabertherm GmbH) and sintered. The ball milled powder and sintered Fe-Mn-Ag scaffolds were then characterized by X-Ray diffraction and Scanning Electron Microscopy.

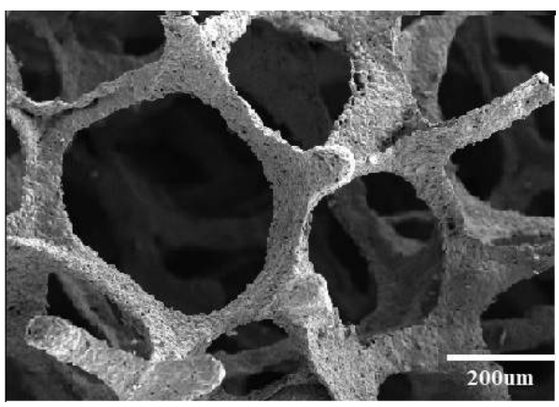


Figure 1: SEM Fe40Mn scaffold after sintering

Results and Achievements

Parameters such as the ball ratio, cycle of milling program, speed and time of milling can affect the powder size.

Table1. Powder size depending on milling time.

Fe-Mn	11(hrs)	26(hrs)	31(hrs)
Powder Size (μ m)	3.5 ±0.80	0.3 ±0.08	0.2 ±0.10

As is shown in Table 1 the powder size decreased with an increase in the milling time. The finer ball-milled powders have better packing within the slurry and therefore result in a better sintered scaffold. As it can be seen in Figure 1 the scaffold which is composed of struts, pores and pore windows has a low amount of defects. A high magnification image (Figure 2) of the strut shows good densification because powders of smaller size have more contact points and therefore this promotes diffusion.

References

[1] He J., He F., Li D., Liu Y., Ye Y., and Yin D., 'Advances in Fe-based biodegradable metallic materials', RSC Advances, 2016, Vol. 6, No. 114, pp. 112819-112838

[2] Jaroslav Č., Květa S., Alena M., Šárka M., Dalibor V., 'Microstructure, mechanical and corrosion properties of biodegradable powder metallurgical Fe-2 wt% X (X = Pd, Ag and C) alloys', Materials Chemistry and Physics, 2016, Vol. 181, pp. 501-511

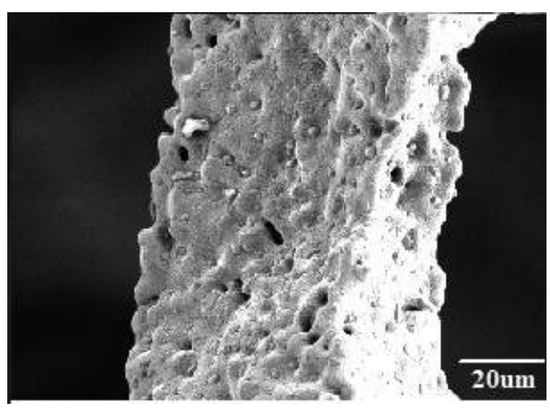


Figure 2: SEM image of a scaffold strut of an Fe30Mn scaffold after sintering

Boriding of Cobalt Chromium Molybdenum for Medical Applications

Student: Damian Muscat / Supervisor: Dr Ing. Joseph Buhagiar

Introduction

The biomedical industry relies on a number of passive metal materials for the successful implantation of medical implants. One of such metals is ASTM F-1537 medical grade Cobalt Chromium Molybdenum. The boriding process is an emerging surface engineering treatment which has not yet been used in the medical industry. The process was applied to this Co-Cr-Mo alloy in an attempt to improve its surface properties such as hardness, fracture toughness and dry wear resistance [1].

Project Objectives

The aim of this work was to study the effects of the boriding surface treatment on the alloy, at three different process conditions, with respect to mechanical properties and corrosion resistance.

Project Methodologies

Co-Cr-Mo sample coupons were borided by Bortec Gmbh (Germany) each at five-hour processing times but at 850°C, 900°C and 950°C processing temperatures.

The surface and layer hardness properties were analysed for the untreated and borided alloys using surface microhardness and layer cross-section nanoindentation tests. Characterisation of all material conditions through microscopy, Energy-dispersive X-ray spectroscopy (EDX), Glow-discharge optical emission spectroscopy (GDOES) and X-Ray diffraction were conducted to analyse the crystallography and phase formation resultant from the boriding process.

The main objective was to compare the electrochemical corrosion response of the untreated Co-Cr-Mo alloy with the borided alloy. This was achieved by potentiodynamic polarisation testing of the untreated and borided specimens in a Ringer's Solution at human body temperatures of 37±1°C.

Results and Achievements

XRD analysis confirmed that the as-received untreated ASTM F-1537 Co-Cr-Mo alloy consisted of mainly an α FCC phase Co-Cr-Mo with a presence of an HCP phase. The three borided conditions showed large presence of the CoB phase together with Co_2B, Mo_2B and CrB phases.

The layer architecture formed involved two boride layers CoB and Co_2B, from top to bottom of the surface, and a diffusion layer formed on the substrate. The results of the nanoindentation tests showed that all conditions started at around a hardness 30 GPa close the surface and started decreasing along the two boride layers and the diffusion zone. An impressive increase in surface hardness was obtained by the boriding treatment, which kept on increasing substantially with treatment temperature from condition one up to condition three. The change in hardness across the layer was analogous to the change in boron content.

Potentiodynamic testing verified that the boriding treatment decreased the corrosion resistance of the alloy surface. However, there was no pitting corrosion.

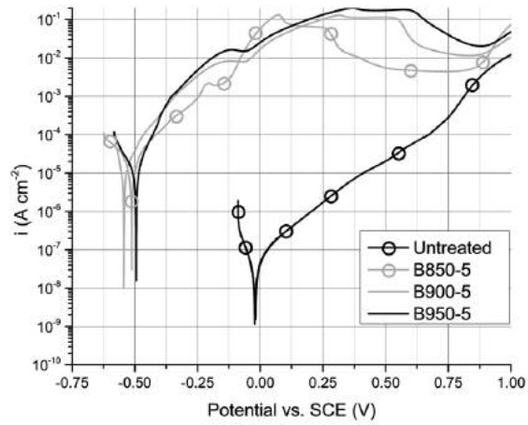


Figure 1: Representative Potentiodynamic Polarization Curve for Untreated, Borided at 850°C, 900°C and 950°C

References

[1] I. Campos-Silva, D. Bravo-Bárcenas, H. Cimenoglu, U. Figueroa-López, M. Flores-Jiménez, and O. Meydanoglu, "The boriding process in CoCrMo alloy: Fracture toughness in cobalt boride coatings," *Surf. Coatings Technol.*, vol. 260, pp. 362–368, 2014.

Laser Induced Breakdown Spectroscopy to Characterize Ceramic Materials: A Preliminary Study

Student: Samuel Psaila / Supervisor: Dr Daniel Vella / Co-Supervisor: Dr Ing. John C. Betts

Introduction

Laser Induced Breakdown Spectroscopy is a type of atomic emission spectroscopy technique that relies on a high-powered laser source to excite atoms within a material into a higher energetic state inside a plasma. The analysis technique is rapid and both qualitative and quantitative elemental analyses are possible. Sample preparation is minimal and analysis is micro-destructive making it popular for applications where damage must be kept to a minimum.

Project Objectives

The main objective of this work was to establish a procedure for the qualitative and quantitative analyses of ceramic based materials, namely terracotta pottery shards and Globigerina Limestone using Laser Induced Breakdown Spectroscopy.

Project Methodologies

In order to gain familiarity with the instrument, operating software and spectral analysis, materials with fairly simple and known composition (table salt, titanium oxide, an aluminum alloy block and soda-lime glass) were first examined qualitatively to establish a working procedure.

The intensity and signal-to-background ratio for the emission lines were varied against laser voltage, laser flash lamp Q-switch delay and lens-to-sample distance, to optimize the set-up for the subsequent quantitative analysis.

Qualitative analysis of the ceramics then followed. These ceramics included seven shards of terracotta pottery of unknown origin, as well as samples of *soll*- and *franka*-type Lower Globigerina Limestone.

Quantitative analysis of the limestone was carried out in an attempt to distinguish between the *soll*-type and *franka*-type limestone using trace elements present in the two stone types. The weight % concentration of elements iron, silicon and aluminum in limestone were determined against calibration curves prepared by mixing known quantities of goethite (FeOOH), alumina (Al_2O_3) and silica (SiO_2) and calcium carbonate ($CaCO_3$). Calibration standards were prepared by cold-pressing.

Results and Achievements

The laser parameters flash-lamp q-switch delay, measured in microseconds, the laser voltage, measured in volts, and the laser-focusing lens-to-sample distance, measured in centimeters, were optimized to produce elemental emission lines with the best balance between signal-to-background ratio and repeatability.

Elemental analyses of the pottery shards and limestone samples were successfully carried out. Quantitative analysis of the limestone samples for the presence of Fe, Si and Al was shown to be possible, however a larger sample size is required in order to draw clear conclusions about elemental composition of the limestone types.

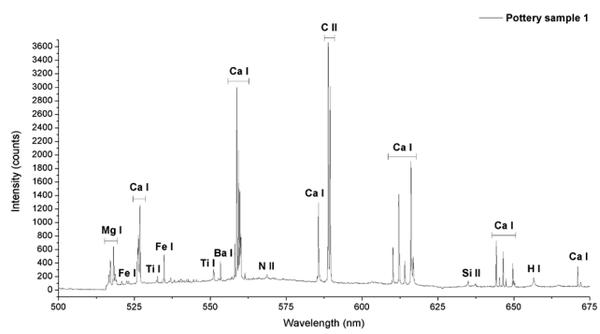


Figure 1: Emission spectrum for pottery sample across the wavelength range 500nm - 675nm. Emission lines are labeled for the respective element

References

[1] J. P. Singh, S. N. Thakur, Laser-Induced Breakdown Spectroscopy, Elsevier Science, First Edition, The Netherlands, Amsterdam, 2007.

[2] R. Lasheras, J. Anzano, C. Bello-Galvez, M. Escudero, J. Caceres, “Quantitative Analysis of Roman Archaeological Ceramics by Laser-Induced Breakdown Spectroscopy”, Analytical Letters, vol.50, issue 8, 2017.

[3] J. Cassar, A. J. Vella, “Methodology to identify badly weathering limestone using geochemistry: case study on the lower globigerina limestone of the Maltese Islands”, University of Malta, Malta, 2003.

A Study On The Effect Of Heat Treatment Parameters On The Microstructure of X46Cr13

Student: Eleanor Saliba / Supervisor: Prof. Ing. Maurice Grech

Introduction

This study was carried out in collaboration with Methode Electronics. The variance in performance of a product manufactured from martensitic stainless steel type X46Cr13 was suspected to stem from variations in heat treatment parameters occurring within large furnaces. A study was thus carried out to establish the effect of heat treatment parameters on microstructure.

Project Objectives

The aim of the study was to determine the effect of heat treatment parameters, namely austenitising temperature, austenitising time and tempering temperature on the microstructure of X46Cr13.

Project Methodologies

To study the effect of these parameters samples were austenitised for 45 minutes at: 980°C, 1010°C, 1040°C and 1055°C. Other samples were austenitised at 1040°C for: 15, 45, 75 and 105 minutes to analyse the effect of time. The effect of tempering temperature was determined using samples tempered for 2 X 2hours at 350°C/375°C, 500°C/525°C and 600°C/625°C.

Microstructural analysis involved the identification and quantification of matrix and carbide phases. The density, size and composition of carbides was also determined. Analysis was carried out using various characterization techniques including optical microscopy, SEM, XRD, EDS and hardness testing.

Results and Achievements

The 'as supplied' material had a ferritic matrix with a fine distribution of $M_{23}C_6$ carbides. Increasing the austenitising temperature resulted in the decrease of $M_{23}C_6$ carbides and the increase in dissolution of carbon resulting in a marginal increase in hardness. Analysis using XRD and SEM showed that increasing the carbon dissolution led to the formation of higher quantities of M_3C carbides after tempering (Figure 1 and Figure 2). This in fact agrees with literature [1]. The effect of increasing the austenitising time was similar but the impact was found to be less pronounced.

Increasing the tempering temperature led to carbide transformations from M_3C to M_7C_3 to $M_{23}C_6$. Sensitisation started at 500°C/525°C and developed at 600°C/625°C. No change in hardness occurred when tempering at 500°C/525°C but hardness decreased sharply at 600°C/625°C as the martensite matrix transformed to ferrite.

It was concluded that austenitising temperature and time have limited impact on microstructure whilst that of tempering temperature was more pronounced. It is unlikely however that fluctuations in temperatures found within furnaces would be within the range needed for a major change in microstructure to occur.

References

[1] A. Hede and B. Aronsson, "Microstructure and Creep Properties of some 12% Chromium Martensitic Stainless Steels," Journal of the Iron and Steel Institute, pp. 1241-1251, 1969.

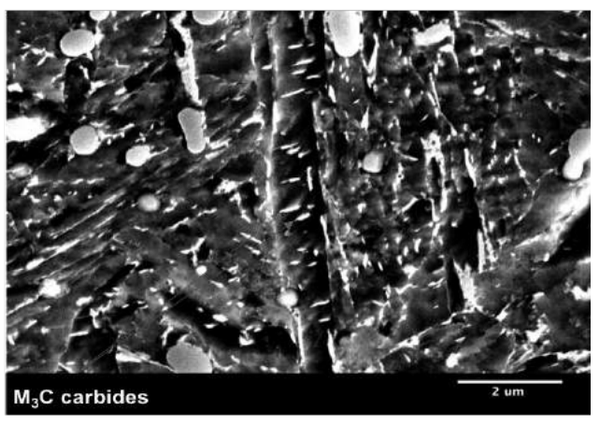


Figure 1: 980°C-45 mins/365°C-2hr/285°C-2hr

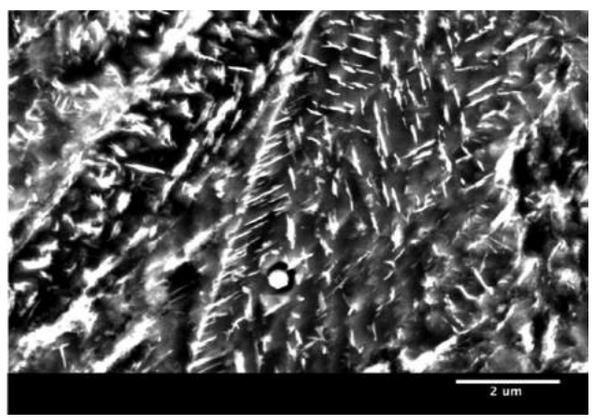


Figure 2: 1040°C-45mins/365°C-2hr/385°C-2hr

Synthesis of Porous Fe-based Implants for Bone Regeneration

Student: Christabelle Tonna / Supervisor: Dr Ing. Joseph Buhagiar / Co-Supervisor: Dr Ing. Bertram Mallia

Introduction

Scaffolds, are porous bone support structures that mimic cancellous bone. Such structures are used in the field of regenerative medicine in order to exploit the bone's ability to heal itself following bone loss through trauma, infection or disease [1]. Biodegradable metals have recently gained particular focus for use as bone scaffolds due to their potential to offer adequate properties while degrading gradually to prevent a second surgical intervention for implant removal. Iron in particular, has the potential to offer improved mechanical properties compared to polymeric and ceramic scaffolds. Moreover, alloying iron with various elements gives endless possibilities for optimized performance and controllable degradation rates *in-vivo.*

Project Objectives

The aim of the project was to develop a suitable powder metallurgy process for the production of Fe foams and to characterise the products for subsequent process optimisation. Indications of the effect of the porous structure on the extent of degradation, were to be obtained through suitable corrosion tests.

Project Methodologies

Macro-porous structures were fabricated using the replication technique. This involved the creation of a slurry using Fe powder, polyvinyl alcohol binder and ethanol. Reticulated polyurethane foams with 45 pores per inch, were dipped into the slurry and squeezed to remove excess slurry from the pores. The structures were then subjected to foam and binder burn-off at 300˚C or 500˚C followed by sintering treatments in a muffle furnace, vacuum furnace or tube furnace at temperatures between 1000˚C and 1200˚C. The resultant metallic foams were analysed using Scanning Electron Microscopy (SEM). Phase analysis was carried out using X-Ray Diffraction (XRD). Moreover, static immersion tests were conducted in 80 ml of Hanks' Balanced Salt Solution (HBSS) with additions of 0.1 wt. % Bovine Serum Albumin (BSA). The samples were incubated in 5.5vol% CO_2 at 37˚C for 2 and 7 days prior to weight-loss measurements.

Results and Achievements

The proposed polyurethane foam replication technique proved to be a suitable technique for the preparation of open-celled Fe foams. Sintering treatments carried out in the muffle furnace under N_2 flow resulted in fully oxidised foams while sintering in the vacuum furnace was more successful, with only minor oxidation of Fe foams taking place. The most promising treatment included sintering at 1200˚C for 4 hours under N_2-$5H_2$ flow in a tube furnace, following a heating rate of 180˚C/hr. The resultant foam, shown in Figure 1, exhibited a highly interconnected porous network with relatively good interparticle bonding and few defects, including hollow struts. XRD analysis confirmed a fully Fe structure with no detectable oxidation, due to the use of the inert and slightly reducing protective gas mixture. Static immersion tests revealed that the foam structures could exhibit a much higher degradation rate than denser structures, as the foam lost approximately 11 times more weight than pressed Fe disks tested in previous work [2], in half the immersion time.

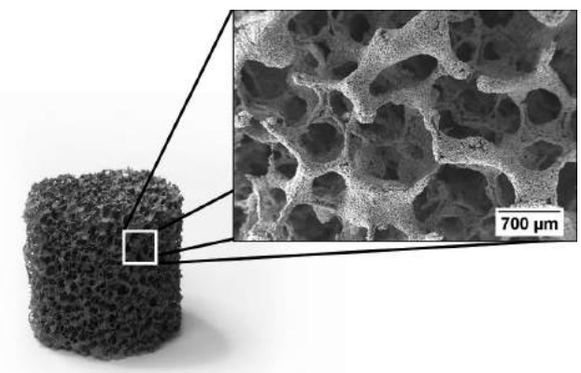


Figure 1: Macro-sized image and magnified SE-SEM image of an Fe foam fabricated using the replication method

References

[1] L. Polo-Corrales, M. Latorre-Esteves, and J. E. Ramirez-Vick, "Scaffold design for bone regeneration," *Journal of nanoscience and nanotechnology*, vol. 14, no. 1, pp. 15–56, Jan. 2014

[2] M. A. Bonello, "Fe based powder metallurgy alloys: Tailoring biodegradability through silver addition," Master's thesis, University of Malta, 2018

Joining Aluminium and Copper in Air Conditioning and Refrigeration Equipment

Student: Nicholas Zarb / Supervisor: Prof. Ing. Maurice Grech

Introduction

Seifert Systems Ltd. Is a leading HVAC company. One of their key processes requires brazing a copper piece to copper piping. Seifert would like to use aluminum piping instead. By doing so the brazing parameters and alloy need to change since copper and aluminium are not intrinsically compatible and will lead to problematic joints if not brazed properly.

Project Objectives

To investigate commercial brazing alloys and parameters used to join Copper and Aluminium. Investigate the effects of joint design and perform quality and metallurgical tests on these joints. Study The feasibility of non-brazed joints.

Project Methodologies

Pipes were brazed [Figure 1] in multiple configurations, three overlap lengths and two joint orientations being Copper in Aluminium and Aluminium in Copper, using three different composition alloys. Two Aluminium – Zinc (22% and 2% Aluminium) and one Aluminium – Silicon (88% Aluminium) brazing alloys were used. Mechanically fit pipes were obtained ready-made. Brazed samples were pressure tested up to 30 Bar and passed samples tensile tested. Pressure tested, pass and failed samples were sectioned, mounted, ground, polished and etched to measure filler alloy penetration and observe and analyse the microstructure for different composition alloys while the mechanically fit samples were only tensile tested.

Figure 1: Pipe joints right after brazing

Results and Achievements

The joint orientation and overlap were found to be a critical factor in determining final joint quality. In fact, joints having the copper in aluminium orientation with a 6.5mm overlap were the best performers overall, with aluminium in copper joints having lesser results. Penetration tests showed that penetration determined the way samples failed in tensile testing, be it from the aluminium, which is good, or from the joint, which is unwanted. Brittle intermetallic compounds such as $CuAl_2$ [1] were found at the copper-filler interface of joints produced with high aluminium content alloys [Figure 2], with the bulk microstructure showing eutectic compositions. It was also found that joints are subject to different cooling rates due to orientation, and these different cooling rates leads to the formation of different intermetallic compounds and microstructures [2]. Mechanical joints gave excellent results compared to brazed joints in tensile testing.

References

[1] J. Feng and S. Xue, “Growth behaviors of intermetallic compound layers in Cu/Al joints brazed with Zn-22Al and Zn-22Al-0.05Ce filler metals,” *Mater. Des.*, vol. 51, pp. 907–915, 2013.

[2] J. Feng, X. Songbai, and D. Wei, “Reliability studies of Cu/Al joints brazed with Zn-Al-Ce filler metals,” *Mater. Des.*, vol. 42, pp. 156–163, 2012.

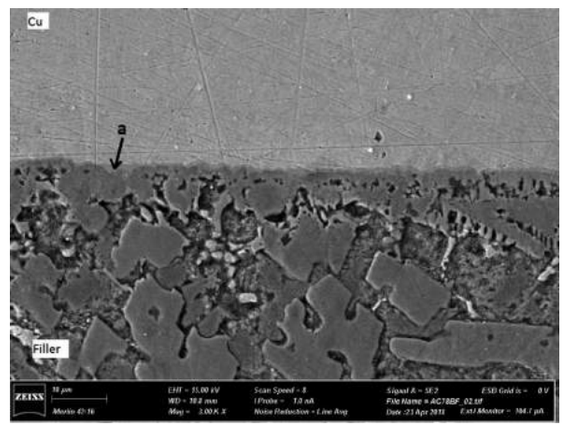


Figure 2: Micrograph shows copper, copper-filler interface layer (a) and filler alloy