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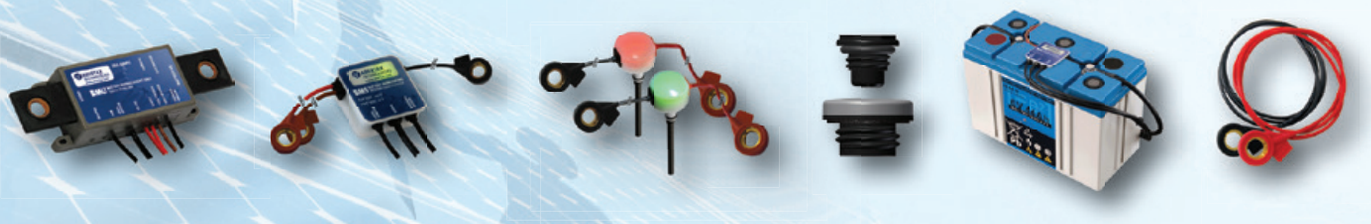

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Projects supervised by members of the Department of Mechanical Engineering

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

FOREWORD

The academic year at the Faculty of Engineering of the University of Malta culminates with the Annual Engineering Projects Exhibition. Now, in its 27th edition, the exhibition has morphed from an event primarily intended to demonstrate the work of undergraduate students to one that showcases the Faculty's capabilities, during which, the Faculty opens its doors to formally welcome its industrial partners, alumni, current and prospective students and their parents. Additionally, the exhibition welcomes the general public and young students who show an interest in science and engineering and gives the opportunity for such individuals to understand better the role of the Engineer within society. During this exhibition, prospective students are given the opportunity to listen in first hand to the experiences of our students, as well as discuss with both academic and technical staff the meaning of the engineering profession, the potentials for job opportunities in the local, European and international markets, as well as opportunities for eventual further studies.

The Bachelor course in Engineering (B.Eng.(Hons)) within the Faculty is a four-year course and is essentially composed of two areas of study, Electrical and Electronics or Mechanical Engineering. The courses are intensely formative and have been designed to ensure the development of students into Engineers. Apart from delivering subject content and ensuring a solid foundation in the fundamental engineering concepts, the courses strive to discipline students in their problem solving skills, giving particular attention to detail, time management and teamwork. The Faculty has over fifty years of experience in the above, with the majority of the Maltese graduates in engineering being alumni of this Faculty.

The Faculty also offers a number of courses at postgraduate level, both on full-time and part-time basis. To date, the majority of these programmes have been primarily by Research. The Faculty, however, has recognised the need and demand for additional taught postgraduate courses, especially evening courses. For this reason, a number of new courses are being developed, to be launched in the very near future.

In the first pages of this booklet you will find an overview of the Faculty's activities, the courses offered and the projects we are leading or participating in. Although not intended to be an exhaustive portfolio of activities, it demonstrates the diversity of the projects and capabilities of the Faculty's staff and researchers. Other sections in the booklet are intended to provide a guide to undergraduate projects held over this past academic year. I invite you to visit the exhibition to talk with our students and experience live demonstrations of the work accomplished over the past few months. I trust you will find this interesting.

Andrew Sammut

Dean, Faculty of Engineering

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The B.Eng.(Hons) in Mechanical Engineering provides students with the necessary knowledge and skills to professionally design, develop, manufacture and maintain mechanical engineering systems. The wide and dynamic range of applications makes this an exciting and rewarding Degree Course which includes high level academic tuition and hands-on practice. The course spans over four years, structured as follows:

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Fundamental mechanical engineering topics are covered together with essential ancillary subjects. Modules cover the following fields: mechanics; structural engineering; thermo-fluids; materials science and engineering; manufacturing and industrial engineering; drawing and computer-aided design; electrical, electronics and control technology; computational techniques; mathematics; and other introductory engineering subjects.

Year 3 and 4

Students are given the opportunity to apply the skills learnt so far in an engineering design project in their third year. At this stage, whilst retaining fundamental core subjects, students can choose from amongst three streams: Applied Mechanics and Thermo-Fluids, Applied Materials in Engineering and Industrial and Manufacturing Engineering. Students will in their final year present a thesis based on a defined engineering project that they are expected to plan, manage and realise.

Undergraduate Entry Requirements

General Entry Requirements together with two Advanced Level passes at Grade C or better in Pure Mathematics and Physics.

Admission to this course is also open to applicants in possession of:

- two passes at Grade 5 or better in the Secondary Education Certificate Examination in English Language and Maltese; and
- either the MCAST-BTEC Higher National Diploma in an area deemed to be relevant to the course by the Board of the Faculty of Engineering, or the MCAST Diploma in Industrial Electronics.

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Master of Science in Electrical Engineering by Research

The M.Sc. in Electrical Engineering by research is a 3-semester degree which is based on a research project implemented by the student. It includes a 5 ECTS unit on research methods, and a research seminar in which students reading for this degree present their work to the Faculty. 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, Power Systems, Power Electronics, 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, Industrial Electronics and Precision Instrumention.

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Master of Science in Integrated Product Development

The M.Sc. in Integrated Product Development is a taught Masters offered by the Faculty of Engineering and has been running for over 10 years. 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 runs over a 3-year period over a part-time basis and is intended to fortify skills and 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.

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.

Postgraduate 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 subjects as approved by the Faculty Board; or

(c) a Bachelor's degree with a Third Class (Honours) in Engineering or in a relevant area of study and are in possession of other qualifications, including relevant experience following their 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.

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
- Water Tank for Electric Outboard Testing

Electrical Machines Laboratory

- Domestic scaled Combined Heat and Power Plant
- DC and AC motor and generator test beds
- Single phase transformer rigs
- Vertical Axis Wind Turbine

Electrical Mobility Laboratory

- Electric Car with Lithium Ion Battery Technology
- Electric Boat
- 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

Robotics and Industrial Automation Laboratory (RIAL)

Mitsubishi RV-6SL 6-DOF revolute industrial 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)

Six Mitsubishi FX1N-24 PLCs

Two flat belt conveyors (one with variable speed)

Machine vision lighting (ring light, strobe)

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

Department of Mechanical Engineering

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.

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

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

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 components (e.g. 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

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
- Low temperature foundry furnace
- Martempering/ Austempering salt bath
- 3-axis CNC machining station
- Universal forced convection drying oven

Mechanical Testing Equipment

- Tension/ Charpy Impact tester with digital acquisition
- 5 ton multipurpose mechanical testing centre
- 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

- NC precision cut off saw
- Thermosetting cold mounting station
- Hot mounting phenol sintering station
- Manual/ automatic sample polishing stations
- Automatic electro polishing 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

Electron Probe Micro-analysis (EPMA) within SEM including:

Energy dispersive spectroscope (EDS)

Wavelength dispersive spectroscope (WDS)

Electron Backscatter Diffraction (EBSD)

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 diffraction analysis with:

θ/ 2θ Goniometer

Parallel beam/ Bragg Brentano optics

Variable temperature (cryo to 450 °C) reaction chamber

High temperature reaction chamber

Thin film attachment

Capillary attachment

4 axis + tilting attachment

SDD/ scintillating detectors

X-ray powder diffraction with:

θ/ 2θ Goniometer

Cu/ Mo primary X-ray source

Bragg Brentano optics

Variable high temperature reaction chamber

Nano Indentation equipment with:

Wet cell attachment

Resistive high temperature reaction chamber

Peltier cooled low temperature attachment

Dynamic testing attachment

Piezo nanopositioner

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 December 2015, Mr Luke Masini and Mr Emanuel Scicluna 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 Farsons Foundation. Mr Luke Masini and Mr Emanuel Scicluna 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. Dean Dr Ing. Andrew Sammut together with Mr Kenneth Pullicino presented these awards.

From left: Mr Luke Masini, Dr Ing. Andrew Sammut, Mr Kenneth Pullicino, Mr Emanuel Scicluna

ONGOING EXTERNALLY FUNDED RESEARCH PROJECTS

Biodegradable Iron Scaffolds

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.

Funding Bodies: **Reach High Funds and Endeavour Funds (ESF)**

Project Fund: **€ 205,000**

UoM Share value: **NA (Voucher Programme)**

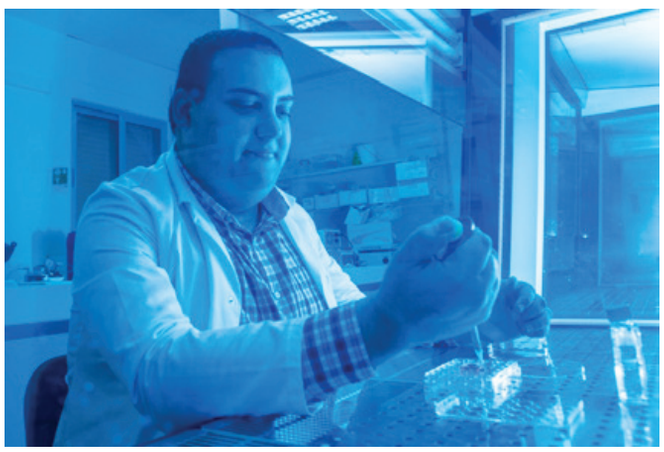
Principal Investigator: **Dr Ing. Joseph Buhagiar (Mentor)**

Co-Investigators: **Dr Malcolm Caligari Conti, Ms Gianella Xerri, Dr Pierre Schembri Wismayer MD, Dr Daniel Vella, Prof. Emmanuel Sinagra and Prof. Diego Mantovani.**

Consortium: **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; and Laboratory for Biomaterials and Bioengineering, Laval University, Canada.**

Project Start Date: **October 2015**

Project Duration: **Ongoing**



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

Low Temperature Carburising for Prosthetic Implant Applications

The Lancet in 2013 reported very high failure rates of orthopaedic metal-on-metal implants. Thus by increasing the hardness by low temperature carburising of medical grade Co-Cr-Mo alloys and Austenitic Stainless Steel, and therefore making them more comparable to the hardness of ceramics, one hopes to achieve an articulating surface which is both biocompatible and corrosion-wear resistance. The aim of this project is to alleviate the problem encountered by metal-on-metal implants by combining different surface modification and coating solutions.

Funding Bodies: **Think10k (Faculty of Engineering); Internal Research Funds (University of Malta); MGSS (Malta); ESF (Malta) and Bodycote Specialist Technologies GmbH (Germany)**

Project Fund: **€ 73,200**

UoM Share value: **€ 27,000**

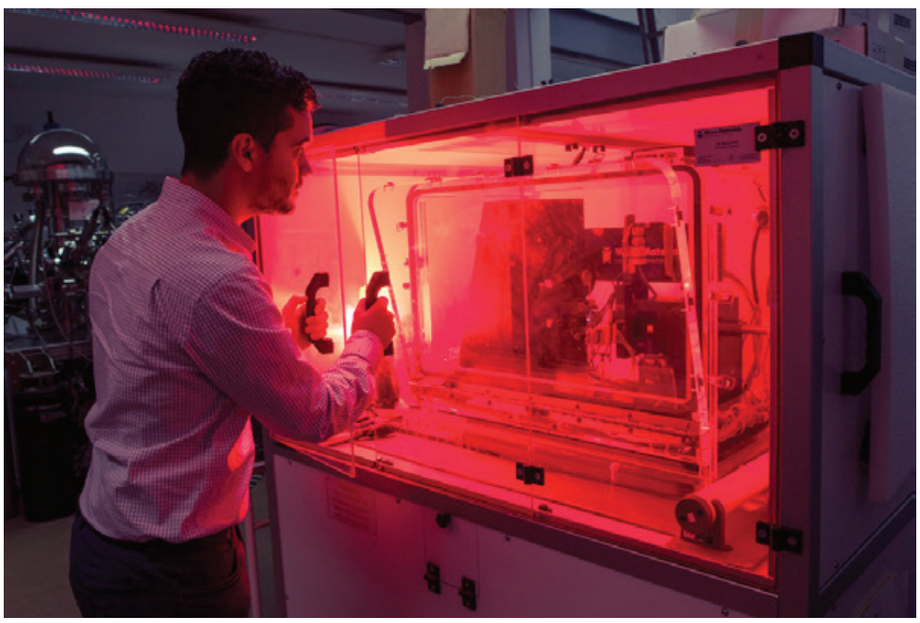
Principal Investigator: **Dr Ing. Joseph Buhagiar**

Co-Investigators: **Dr Malcolm Caligari Conti, Ms Josianne Cassar, Mr Shaun Maniscalco, Mr Nicholas Brincat, Mr Antonino Mazzonello, Dr Pierre Schembri Wismayer MD, Dr Ing. Bertram Mallia, Prof. Emmanuel Sinagra, Dr Ing. Pierre Vella and Dr Ing. Andreas Karl.**

Consortium: **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; Department of Industrial and Manufacturing Engineering, UoM; and Bodycote Specialist Technologies GmbH, Germany.**

Project Start Date: **October 2010**

Project Duration: **Ongoing**



Shaun Maniscalco: Master of Science researcher working on nano-indentation and tribology

Reciprocating Sliding Tribocorrosion Testing of Surface Modified Biomaterials

The project involved the design and building of a custom made reciprocating sliding tribocorrosion tester. This new facility in conjunction with physical vapour deposition and state-of-the-art materials characterisation facilities were used to develop novel surface treatments for the tribocorrosion protection of biomedical grade 316LVM stainless steel. This research led towards the better understanding of tribocorrosion mechanisms exhibited by surface engineered materials through a combination of physical vapour deposition and diffusion treatment processes. Work is being currently undertaken to minimise tribocorrosion damage at the interface(s) between the treated layer(s) and original substrate surface.

Funding Bodies: **Internal Research Grant; Master it! Scholarship and Endeavour Scholarship (Bench Fees)**

Project Fund: **€ 42,000**

UoM Share value: € 17,000

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

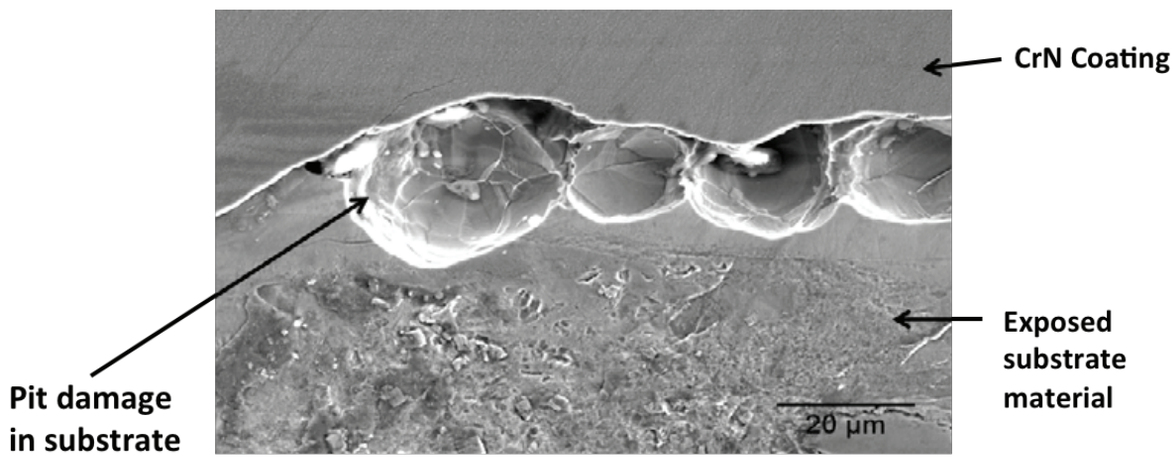
Co-Investigators: **Dr Ing. Joseph Buhagiar, Dr Ing. Glenn Cassar, Mr Antonino Mazzonello, Ms Sarah Farrugia, Mr Nicholas Brincat; Ms Josianne Farrugia; Mr Shaun Maniscalco; Ms Brenda Farrugia, Mr Imer Cardona, Ms Miryea Borg, Mr Christian Micallef, Ms Christine Borg, Ms Julia Sammut, Mr Karl Laspina, Mr Mark Bonello, Ms Raisa Chetcuti and Mr Aaron Farrugia**

Surface treatments in Kind: **Boride Services Ltd. (UK), Bodycote Hardiff GmbH (DE), Wallwork Heat Treatment Ltd. (UK), Hauzer Techno Coating BV, (NL)**

Consortium: **Department of Metallurgy and Materials Engineering, Faculty of Engineering, UoM; Boride Services Limited, UK; National Centre for Advanced Tribology (nCats), University of Southampton, UK; School of Engineering and Sustainable Development, De Montfort University, UK; and Bodycote Hardiff, DE.**

Project Start Date: **January 2010**

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

Numerical Modelling and Experimental Testing of Novel Materials for CERN LHC Collimators

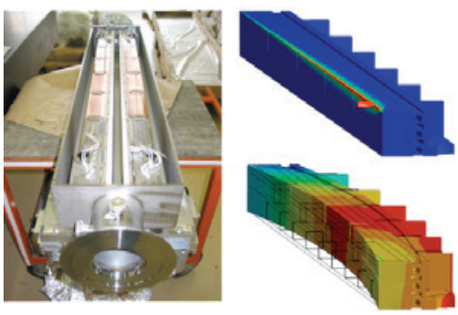
The European Organisation for Nuclear Research (CERN) caters for innovative advances in particle physics utilising the world's largest particle accelerator, the Large Hadron Collider (LHC). Currently operating at colliding beam energy levels of 7TeV, the LHC is being upgraded to operate at twice such energy levels. LHC performance greatly depends on proper functionality of protective beam collimation system, essential for safe beam cleaning and machine protection. Analysis of accidental beam collision scenarios must be carried out to assist in design aimed to withstand damaging beam deviations. HRMT-23 constitutes a dedicated beam experiment campaign at the CERN High Radiation to Materials (HiRadMat) facility, aiming to test collimation jaw materials. Experimental results are used to validate and calibrate numerical Finite Element (FE) models developed to investigate the thermo-mechanical response of critical components.

Thermal and structural characterisation campaigns were embarked on for jaw inserts involving Copper Diamond, Molybdenum Carbide-Graphite and Carbon-Carbon composites. Dedicated experiments have been successfully carried out. Results indicated agreement between FE models and experimental data, with interesting observations noted via beam-induced shockwave behavioural analysis at a preliminary level, partially validating the developed FE models. This is an important stepping stone for future larger scale collimation development.

Funding Body: **EUCARD2, FP7, EU Commission**
Project Fund: approx. **€ 23,400,000**
UoM Workshare Value: **€ 62,080,000**
Ph.D. student, completed in 2015: **Dr Marija Cauchi**
M.Sc. student: **Ms Miryea Borg**
Ph.D. and M.Sc. by Research supervision: **Dr Ing. Pierluigi Mollicone , Dr Ing. Nicholas Sammut**

Consortium/Partners: **CERN (coordinator), Department of Mechanical Engineering, Faculty of Engineering and Department of Microelectronics & Nanoelectronics, Faculty of ICT, University of Malta et al; full list: http://eucard2.web.cern.ch/about/partners**

Project Start Date: **1 May 2013**
Project Duration: **4 years**



Collimator and thermo-mechanical simulations

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: **Department 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

Thermo-Mechanical Studies of Novel MEMS Micro-grippers for Manufacturing in Malta

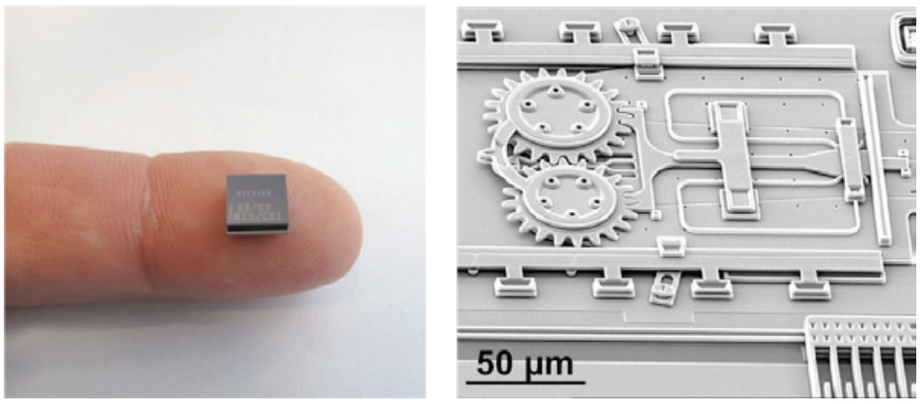
Micro-electro-mechanical systems (MEMS) are advanced commercial microchips currently available on the market. These devices are composed of a microelectronic part and a miniaturised mechanical sensor/actuator that are embedded on the same semiconductor microchip using the techniques of microfabrication. The advances of MEMS have been instrumental in the development of new devices and applications, as well as in the creation of new fields of research and development. A typical example includes the MEMS gyroscope devices that STMicroelectronics has developed for smartphones to enable screen tilting. MEMS devices can be categorised as micro-sensors and micro-actuators. Research on micro-actuators is a relatively new field for Malta.

This research project will deliver an advanced thermo-mechanical study of micro-actuators as micro-grippers, which will be the basis to develop novel applications such as handling of living cells on the micro-scale level, and micro-assembly, micromanipulation and micro-manufacturing of micromechanical parts.

Funding Body: **Reach High Post doc scholarship, Malta**
Project Fund: **€ 200,000**
UoM Workshare Value: **€ 60,000**
Principal Investigator: **Dr Marija 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 devices: the entire MEMS chip with around 100 functioning elements on a fingertip [HP Press Kit: HP Sensing Solutions, http://www.hp.com/, Accessed: 08.06.15] (left), and an optical image of a complex MEMS clutch mechanism (adapted from [Sandia National Laboratories, http://www.sandia.gov/mstc/mems/, Accessed: 09.06.15]) (right)

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**

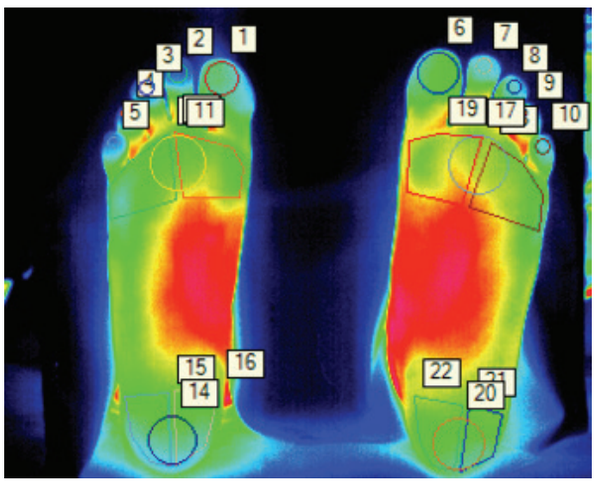
Principal Investigator: **Dr Owen Falzon**

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

Consortium/Partners: **Centre for Biomedical Cybernetics (UoM), Department of Systems and Control Engineering, Faculty of Engineering (UoM), Department of Podiatry, Faculty of Health Sciences (UoM), Department of Surgery, Mater Dei Hospital**

Project Start Date: **1st June 2014**

Project Duration: **32 months**



Foot temperature monitoring using thermography

WALNUT Brain-controlled Music Player

We are developing a brain-controlled music player application for a mobile device. This application is not controlled through conventional push buttons, instead the user wears the WALNUT headband and simply focuses at the icon of interest on the music player app to select and control music. The music player icon elicit particular brain patterns that are detected and translated into commands by the system. A prototype of this brain-computer interface had been developed and tested on numerous subjects using a laptop and clinical research grade brain signal acquisition system. The goal of this project is to translate this prototype to a portable system on a mobile device and using a low cost wireless brain signal acquisition headband.

Funding Body: **The Centre for Entrepreneurship and Business Incubation (CEBI) at the University of Malta and the Ministry for the Economy, Industry and Small Business (MEIB) through the TAKEOFF Proof of Concept Fund 2014.**

Project Fund: **€ 7,500**

Principal Investigator: **Dr Owen Falzon**

Co-Investigators: **Ms Rosanne Zerafa, Dr Tracey Camilleri, Prof. Kenneth P. Camilleri**

Consortium/Partners: **Centre for Biomedical Cybernetics and Department of Systems and Control Engineering at the University of Malta**

Project Start Date: **June 2014**

Project Duration: **1 year**

Developing a portable system of the WALNUT Brain-controlled Music Player

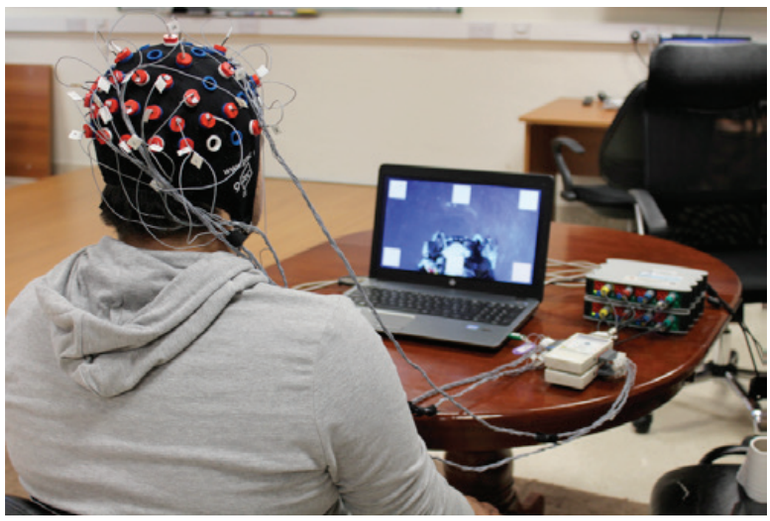
R&I-2015-032-V - Brain Controlled Application

This project is concerned with brain controlled applications based on steady-state visually evoked potentials (SSVEPs) and seeks to look into specific aspects that will improve the response time, accuracy and usability of SSVEP-based brain-computer interfaces. At this stage of the award, the project is concerned with the first three stages of the Voucher Programme, namely, the IP Check, Market Research and Product Development Costing, and the Economic Impact and Risk Profile.

Funding Body: **FUSION Programme 2015, MCST**
Project Fund: **€ NA (Voucher Programme)**
Principal Investigator: **Prof. Kenneth P. Camilleri**
Co-Investigators: **Dr Tracey Camilleri, Dr Owen Falzon, Ms Rosanne Zerafa**

Consortium/Partners: **Centre for Biomedical Cybernetics and Department of Systems and Control Engineering at the University of Malta**

Project Start Date: **August 2015**
Project Duration: **9 months**



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

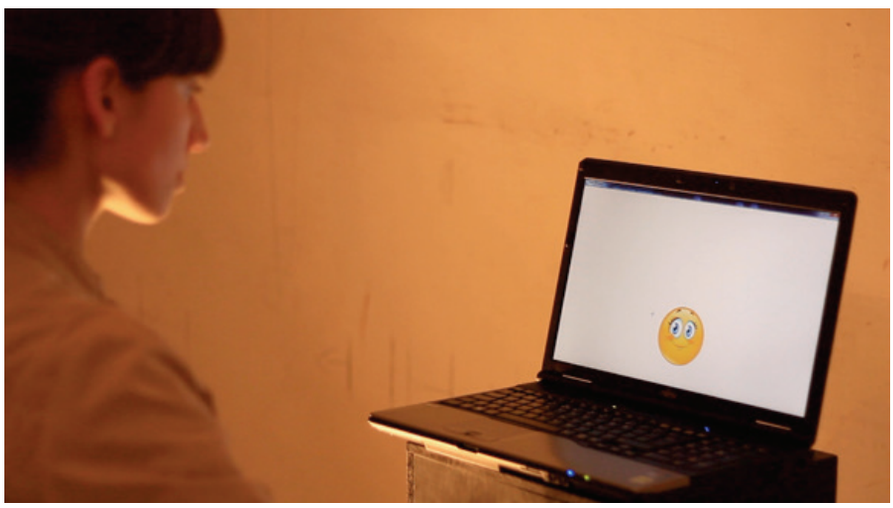
R&I-2016-010-V Eye-Gaze Tracking in the Wild

This project aims to provide an alternative communication channel for persons with physical disabilities via the eye movements alone using a hardware setup that comprises a notebook computer with an integrated webcam. In this regard, the project seeks to address various challenges associated with eyegaze tracking under uncontrolled daily life conditions, including handling of head and non-rigid face movement, and reduction or elimination of user calibration for more natural user interaction. At this stage of the award, the project is concerned with the first three stages of the Voucher Programme, namely, the IP Check, Market Research and Product Development Costing, and the Economic Impact and Risk Profile.

Funding Body: **FUSION Programme 2016, MCST**
Project Fund: **€ NA (Voucher Programme)**
Principal Investigator: **Prof. Kenneth P. Camilleri**
Co-Investigators: **Ing. Stefania Cristina**

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

Project Start Date: **March 2016**
Project Duration: **9 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

R&I-2015-042-V - 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.

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 Commercialisation**

Project Fund: **€ NA (Voucher Programme)**

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

Consortium/Partners: **Department of Manufacturing and Industrial Engineering at the University of Malta**

Project Start Date: **August 2015**

Project Duration: **9 months**

ELCORR - Investigating and Mitigating the Electrochemical Corrosion Mechanisms Active in Industrial Diesel Engines in use at Malta Freeport

The Maintenance and Repairs section at the Malta Freeport have reported repeated corrosion related failures with their industrial Diesel engines. This study aims to identify the corrosion mechanism and provide a means to mitigate the problem.

Preliminary analysis exposed severe corrosion of aluminum components close to areas in direct contact with brass and/or cast iron components. Pitting corrosion was also visible further away from galvanic couples. Galvanic corrosion tests were conducted to assess the problem at hand. The conditions of the engine were replicated through the use of a closed loop system as a corrosion cell. Gravimetric measurements were carried out on both coupled and uncoupled coupons to study the variation in corrosion rate due to galvanic coupling. Microscopy of the coupons before and after exposure was also used to study the corrosion morphology. X-ray diffraction (XRD) and EDS were used to analyse the composition of corrosion products formed.

Tests results indicate that the coolant, which is currently used, provided limited pitting and galvanic corrosion protection and the resulting damage is extensive. A new coolant formulation was investigated resulting in an overall marked reduction in corrosion rates. This was achieved by precipitating an adherent film of passive corrosion products on the cast iron surfaces effectively neutralizing the galvanic cell and reducing the anodic polarization on the aluminum parts.

The corrosion products formed on the cast iron tested using the alternative coolant proved to be extremely tenacious and of a glassy consistency. Coupling of dissimilar metals without any insulation is to be avoided however the corrosion inhibitor solutions can severely reduce the adverse effect of the galvanic coupling.

Funding Body: **RTDI project sponsored by Malta Freeport**
Principal Investigator: **Dr Ing. Stephen Abela**
Co-Investigators: **Mr Clayton Farrugia**

Consortium/Partners: **University of Malta and Malta Freeport**

Project Start Date: **May 2012**
Project Duration: **3 Years**

ONGOING MASTERS AND Ph.D. RESEARCH PROJECTS

Ongoing Masters and Ph.D. Research Projects

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

M.Sc. by Research

Robert Zammit	Development and Performance Analysis of Prosthesis Fabricated Using Additive Manufacturing
Nathan Gatt	Sustainable Management of Industrial Processes at a Waste Treatment Facility: a simulation based approach

Ph.D.

Emmanuel Francalanza	Digital Factory Planning for a Range of Products: A Changeability Knowledge-Based Integrated Product Development Approach
Lawrence Farrugia	Emotional 'Design for X' : A 'Human and Life-Phase Meetings' Consequence Knowledge Approach

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

M.Sc. by Research

Claire Bezzina Cornish	Investigation of stress and fatigue response of shot peened austempered ductile iron
James Camilleri	Study of Fluorine-Containing Surface Active Agents Epilame Deposited on Ti-6Al-4V-Alloy
Gianella Xerri	Towards Bio-Resorbable Metallic Implants
Antonino Mazzonello	Tribocorrosion Response of PVD treated Biomedical Stainless Steel

Ph.D.

Malcolm Caligari Conti	Engineering an antigen sensitive, rapid osteoregenerative, bioresorbable scaffold

Anthea Agius Anastasi	Molecular Simulation and Atomic Probe Studies of Graphene
Diana Cini	Protective coating for Heritage Metals

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M.Sc. by Research

Shawn Azzopardi	Emulator test Rig for the Electrical Loading of Wave Energy Converters
Noel Darmanin	Investigation of the Effects of Integrating Large Scale Photovoltaic Systems on the Maltese Power Network
Joseph Azzopardi	Analysis of Malta Freeport Terminals Power Network
Samuel Bonanno	Analysis and Simulation of power quality, distributed generation and interconnection of an island's power system to an infinite busbar system
Diane Cassar	An Electric Catamaran designed with a Smart Charging System
Andrea Brincat	Design and Development of Electronic Control Systems for Hybrid PV+CHP Residential Grid Connected Set-ups with Battery back-up.
Jurgen Bonavia	Energy Management Optimisation of Grid-Connected PV Systems with Storage to Increase Self-Consumption

Ph.D.

Daniel Zammit	Control of Microgrids for Distributed Generation including Energy Storage
Kris Scicluna	Sensorless Control in Steer-by-Wire Application

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M.Sc. by Research

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Axisa Reedemeer	Structural Evaluation and Testing of a Multiple- Bladed Wind Turbine Prototype
Bonnici Colin	Engineering Analysis of the S.S. Ohio
Borg Miryea	Numerical Modelling and Experimental Testing of Novel Materials for LHC Collimators
Farrugia Nicholas	Loading Conditions on Human Sternum
Xuereb Emilio	Analysis of the Diesel Particulate Filter Blockage and Regeneration

M.Phil.

Almehat Mahmoud Ayad	Development of Benefits accruing from Implementation of Environmental Management Systems in Wasteserve Malta Ltd
Catania Justin	Design and Simulation of Implants for Regenerative Medicine Applications

Ph.D.

Buhagiar Daniel	Design and Analysis of a Hydraulic Power Transmission System for an Offshore Wind and Thermocline Energy Production (OWTEP) System
El Gammi Moutaz	Modelling the Self-Induced Cycle-to-Cycle Variations in the Aerodynamics Blade Loads of a Yawned Wind Turbines under the Controlled Operating Conditions
Ellul Brian	Assessing the Structural Performance of Fibre Re-inforced Composites through Numerical Modelling Techniques
Omar Salem Osta	A Solar Powered Absorption Air conditioning System

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

M.Sc. by Research

Joseph Agius	Data Monitoring and Control of Solar Cooling Systems for Industrial Wine Production
Jean Gauci	Automated Analysis of Thermal Images for Peripheral Vascular Disease Monitoring

Ph.D.

Luana Chetcuti Zammit	Autonomic Control for Road Network Management using Geocomputational Tools
Stefania Cristina	Eye-Gaze Tracking by Video-based Joint Head and Eye Pose Estimation
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

FINAL YEAR
ENGINEERING PROJECTS
ELECTRICAL STREAM

An Industrial Cable Insulation Tester

Student: André Aquilina / Supervisor: Dr Ing. Marc Anthony Azzopardi

Introduction

The chemical industry monitors the acidity and alkalinity of aqueous solutions by sending weak signals over very high performance low noise coaxial cables, sometimes over distances of 20m in noisy environments. To ensure optimum reliability before being sent out the final user, these must be tested individually.

Project Objectives

The aim of this project was to design and build a cable test rig capable of measuring the extremely high resistance of the polyethylene insulation such that the cable leakage may be tested. Furthermore, the test should be capable of also testing continuity.

Project Methodologies

In order to measure these extremely large resistance, different methods were explored and finally the constant-voltage method was chosen. This method uses a precision test voltage applied across the insulation resistance and measures the resulting current. Due to this extremely high resistance, the current being measured is on the order of picoamps (10^{-12}A). These low level measurements require careful selection of components and materials as well as special low leakage techniques in the PCB design [1]. For the continuity test, a loop back test was used such that the signal is sent along the inner conductor of the cable and returns on the outer conductor.

Results and Achievements

After designing and manufacturing of the PCB was completed, functional testing was performed and user interface to be used by the manufacturing operator.

These consisted of a central microcontroller which controlled the testing procedure and interface, a liquid crystal display (LCD, light emitting diodes (LEDs) and an electrically erasable programmable read only memory (EEPROM) to store manufacturing data figures.

Error characterization was performed on both the current measurement channels and the voltage references. The low current measurement channels were tested using a Keithley 2400 SourceMeter® as a constant current source. This instrument was used to supply currents between 60pA and 990pA. The system showed almost ideal linearity with R^2 values of 0.99999 for each channel and any gain and offset error was calibrated out in firmware.

References

[1] Keithley Instruments, "Low Level Measurements Handbook 7th Edition," 2015, pp. 39-113.

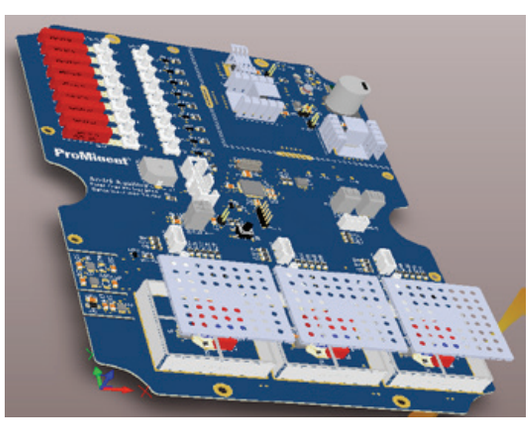

Figure 2: PCB Design 3D Model

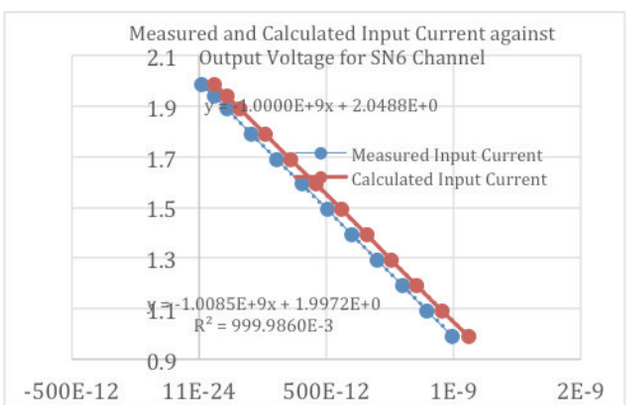

Figure 1: Channel Output Error Characterisation

The Study to find the best shape possible for the Quenching function of a Super-Regenerative Receiver

Student: Charles Aquilina / Supervisor: Prof. Carmel Pulé

Introduction

This project is concerned with the study to find the best shape possible for the quenching function of a super-regenerative receiver. Sensitivity in receivers for long range is obtained by designing a receiver with a system which is on the verge of continuous oscillation. As this is never possible, a system which quenches itself to operate such that it oscillates and then stops is to be aimed at. The function in which the oscillator is started and stopped is of great interest and decides the performance of the circuit to have selectivity and sensitivity.

Project Objectives

The aim of the project is to design and construct a working proposition, study different forms of quenching and measure the parameters which are to be aimed at, so as to produce a good receiving system with the maximum longest range possible through the sensitivity of the circuit.

Project Methodologies

The most important aspects of the project include; the task involving the design and construction of a tuned oscillator with a feedback loop transmitting a carrier signal, an LC tuned circuit which picks up the carrier signal being transmitted, and the construction of a super-regenerative receiver. The frequency of operation (carrier signal) used in this project is 192kHz. Loop antennas of similar dimensions are used for both the tuned oscillator and the LC tuned circuit in the transmitter and receiver side respectively. For the super-regenerative receiver, another loop antenna is built having a smaller size when compared to the previous two loop antennas mentioned. This is because if it is the same size, there exists the possibility that it will radiate and be picked up by the first loop in the amplifier, with the result that it will oscillate. Obviously this is something which needs to be avoided. Although this loop antenna has a smaller coil, it is tuned to the other loop antennas, and positioned at right angle to the loop antenna of the common emitter-amplifier so that they will not couple energy from one to the other.

Testing is carried out along the period of constructing and implementation of the various important aspects of the project, as well as after the functionality of the whole project.

Results and Achievements

The results achieved through this project were a wide range between the transmitter and receiver of over 2m, with the latter having a receiving system consisting of good sensitivity. Although the output from the receiver was not optimal and a better quenching could have been obtained, the quenching waveform attained was fine.

Possible suggestions for future work include; studying in more detail the contribution of each component in the super-regenerative circuit, studying the values of the feedback capacitor and the value of the choke when the super-regenerative circuit is used at very low frequencies, studying the circuit when using whip antennas feeding different points in the circuit, studying the circuit for different temperature working as far as the effect on regeneration, doing more experiments to study about the selectivity of the circuit used.

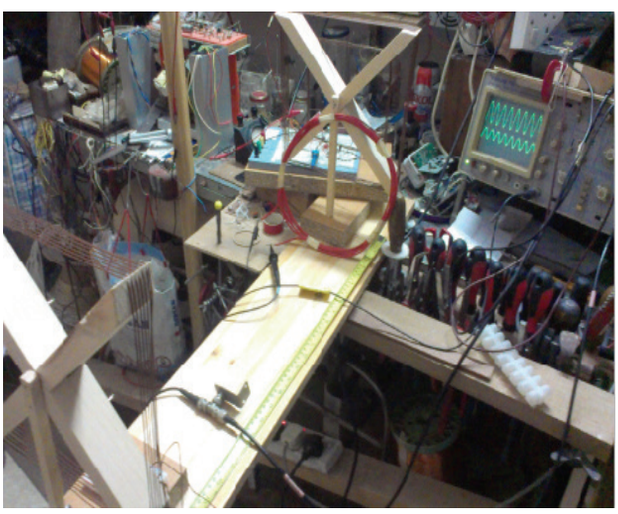

Figure 1: Testing Range

Data Fusion for Accurate UAV Navigation

Student: Marvic Attard / Supervisor: Dr Ing. Brian Zammit

Introduction

Data fusion has become quite popular in navigation systems. The data fusion algorithm takes measurements from a number of inaccurate sensors, and output the best estimate of the parameter being monitored. Since multiple sensors are being used, should one malfunction, the algorithm uses the remaining active sensors to still provide a valid output.

Project Objectives

The main objectives of this project were to identify the most popular fusion techniques, implement them and finally conduct a number of experiments to identify the features and limitations of each one.

Project Methodologies

There exists many ways one can perform data fusion. In this project, the fusion techniques used were based on the Kalman Filter which was developed by R.E. Kalman [1].

The easiest way to perform fusion is by having a sensor as a measurement update for each parameter being monitoring, called the Group Sensor method. Another way is to connect a number of Kalman Filters sequentially, which is called the Sequential Filter. Also one can have multiple Kalman Filters and combining the outputs of each one by using the Track-to-Track method. Instead of having multiple Kalman Filters, the Inverse Covariance or the Data Compression methods can be used to modify a single Kalman Filter to accept multiple measurement updates [2]. Finally the Indirect Kalman Filter can also be utilized as a fusion method.

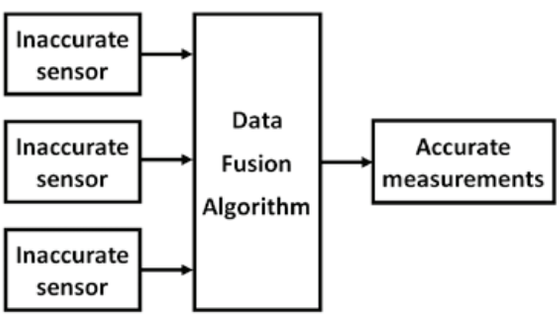

Figure 1: Principle of Data Fusion

Results and Achievements

Two different types of experiments were conducted: at different constant angular velocities, and finally the fusion methods were given a specific angular velocity profile, in order to analyze the response at different changes in angular velocity.

The experiments reached the conclusion that the Inverse Covariance and Data Compression filters outperformed the others in terms of uncertainty reduction at the output. If all the sensors are giving measurement updates of the same state variable, then the Data Compression is superior in terms of algorithm simplicity when compared to the Inverse Covariance filter. However, if this is not the case, then the Data Compression filter cannot be used. On the other hand, the Indirect Kalman filter showed the most promising results in terms of removing sensor offsets

All the experiments were carried out inside a laboratory using ideal conditions to minimize unaccounted errors that can be introduced by external factors such as varying weather conditions and stability of the vehicle.

References

[1] Faragher R., 'Understanding the basis of the Kalman Filter' IEEE Signal Processing Magazine, 2015, pp.128-132

[2] Durrant H., 'Multi Sensor Data Fusion' University of Sydney, Sydney, 2001,

Figure 2: MQ-9 Reaper, UAV used for border patrol

A Novel Design of an Unmanned Hybrid Vehicle

Student: Carl Bugeja / Supervisor: Dr Ing. Marc Anthony Azzopardi

Introduction

Aerial and terrestrial mobile robots are considered to be an invaluable tool in search and rescue missions. Several studies are currently being conducted to improve the performance of these vehicles, however this has proven to be difficult to accomplish when operating within different environments. Unmanned Hybrid Vehicles (UHVs) resolve this problem by merging the two robotic architectures into one unit.

Project Objectives

This project aims to investigate the practicality of a novel UHV configuration. Its electrical and mechanical aspects were designed from scratch, to develop a preliminary prototype of the proposed system. Due to the vast control algorithms associated with the adopted design, the main goal was limited to the development of the hardware.

Project Methodologies

After studying different robotic architectures, a symmetrical quadruped robot was integrated with a ducted coaxial-rotor as shown in Figure 1. Both the aerial and terrestrial locomotion can be controlled by actuating the robot's kinematic chain. This concept was intended to enhance the vehicle's mobility, compactness, efficiency and safety.

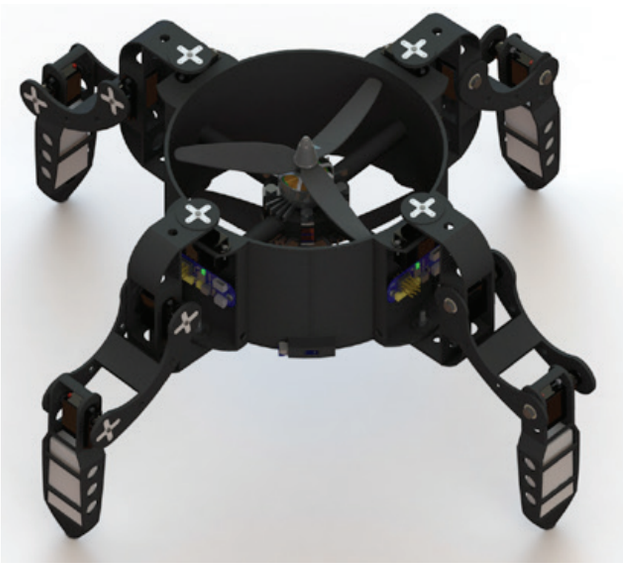

Figure 1: Hybrid Robot's 3D CAD Model

The mechanical dimensions of the robot were restrained to reduce the manufacturing costs of the prototype. These restrictions effected the maximum attainable thrust of the rotor, which also limited the allowable mass of the platform.

In order to meet these constraints, the electronic circuitry was required to be miniaturized to fit in small and confined spaces. As seen from Figure 2, the designed embedded system was implemented on eight Printed Circuit Boards (PCBs) in order to utilise space more efficiently. Each component was selected according to its weight, cost and functionality. Thus, bulky and heavy components were avoided and packages with small footprints were preferred.

The robot's mechanical structure was 3D printed using a polyamide nylon fabric, to compromise between strength and weight.

Results and Achievements

The developed prototype was successfully held within the defined limitations. The total mass of the robot reached 442.8g, while the maximum thrust generated by each propeller was 400g. Based on these results, the twin rotor could theoretically generate enough thrust for take-off.

These results were supplemented by testing the sensors, actuators and signal conditioning circuitry of the designed embedded system. The kinematic model was also derived, simulated and then tested in practice to exhibit the capabilities of the robot.

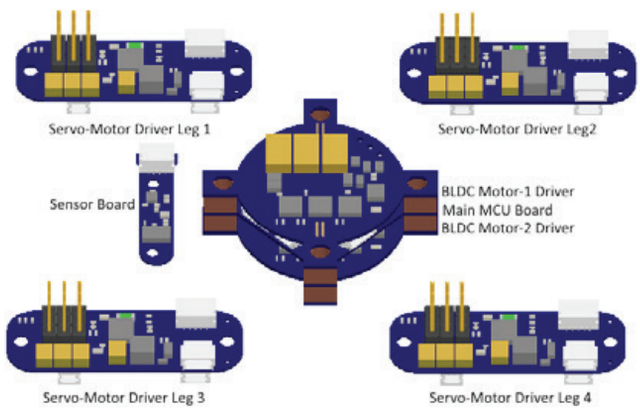

Figure 2: Illustration of the Designed PCBs

Electromyographic Signal Capture

Student: Mark Cutajar / Supervisor: Dr Ing. Marc Anthony Azzopardi

Introduction

Electromyography (EMG) signals are widely used in the clinical and research fields to analyses neuromuscular activation [1]. However, bio-signal acquisition suffers greatly from skin condition and ambient noise. Usually these signals are read using amplifiers which are considerable in size, consume a substantial amount of power, and cost hundreds of euros. Consequently, few EMG capturing devices are available on the consumer market and those present have considerable limitations.

Project Objectives

The objectives of this project included a feasibility analysis of whether a high density micro-module 16-channel device can be constructed cheaply, the design of new, novel acquisition systems which are independent of ambient noise and skin condition and the modification of a notch filter to use only fixed point variables for EMG filtering.

Project Methodologies

Testing feasibility involved comparing different components and noting the best options. Tested devices included operational amplifiers, transceivers, microcontrollers, instrumentation amplifiers and digital-to-analog converters. Numerous analog acquisition systems were designed. Each iteration aimed to improve on the previous one.

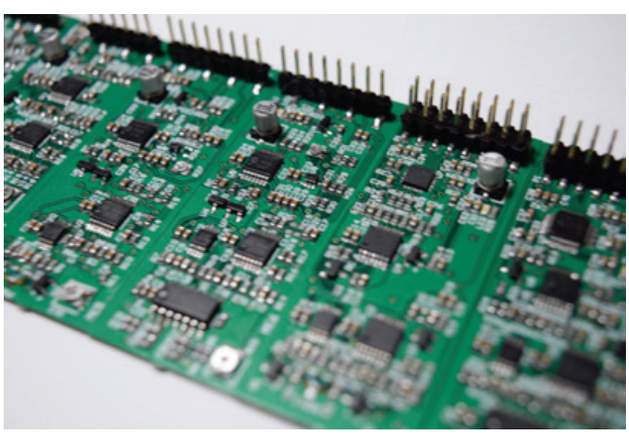

Figure 1: Designed Prototypes

Improvements involved a front-end transimpedance amplifier circuit, controlling the body potential through a weak link resistance, driving the body to a fixed potential or introducing the body in a negative feedback loop using a modified right-leg drive. A skin model was also developed to test the designed systems. Viability of having digital filters on a microcontroller was also analysed, together with some modifications for floating point calculations.

Results and Achievements

A number of literature statements were confirmed through testing and comparison. The transimpedance amplifier with a weak resistive link to the body was best performing of the designed systems being the most resilient to changes in skin condition. On the other hand, the systems with the negative feedback loop were ineffective when a high skin-to-electrode impedance was present and all systems suffered reduction of common-mode attenuation due to large impedances. When tested on skin using on-board electrodes, these suffered from high noise content due to incorrectly designed electrodes. It is suggested that in future systems these would be made of stainless steel as it has relatively good corrosion and conductivity properties. Furthermore, IIR notch filters can be modified to avoid floating point numbers. Finally, it was confirmed that a multi-acquisition system is feasible

References

[1] Criswell E., 'Introduction to Surface Electromyography' Jones and Bartlett Publishers, London, 1998.

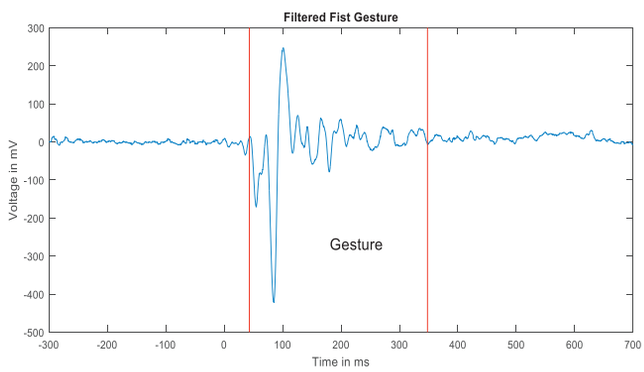

Figure 2: EMG filtered signal when making a fist

Development and Testing of a Race Car Data Network

Student: André Farrugia / Supervisor: Dr Ing. Brian Zammit

Introduction

The University of Malta Racing Association build and race their own racing car in an international competition called Formula SAE. The complex analogue network linking the several sensors to the engine control unit where it would be converted into a digital signal and logged was identified as a major area that needed to be sorted out.

Project Objectives

The aim of this project was to develop a data network for UOMR race car. The network had to be tested and a noise susceptibility analysis had to be conducted in order to recommend solutions in order to improve the networks' immunity.

Project Methodologies

The Controller Area Network (CAN) was chosen as the automotive network to be implemented on the racing car.[1] In order to implement CAN, basic nodes were designed instead of using development boards.

Basic nodes created contained the bare minimum in order to create a functioning CAN. The nodes created had an integrated CAN controller and microcontroller on one chip, apart the microcontroller chip, a CAN transceiver was present. The last component on the node was a voltage regulator in order to step down the voltage from the battery voltage of the car which was 12V, to 5V the voltage on which the circuitry was designed to work

When designing the PCB, a number of different terminations were added apart from the basic 120 ohm resistor in order to improve the network susceptibility to noise. The components added were of different nature, components that protected the transceiver whilst other had the role to attenuate the noise present on the bus.[2]

Another integral component of any network is the physical medium upon which data is transmitted. In this case two media were tested one was a 120 ohm characteristic impedance twisted pair and shielded cable whilst the other was a CAT5e Ethernet cable

Results and Achievements

After the construction of the different nodes, the nodes were tested for their compliancy with the ISO 11898:2 (High-Speed CAN Protocol) using a CAN Bus Analyser. A network of a few interconnected nodes was built when to check that the network worked according to specification.

The next step was to test the network's susceptibility to noise. This was tested by injecting a continuous wave (CW) sine wave signal onto the bus and an analysis of the performance was recorded and discussed for several terminations and the cables mentioned earlier. The tests were repeated using an amplitude modulated signal.

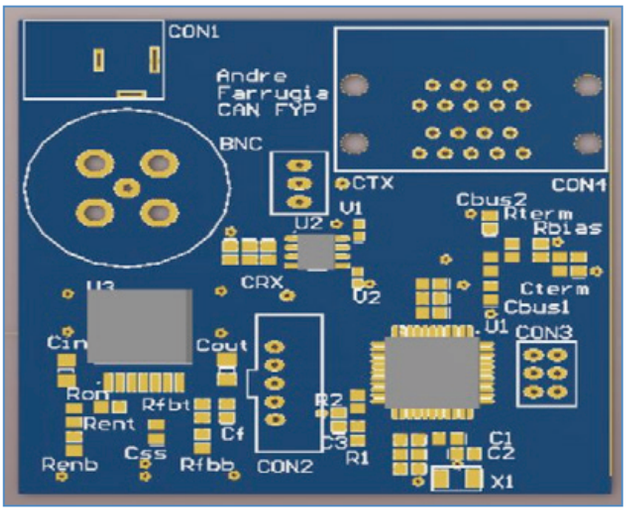

Figure 1: CAN node designed

References

[1] D. Paret, *Multiplexed Networks for Embedded Systems*. Chichester, UK: John Wiley & Sons, Ltd, 2007.

[2] ON Semiconductor, "AND8169 / D EMI / ESD Protection Solutions for the CAN Bus," no. AND8169/D, pp. 1–15, 2007.

Towards a Localisation System for Multiple Micro-Aerial Vehicles

Student: Karl Galea / Supervisor: Dr Ing. Marc Anthony Azzopardi

Introduction

Most autonomous systems require some form of localisation technique through which a robotic agent can be localized in relation to a given datum. Aerial vehicles, in particular, require a localisation system to be properly controlled. Most current localisation techniques, however, are either expensive, restricted to a single user, or ideal only for specific scenarios.

Project Objectives

This dissertation aims to initiate the design of a localisation system that may be used by multiple aerial robotic agents which are miniature in size. It is therefore required that the system is lightweight and offers a high update rate.

Project Methodologies

Through localisation research the medium of choice was selected to be ultrasound. Codification of ultrasonic signals was attempted to modulate Pseudo-Noise Sequences on ultrasonic waves. This provides a multiple access technique similar to Code Division Multiple Access (CDMA) as used in telecommunications.
Piezo-ceramic transducers were utilised to send the ultrasonic signals. On the receiving end, CMUT ultrasonic receivers were used since these offer a better ultrasonic response.
The proposed design, as seen in Figure 1, consisted of the micro-aerial vehicles transmitting the ultrasonic signal whilst also determining their own heading
Five stations receive the ultrasonic transmission and locate the vehicle through Difference in Time of Arrival (DTOA) calculations, [1]. The electronic circuitry to be added on the Micro-Aerial Vehicle was designed to weigh less than four grams, and have dimensions of 2.5cm x 3cm, as shown in Figure 2, to the right.
An FPGA is used to perform correlations to decode the ultrasonic signals and detect each specific ultrasonic transmission. This requires 5120 multiplications to be computed within a margin of 1.9µs. The FPGA is interfaced with a computer for further processing and control. Figure 2 shows the designed Printed Circuit Boards.

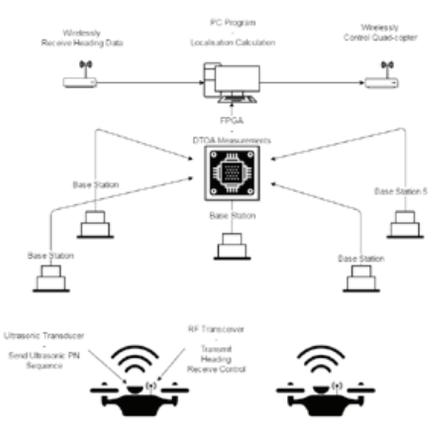

Figure 1: Proposed Design

Results and Achievements

The dissertation served as a means to initiate the proposed design. From the dissertation, the required software was designed to locate the aerial vehicle in three-dimensional space. Furthermore, the controls of a Ready-to-Fly cheap quad-copter were reverse-engineered to obtain control over the quad-copter through computer software. In addition, the required circuitry that is, the FPGA architecture, ultrasonic acquisition board, and micro quad-copter hardware were developed. It was also concluded that such a localisation system is a viable option for micro-aerial vehicles.

References

[1] Mahajan A., Walworth M., '3D position sensing using the differences in the time-of-flights from a wave source to various receivers' IEEE Transactions on Robotics and Automation, 2001, Vol. 17, No.1, pp.91-94

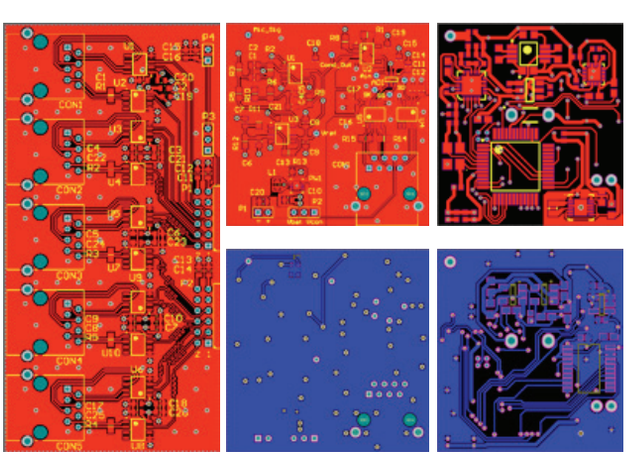

Figure 2: Designed PCBs

Direct Digital Synthesis Function Generator using an FPGA

Student: Andrea Mifsud / Supervisor: Dr Ing. Marc Anthony Azzopardi

Introduction

Applications such as communications and strain/margin testing require generation of arbitrary waveforms with fast frequency switching and low frequency resolution. Direct Digital Synthesis (DDS) is a method that can be used to generate such arbitrary waveforms.

Project Objectives

The project is aimed at achieving the following objectives, listed in order of importance:

- The design and implementation of a high bandwidth (>300MHz) Arbitrary Function Generator (AFG). This would enable the end product to be used in applications requiring frequency synthesis of up to the Very High Frequency (VHF) RF band.
- The investigation, design, and implementation of high frequency design techniques. These would permit the electronic product to reach the above-mentioned goal.
- The development of a user friendly Graphical User Interface (GUI) which could be used to control the AFG.

Project Methodologies

The methodology adopted consisted of the following steps:

- A review of DDS architectures was undertaken and an internet search for commercially available devices was made.
- The required subsystem (FPGA processing board used in a previous project), and devices to implement a high bandwidth AFG were selected.
- A PCB was designed containing a 2.7Gsps, 11-bit Digital to Analogue Converter (DAC) to be able to convert the digital signal into an analogue current.
- PCB manufacturing was outsourced, however SMT components were assembled in-house as shown in Figure 1.
- All required firmware, including the GUI, were developed, loaded and tested on the FPGA and microcontroller.
- The system was then tested gradually with final performance testing giving the performance characteristics of the AFG. Figure 2 illustrates the results obtained for Narrowband Spurious Free Dynamic Range (NSFDR) at different output frequencies.

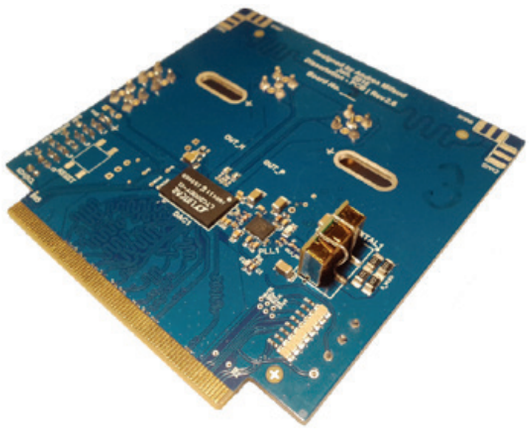

Figure 1: Printed Circuit Board of the DAC system

Results and Achievements

The developed AFG has a 600MHz bandwidth with a frequency resolution of 19.2μHz and a 500ps rise time. Furthermore, a maximum NSFDR of -56dBc and a maximum Wideband Spurious Free Dynamic Range (WSFDR) of -31.5dBc were obtained at 675MHz. In addition, a maximum phase noise of -77.5dBc/Hz at a frequency offset of 20kHz from 675MHz was achieved.

Finally, the control of the AFG was provided through the development of a GUI. The features available through this interface included the changing of the frequency and the waveform of the output signal.

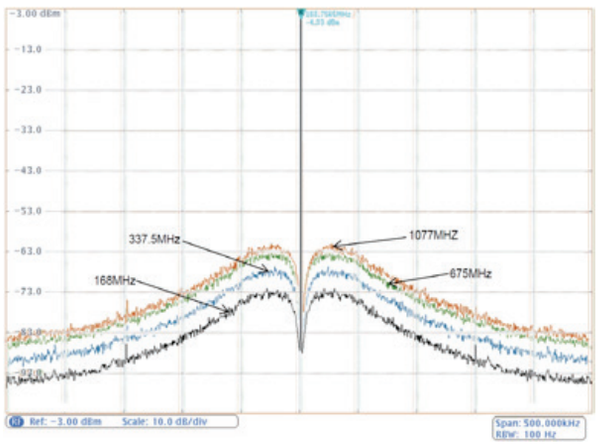

Figure 2: NSFDR of implemented AFG

An Autopilot System for a Quadrotor

Student: Malcolm Schembri / Supervisor: Prof. D. Zammit Mangion / Co-Supervisor: Dr K. Chircop

Introduction

In the last two decades, Unmanned Arial Vehicles have received increasing attention due to the large number of applications they can be applied to and due to technological advancements. They are being used for indoor and outdoor applications where the desired task is repetitive, dangerous or inaccessible by a human.

Project Objectives

The objectives to reach the goal of this work are to create a faithful simulation model, design suitable PID controllers to control attitude and height of the quadrotor, build a custom quadrotor platform and implement the control algorithms to manage flight.

Project Methodologies

The thesis starts by introducing the basic movements that can be performed by a symmetrical quadrotor during flight followed by a derivation of a mathematical model using the Newton-Euler formalism. Based on this dynamic model, a set of equations were used to simulate the system on Simulink.

To achieve a faithful simulation, the parameters of the quadrotor and its components were obtained either experimentally or mathematically as accurate as possible.

A platform was developed using the necessary components and electronics. A microprocessor unit hosts the necessary algorithms to control the system and is used to interface the sensors and components. An IMU is used to obtain orientation data and range finders are used to obtain height data. The design makes use of a remote controller to allow the user to operate the quadrotor. A Bluetooth module is used to transmit important real time data to a third party monitoring software hosted on a Windows platform.

The quadrotor was tested and tuned on stands which allowed it to rotate on the axis that is being tested. This provides the opportunity to fine tune each controller that was based on the mathematical model to achieve the best performance. Finally it was tested safely in indoor flights.

Results and Achievements

During flight, the roll and pitch errors are always less than ±3.5°, while those of the yaw are always less than ±4°/s when the other controllers are also enabled. The height had peak errors of ±10cm of the reference height and thus still needs more fine tuning to achieve a satisfactory result and to conclude if a PID algorithm is suitable.

The quadrotor is capable of hovering autonomously and is capable of performing a maximum tilt of ±20° on the roll and pitch axes. Maneuvers done by the operator allows the quadrotor to change its position in 3D space.

Figure 1: Quadrotor Platform

Identification of PCB and Solder-Joint Defects through X-ray Inspection

Student: David Scicluna / Supervisor: Dr Ing. Andrew Sammut

Introduction

The process of soldering components onto a printed circuit board is necessary to any electronic system built today. However soldering process is not perfect and defects may arise in the solder joints such as voiding seen in Figure 1. A void is a pocket of air trapped inside the solder joint. With the help of an X-ray machine these voids can be inspected without destroying the joint.

Project Objectives

The objectives of this project were to analyse the soldering process and find possible causes for the voiding. Some of these causes were then tested by using a robust test method. The data gathered from the experiment was then analysed to find any relationships.

Project Methodologies

The Electronics Systems Engineering Department Laboratory provided all the equipment used to conduct the testing and analysis. The soldering process starts from the design of the printed circuit board. A good design is necessary so that the equipment is compatible with the board. Next is the dispensing of the solder paste onto the board. The amount of paste was varied during the experiment with respect to the size of the pad of the component. A pad is the part of the component where it should be soldered. The components were then placed on top of their respective pads. Four types of components were used during this dissertation. The board was then soldered using a reflow oven. The peak temperature of the oven was varied from 225 degree Celsius to 255 degree Celsius. The components were then analysed manually using the X-ray machine.

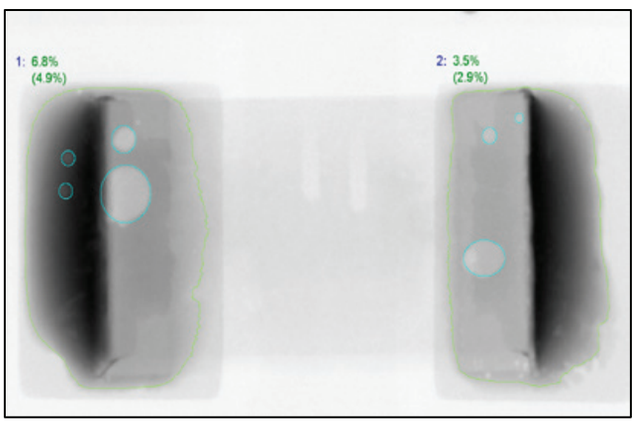

Figure 1: Example of Voiding

Results and Achievements

Four categories of results were extracted by using the X-ray machine: the total void ratio, the maximum void ratio, the void count and the degree of champagne voiding. The results obtained from the analysis suggest that the component size is significant in all four types of voiding analysis. From analysing of the void count it resulted that a lower peak temperature such as 225 degree Celsius gives a more constant void count outcome as seen in Figure 2. It also results in a lower and more constant total void ratio. The analysis of the largest void ratio shows that using smaller components will result in having bigger voids with respect to the pad size. Results obtained from champagne voiding suggest that using less solder paste shows a lesser degree of champagning for smaller components. However for larger components using less solder paste degrades the joint in terms of champagning. Champagning is an unnatural number of voids concentrated either in one area or though out the pad. From these results it can be concluded that manufacturers are able to obtain better results by using less heat, saving both energy and thermal stresses on the components.

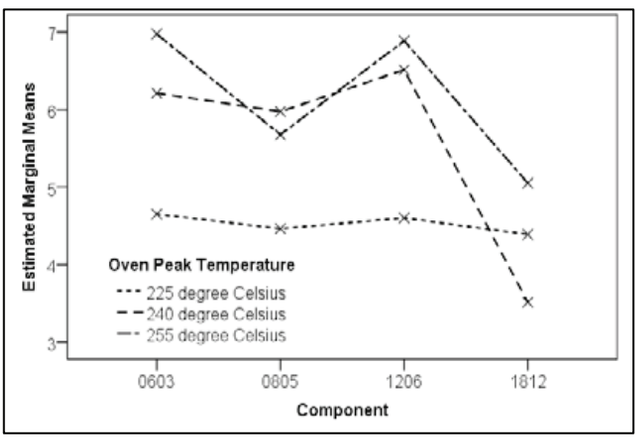

Figure 2: Interaction of oven peak temperature with component size for void count

The Use of Microcontrollers to Change Control of Gozo Ferry Boats from Two Stick to a Single Stick Control System

Student: Brandon Theuma / Supervisor: Prof. Carmel Pulé

Introduction

Ferry boats with frequent short trips are required to be highly maneuverable and so the control stick movement has to be mentally easy and correspond to the required actions of the ferry. Currently, the three modern Gozo Ferry Boats used by Gozo Channel Company Limited employ a two-stick control system in order to control their four azimuth thrusters to obtain the required ship maneuvers. The proposed control system described in this project makes use of a single 4-axis joystick to achieve all the control combinations required to maneuver such ferries.

Project Objectives

The main objective of this project was to deliver a practical working proposition that proves the point that a single control stick is more intuitive than the two-stick system currently available on the three Gozo Ferry Boats. Furthermore, a GPS receiver had to be incorporated in the system to produce the instantaneous latitude and longitude of the model so as to enable the navigation of the ferry from one location to another autonomously.

Project Methodologies

A suitable 4-axis joystick was chosen according to the project's requirements and a one meter watercraft model, which can be controlled remotely through radio control, was constructed. An algorithm was developed such that through the combination of microcontrollers and sensors on the joystick, all the required ship control maneuvers were accomplished. All the control combinations were achieved through the use of two dc propulsion motors and two servo-controlled rudders located at the bow and stern of the model ship. Two Proportional-Integral controllers were simulated and implemented to control the speed of the two DC motors used, including the design of their optical rotary speed encoders.

A Global Positioning System (GPS) receiver was used such that its incoming NMEA messages were parsed. This positional information was fused with the data obtained from other navigational sensors such that the watercraft model could be navigated from one location to another autonomously. A number of waypoints, which can be set by the captain through software, control the trajectory of the model when the autopilot system is engaged.

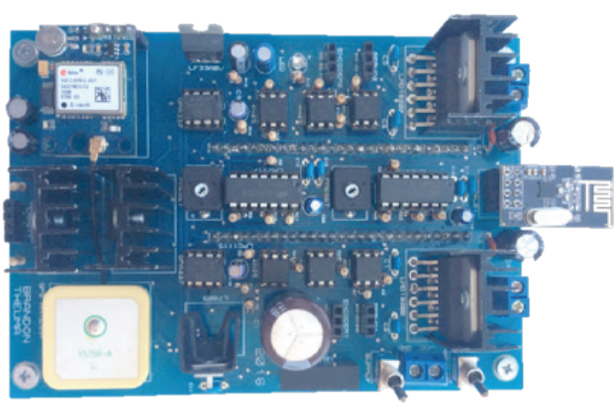

Figure 1: The Printed Circuit Board onboard the Watercraft Model

Results and Achievements

From the movement of a single control stick, the watercraft model is able to move ahead and astern, move sideways, turn on the same spot, and perform a combination of all these possibilities, thus proving that through a single 4-axis joystick, the required maneuvers to effectively steer a ship can be obtained. The waypoint-based autopilot system was also successfully implemented.

Figure 2: The Watercraft Model and its 4-Axis Control Joystick

Collision Avoidance System for RPAS

Student: Melvin Zammit / Supervisor: Dr Ing. Kenneth Chircop

Introduction

Remotely Piloted Aircraft Systems (RPAS) are becoming increasingly popular on the market. Despite of this, there is currently no Collision Avoidance System (CAS) designed specifically for RPAS. To reap the full benefits of RPAS by integrating them in civil airspace, a CAS specifically designed for RPAS must be developed.

Project Objectives

The aim of this project is to develop a CAS that issues a Resolution Advisory (RA) to the pilot if there is a significant probability of collision. Moreover, the algorithm should have the following features:

- The fact that the pilot is in a remote location introduces additional latencies. Thus, it must be taken in consideration that advisories will not be performed instantly by the pilot.
- Issue the minimum number of RAs.
- Require minimal computational power on board the RPAS to achieve a one second refresh rate.

Project Methodologies

A literature review was carried out to determine the best algorithm for this problem. Ultimately, the CAS was based on the Markov Decision Process (MDP) algorithm due to its positive results in previous work [1], [2]. This allowed for most of the computations to be performed off-line, allowing for negligible online computation on board the RPAS. A five dimensional lookup table, referred to as the policy, was used on board the RPAS to determine the optimal RA based on the current system state. A single slice of the policy is shown in Figure 1. Using the MDP, costs were given to the states that represented a collision and upon issuing a RA. The optimal policy was then computed by determining which RAs obtain the minimum cost.

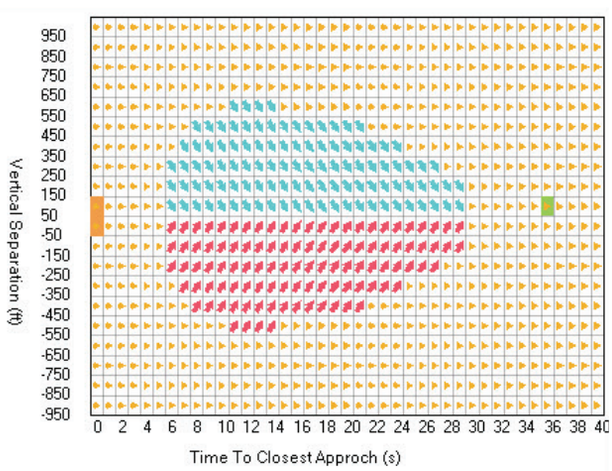

Figure 1: Policy Slice with arrows representing RAs

Results and Achievements

Fast time simulations were used to test and validate the algorithm. With the performance evaluation performed, a RPAS equipped with a MDP-CAS algorithm achieved a Near Mid-Air Collision (NMAC) reduction of 93.86 per cent when compared to a RPAS with no CAS equipment. When compared to the FlightGear TCAS, the MDP-CAS algorithm produced a 51.4 per cent decrease in NMACs. Moreover, the MDP-CAS algorithm achieved a 19.45 per cent decrease in RAs over the FlightGear TCAS. Figure 2 illustrates the result obtained when a head-on encounter was simulated. As one may observe, the MDP-CAS algorithm issued a descend maneuver to the pilot, which avoided a collision.

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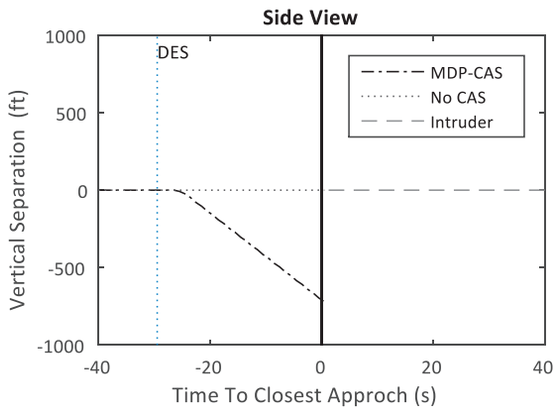

Figure 2: Simulation of a head-on encounter

Investigation of Supercapacitor Energy Storage for Network Integration of Renewable Energy

Student: Nicole Borg / Supervisor: Dr Cedric Caruana / Co-Supervisor: Dr John Licari

Introduction

The fast growth of inexhaustible renewable energy systems such as wind energy has led to increasing research on utilization of the wind energy in the most efficient manner. Due to the intermittent nature of the wind output power, this dissertation focuses on integration of supercapacitor energy storage in order to reduce the fluctuations in the net power fed into the grid.

Project Objectives

The main aim of this project is to model a supercapacitor energy storage system and test its performance in combination with wind energy conversion system.

Project Methodologies

The energy storage system consisting of the supercapacitor and the bidirectional DC-DC converter, was interfaced with the wind energy conversion system to smoothen the fluctuations in the grid. To obtain the main supercapacitor parameters which include the voltage rating, capacitance and the equivalent series resistance, a Maxwell module rated at 75V, 94F and 13mΩ was used as a building block. The voltage rating of the supercapacitor depends on the DC link voltage of the bidirectional DC-DC converter. The capacitance is obtained by calculation of the number of cells in series and in parallel which can also be used to obtain the equivalent series resistance.

The interleaved converter was implemented in simulation were the current ripple was significantly reduced and hence allows the use of lower switching frequencies. The controllers include a cascaded control system consisting of an outer power loop and in inner current loop. The inner current loop controls the current through the supercapacitor such that the switching of the interleaved converter is continuously being controlled. The outer power loop is implemented such that the DC link power is able to track the wind power reference.

The energy storage system was introduced on the dc link of an emulated wind energy conversion system. Different constant power references were then used to examine the performance of the energy storage system in smoothing the net power flow to the grid.

Results and Achievements

A turbulent wind profile was used to test the performance of the energy storage system. The net power at the DC link, which initially showed considerable ripple due to the variability of the wind, was smoothed to an almost constant value as shown in Figure 1. The tests carried out showed that the supercapacitor energy storage system provides a fast response for wind power smoothing. The reference power was increased/decreased to show the resulting effect on the supercapacitor voltage when the system is predominantly discharging/charging. It is shown that the operation under such conditions will limit the operating time of the storage system as the voltage will approach one of the limits. It is therefore suggested to automatically update the power reference to maintain a healthy charge on the capacitor.

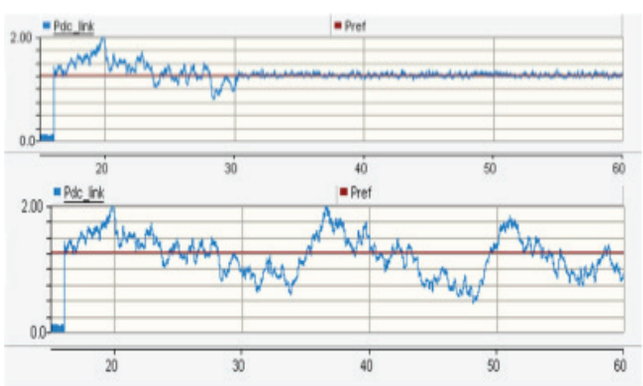

Figure 1: (a) Resulting net power after introduction of smoothing at 30s (b) Original wind power at the DC link

Simulation of Smart Domestic Grid/Stand-alone Energy System

Student: Charlotte Camilleri / Supervisor: Prof. Ing. Cyril Spiteri-Staines / Co-Supervisor: Dr Alexander Micallef

Introduction

Domestic PV systems consists of PV panels and a grid connected inverter which converts the DC power obtained from the PV to AC. The excess power not being consumed by the local loads, is sold to the utility grid. This setup is ideal if attractive PV feed-in tariffs are in place however this might not be the case if the feed-in tariffs are reduced. In such a cases, it would more sense to store the excess energy generated by the PV and use the stored energy during low generation period

Project Objectives

The aims of this project are to: review the possibility for stand-alone system implementation, review and model seasonal domestic load profiles, model storage and the grid connected system and develop a control algorithm for energy usage according to tariff costs and energy type.

Project Methodology

The simulation model of the energy management system includes the PV power profiles, a lead-acid battery model and charger, utility grid and a power router including the Energy Flow Control Algorithm (EFCA). PV power profiles were modeled in Matlab using measured data from a 2.25kW PV system obtained from Sunny Portal [1]. Typical load profiles which were obtained from literature, were then adapted to the Maltese climate and lifestyle. Cyclic load profiles were considered depending on the particular month of the year (e.g. air conditioner is used in the Summer for cooling and Winter for heating). The EFCA depends on the operation time, battery storage availability and type of energy e.g. energy demand from loads or energy generated from PV.

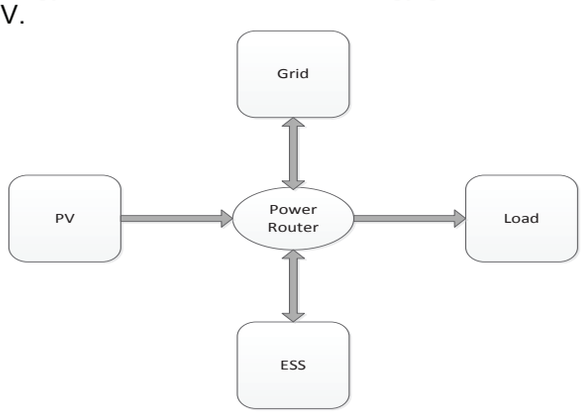

Figure 1: Block diagram of EFCA

Four different tests were conducted using different battery storage size for 6 different months (covering all seasons) in order to establish the energy consumption costs.
Costs were determined using the single tariff (Maltese electricity tariff) and a day/night tariff where the costs of energy consumed during the day is higher than the energy consumed during the night.

Results and Achievements

From the simulations, it was concluded that in order to obtain a stand-alone system, a PV system of approximately three times the size considered in the simulations must be installed. In addition, most of the energy generated from the PV is sold to the grid since it is generated during low consumption period.

It was found that a battery of 750Ah capacity is required to fully supply the load energy demand during the day (using load prioritization). The costs around €1500 [2]. Furthermore, the system using the day/night tariff saves approximately 31% per year. The payback of such a system is around 7 years (excluding PV and inverter capital cost).

References

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[2] [[“12V-150Ah-AGM-VRLA Kanglida battery [Available on https://www.alibaba.com/product-detail/] Accessed on 15/05/16

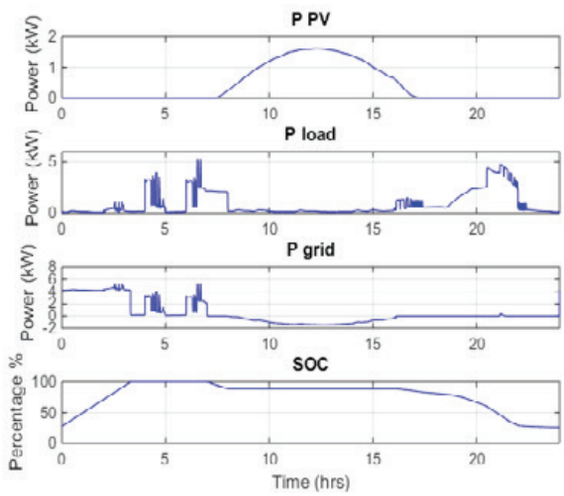

Figure 2: (a) PV power generated, (b) Load power demand, (c) Grid power supplied (d) Battery SOC vs time in hours

Design of an Automatic Synchronisation System for an Electrical Generator to the Grid

Student: Ariana Cassar / Supervisor: Dr Ing. Reiko Raute

Introduction

Power systems are a vital part of today's economy. Their constant use together with the infrastructure cost involved make it impractical to perform tests on real power systems. However, a small generator set rated at a lower power, current and voltage should performance just as larger scale system under certain conditions. It can therefore be used to test the performance of the system under such conditions.

Project Objectives

The aim of this thesis is to design an automatic synchronisation unit for synchronising and connecting a small generator to the grid. Once the generator is connected to the grid, its performance under all power generation conditions will be tested. Hence the unit will also be responsible for the control of real and reactive power supplied to the grid.

Project Methodologies

A generator set composed of a prime mover and a synchronous generator was set up. A DC machine was used as the prime mover and a doubly fed induction machine was operated as a synchronous generator. The system was initially simulated in Matlab to confirm its correct operation with the designed control. Prior to connecting the generator to the grid, the frequency, phase and magnitude of both three-phase sets must be matched. This was obtained by controlling the armature voltage of the DC motor, and the field voltage of the generator. Space vector notation and control theory were used to achieve the required conditions for synchronisation. Ideal synchronism conditions were obtained through measurement of the grid and generator three-phase voltages, and performing space vector calculations using their instantaneous magnitudes.

When the generator and grid three-phase voltages were synchronized in frequency, phase and magnitude, the generator was automatically connected to the grid. Then, by capturing the three-phase currents and performing the same space vector theory calculations, generated power was computed and its control was achieved.

The system was then implemented in hardware. The control unit consisted of a three-phase inverter incorporated with a programmable microcontroller board. The microcontroller was assigned to perform the necessary calculations of the discrete real time control algorithms. It also provides the pulses for the inverter gate drivers, which was used to obtain a variable voltage supply to the field of the generator and the armature of the DC motor.

Results and Achievements

The system was successfully implemented and good results were obtained. Proper synchronisation was achieved, and the generator was successfully controlled to operate in all possible power generation modes. 500W real power were supplied to the grid, whilst 590VAR and 80VAR reactive power were supplied and absorbed to and from the grid system respectively. This was the approximate permissible power which the generator can safely produce. The performance of the system during the tests confirmed that the behavior of the small generator was identical to that of a large scale generator used in real power systems.

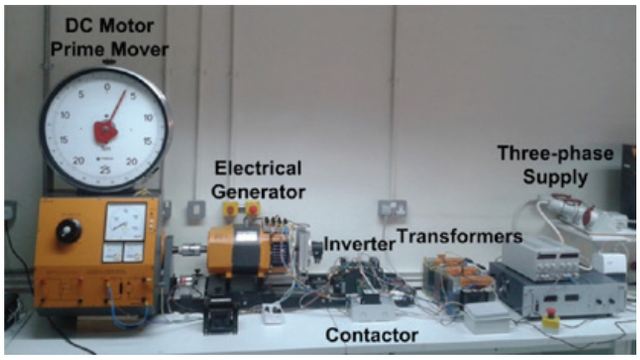

Figure 1: Experimental Setup

Investigation of the Performance of a Linear Drive in Industrial Applications

Student: Antoine Cini / Supervisor: Dr Cedric Caruana

Introduction

Electric machines find a wide range of applications in industrial process. Significant effort is directed to reduce the energy costs associated with such processes. Permanent magnet (PM) motors allowed for higher conversion efficiencies. Linear motors are a promising technology for further improvement of process involving linear motion [1]. A tubular linear motor is used in this work.

Project Objectives

The aim of this thesis is to test the performance of a linear servomotor drive operating a tubular permanent magnet motor. The objectives are:

- Revamp of an existing linear motor test rig
- Operate the drive under different modes of control and tune for high performance
- Develop a software model
- Experimental test of the drive performance under different emulated conditions

Project Methodologies

The permanent magnet linear motor equations expressed in the dq frame were used to implement a software model of the motor under position control using Matlab SIMULINK. Relevant motor parameters were derived from the linear motor datasheet and experimental tests. The cascaded current, speed and position controllers were tuned to achieve the desired performance.

The Yaskawa servopack was set to operate in position control. A number of parameters were set to match the driven linear motor.

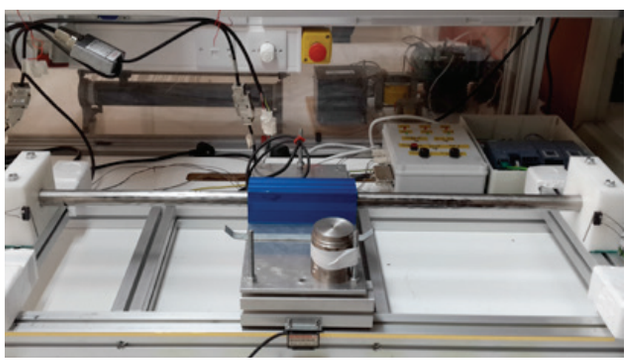

Figure 1: Linear Motor Set-up

The controller parameters were tuned to match those of the software model. A PLC was introduced on the rig to set the required trajectory path to be performed by the linear motor and output reference position and direction pulses to the servopack. A number of tests were carried out using different trajectories with different weights carried by the linear motor.

Results and Achievements

The linear motor was driven with a number of set trajectories with different values of acceleration, deceleration and jerk limits. These emulated different industrial applications. The performance of the motor was tested under no load and with introduced loads up to 3Kg. The same trajectory was used in the software model and its response was compared to the experimental results.

The experimental results showed a close match to the simulated performance. When comparing the no load case with the 3Kg load case, it was noted that the current peaks (or thrust spikes) are much less and for some cases the smaller peak is kept for some time till the slider (linear motor) reaches the desired speed. Also, it is noted that with a 3kg load, the linear motor requires more thrust when compared to no load conditions.

References

[1] J. F. Gieras, Z.J. Piech and B.Z. Tomczuk, Linear Synchronous Motors, Connecticut: CRC Press, June 2011.

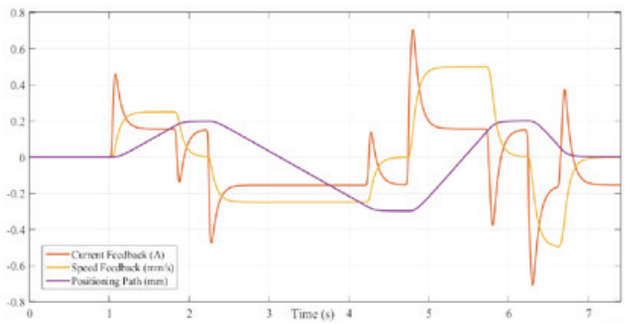

Figure 2: Motor model Simulation results

Control Electronics Design for XY Plotter

Student: Andrew Schembri / Supervisor: Dr Ing. Reiko Raute

Introduction

This project focuses on the design and implementation of an XY Plotter for line drawing purposes. XY Plotters offer a creative alternative to traditional printing methods, whereby drawings are created with the use of connecting lines. Designing an XY Plotter offers an insight into the methodology used to operate Stepper Motors, which are extensively used in countless consumer products.

Project Objectives

Following is a list of the main objectives of the project:

- Design, test and implement a working Stepper Motor Driver on its own circuit board
- Program the necessary functions on a micro-controller to interface this driver
- Design a Graphical User Interface to construct basic line drawings
- Integrate all the subsystems into a working XY Plotter
- Compare the design with an off the shelf product

Project Methodologies

The design involved all the necessary research and calculations in conjunction with the different methods used to achieve a working prototype. Different types of motors were considered. A Bipolar Stepper Motor was made based on the advantages it offers over a Unipolar wound motor [1]. Once the motor was selected, an appropriate drive circuit was designed. This drive circuit was designed while ensuring that it can provide the necessary signals at the correct current levels so as to operate a Bipolar Stepper Motor at its rated parameters. The same circuit was then used for both the X and Y axes. After having a successfully operating circuit, the necessary software was developed to correctly control the driver while reducing the possibility of having the motor losing steps. This was done through the implementation of Motion Profiles. Once this setup was functioning, all the ancillary subsystems were designed and implemented.

Once a satisfactory level of operation was achieved, a set of test drawings were created by both the implemented design and an off the shelf controller in order to achieve a visual comparison between the two.

Results and Achievements

The tests conducted were done specifically to produce a visible comparison between the half-stepping motor driver implemented by the prototype board, and the micro-stepping driver implemented by the off the shelf controller. Both the prototype and readymade controller performed as desired.

The 1/8th micro-stepping driver naturally produced less noisy drawings, which is directly related to the smaller stepping angle, and hence finer ink dots on the paper. The micro-stepping also removed any resonance issues that may be encountered with the coarser half-step control. All testing stages performed as expected, and the working prototype XY Plotter was successfully implemented.

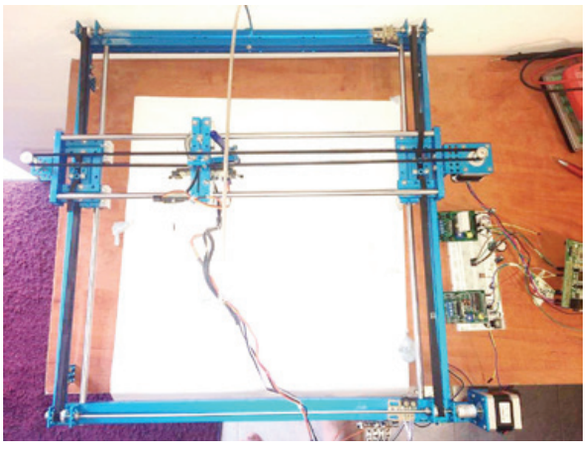

Figure 1: Assembled Plotter

References

[1] HopkinsThomas ‘AN235 Application note Stepper motor driving’

Controlling a computer application using EOG signals

Student: Nathaniel Barbara / Supervisor: Dr Tracey Camilleri

Introduction

Electrooculography (EOG) is an eye movement recording technique which requires a set of gel-based electrodes attached to the user's face [1]. Such a technique could be used in human computer interfaces (HCIs) whereby the user can control a computer application using simple eye movements. This is advantageous for people with mobility impairments such as paralyzed stroke patients or those suffering from Amyotrophic Lateral Sclerosis (ALS), amongst other conditions which prohibit one from using the traditional mouse, keyboard and touch-based interfaces typical of modern

Project Objectives

Recently, JINS Company Limited has developed a sleek, easy-to-wear and wireless EOG glasses, which they call the JINS MEME, as an alternative EOG recording system to the standard gel-based setup. This includes three dry electrodes which are mounted on the spectacles' bridge and nose pads [2]. This project investigated the feasibility of using such glasses to control a computer application and compared these to the conventional gel-based electrode setup. This required the recording of EOG signals using the different modalities, the processing of the signals to identify different eye movements and the development of a real-time application which could be controlled using EOG signals.

Project Methodologies

A threshold-based algorithm was implemented in this project to detect the different eye movements, specifically blinks and saccades. The thresholds for this algorithm were determined automatically by processing the data recorded in a short training session where the subject was asked to look at certain cued positions on a computer screen. A comparison of the two EOG recording modalities was then carried out in an offline study by comparing the saccade and blink classification accuracies obtained while the subject looked at different horizontal, vertical and diagonal positions on a screen. The two techniques were then also used to interface a novel eye-controlled speller application where subject performance was measured in terms of writing speed and classification accuracy.

Results and Achievements

In the offline study, average saccade classification accuracies of 75% and 65% and average blink accuracies of 94% and 95% were obtained using the gel-based electrodes and the JINS MEME, respectively. Such results confirm that the JINS MEME offers a good EOG recording alternative which is easier to use in everyday applications.

When controlling a virtual keyboard using eye movements, writing speeds of 6.44 and 7.11 letters per minute were obtained using the gel-based electrodes and the MEME glasses respectively. Tests showed that these results could be improved once the subject becomes more familiar with the speller's interface. In fact speeds of up to 9.45 letters per minute were achieved by an experienced

Figure 1: Eye-controlled speller application

References

[1] A. Bulling and P. Majaranta, "Eye Tracking and Eye-Based Human-Computer Interaction," in *Advances in Physiological Computing*, London, Springer, pp. 39-65, 2014.

[2] S. Kanoh, S. Ichi-nohe, S. Shioya, K. Inoue and R. Kawashima, "Development of an eyewear to measure eye and body movements," in *37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, pp. 2267-2270, 2015.

Reducing the training time of the brain-controlled music player

Student: Kimberlin Bartolo / Supervisor: Dr Tracey Camilleri

Introduction

A brain computer interface (BCI) system is a non-muscular communication link between the user's brain activities and the surrounding environment [1]. Brain activity is typically recorded using electroencephalography (EEG) which is a non-invasive technique of recording the electrical activity of the brain through a number of electrodes placed on the human's scalp.

Project Objectives

This project focused on analysing a brain controlled-music player which was developed by Zerafa et al. [2]. Specifically the goal was to identify the techniques which could help reduce the long, 21 minutes training session of this application.

Project Methodologies

The first part of the project involved a detailed analysis of the music player to understand the type of features being extracted, the classifier being used and the nature of the training process.

Different methods which could help reduce the training session were then identified. Some of these methods were implemented and an analysis of their effect on the classification performance was carried out. This helped identify the best technique from the set to reduce the training time needed, which was then incorporated into the real-time evaluation of the music player.

Results and Achievements

The brain-controlled music player is a menu-driven application with each menu having different number of flickering stimuli. Results showed that training can be done only on the menu consisting of all the possible stimuli, thus avoiding the need to train on each respective menu. An average over six subjects showed that this approach resulted in no statistical significance in performance when compared to the original system but succeeds in reducing the training time by 38.90%, down to 12.83 minutes.

Figure 1: Subject testing the music player application

References

[1] S. Kanoh, K. Miyamoto and T. Yoshinobu, "Development of Brain-Computer Interface (BCI) System for Bridging Brain and Computer," in *13th International Conference on Biomedical Engineering*, Singapore, Springer Berlin Hiedelberg, 2009, pp. 22645-2267.

[2] R. Zerafa, "SSVEP-Based Brain-Computer Interface (BCI) system for a real-time application," B.Eng Dissertation, University of Malta, Malta, 2013.

Optical Music Recognition of Piano Sheet Music

Student: Joseph Bezzina / Supervisor: Dr Alexandra Bonnici

Introduction

Optical music recognition (OMR) is a field in character recognition that focuses on the automatic recognition of piano sheet music. In an OMR system a music sheet is usually recognised and converted to an audible MIDI file. However OMR systems have other applications such as archiving of music sheet to digital format, automatic transposition of music sheets and conversion into braille.

Project Objectives

The goal of this project is to design and implement an OMR system capable of recognizing printed music sheets acquired using a camera from a mobile or tablet, and convert the recognized musical symbols into an audible MIDI format.

Project Methodologies

The design of the implemented OMR system loosely follows the same flow described in [1]. It consists of four main processes, namely staff line removal, symbol recognition, musical recognition and MIDI conversion as shown in Figure 1. Staff line removal is important to separate the background from the foreground pixels being the staff lines and symbols respectively, since the machine would otherwise interpret them as a single connected component. Symbol recognition is implemented with the novel use of the COSFIRE filter. This filter recognizes structures that match a prototype structure given to the filter. In the musical recognition stage the pitches of the notes are found by measuring their position on the staff lines and assigning clefs, accidentals and key signatures to them. The collected data is finally converted to a MIDI file.

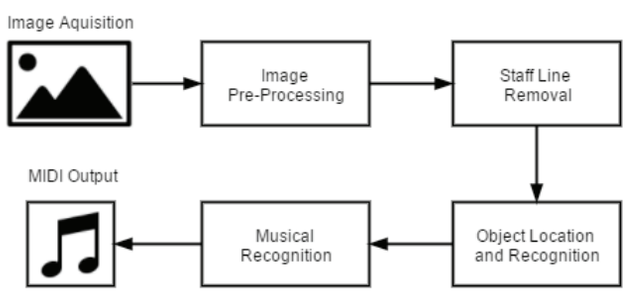

Figure 1: Flow chart of the proposed approach

Results and Achievements

The staff line removal algorithm was evaluated using a database of musical sheet images and their respective ground truth as documented in [2]. With the images in this data set, we obtain an average precision rate of 94.13% ± 3.71% and an average recall rate of 96.53% ± 0.94% which compares to the reported precision and recall rates described in the literature. This confirms that the staff line removal algorithm is successful in removing the staff lines from the score. In order to evaluate the COSFIRE driven symbol recognition algorithm, 153 symbols from eleven different sheet music scores were collected into a single image. These symbols were manually labelled, allowing the comparison of the COSFIRE symbol recognition against the ground truth. The symbol recognition algorithm obtained a precision rate of 97.7%. Moreover, the note pitch identification was evaluated against 220 manually labelled note pitch values, obtaining a precision rate of 93:82% of the note pitch names. Midi recordings obtained for sample scores may be found by scanning the QR code in Figure 2.

References

[1] Bainbridge D., and Bell T., 'The Challenge of Optical Music Recognition' Computers and the Humanities, 2001, Vol. 35, No. 2, pp. 95-121

[2] Fornés A., Dutta A., Gordo A. and Lladós J., 'CVC-musicma: a ground truth of handwritten music score images for writer identification and staff removal' International Journal on Document Analysis and Recognition (IJDAR), 2012, Vol. 15, No. 3, pp. 243-251

Figure 2: QR code to demonstration video

A Brain-Computer Interface for Rapid Image Searching

Student: Elysia Calleja / Supervisor: Dr Owen Falzon / Co-Supervisor: Prof. Kenneth P. Camilleri

Introduction

Even though there have been great advances in computer vision systems, no system has come close to replicating the complexity of the human vision system for object detection. Humans can recognize objects of interest at a glance, even when the objects are shown under different angles and lighting. The recognition of a target object evokes an identifiable brain activity pattern in an individual, which can be recorded using electroencephalography (EEG). This pattern can be used to increase the efficiency of object detection by using the human vision system for object recognition, and computer processing power to analyse the EEG data and determine whether an object of interest was shown.

Project Objectives

The main aim of this project is to implement a brain-computer interface (BCI) to decode EEG data and determine objects of interest from a series of images shown at a high rate by using rapid serial visual presentation (RSVP).

Project Methodologies

An overview of the system would compose of a stimulus consisting of a series of images containing both target and non-target images. A participant would be subjected to a stimulus and the EEG data would be recorded. The images would then be classified as target or non-target images by using features extracted from the recorded EEG data to train a classifier.

In this project, a stimulus was implemented and data synchronised with the stimulus was recorded from eight subjects. The stimulus consisted of images shown at a rate of five images per second using RSVP. The recorded data was then processed and different feature extraction methods were used to classify the data into target or non-target images. The different feature extraction methods analysed are the decimation method, a method used previously in the reviewed literature, and three other methods where a t-test is performed on the training data to find the maximally discriminable points from the EEG data window. The first method uses all the points from the t-test result (APT method); the second method uses only consecutive points from the result (CPT method); whilst the the last method uses the mean of the consecutive points (MCPT method). A linear discriminant analysis (LDA) classifier was used to classify the data into targets or non-targets.

Results and Achievements

Eight subjects participated in the study and the EEG data was recorded and analysed when the subject was subjected to a stimulus. As a means to compare the results obtained for each method used, the mean across all subjects was taken. There was no statistical difference for the target detection rate between the four methods used, however the decimation method performed the best with a statistical difference for the non-target detection rate. Nevertheless, the other methods proved to perform better with a smaller training data. With the available training data, the decimation method provided positive results with a target detection rate of 75% and non-target detection rate of 86%.

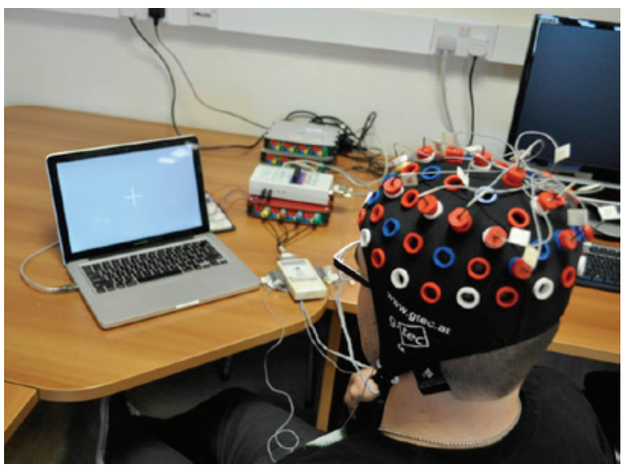

Figure 1: Setup used during the EEG recording sessions

The system provided positive results for both target detection and non-target detection rate, however the results can be greatly improved by using different classification techniques. Once the system provides sufficient results, a real-time system can be implemented. The real-time application with such a system can be used for various different applications in which the aim would be to reduce the object detection time as much as possible.

Thermographic Analysis of the Abdominal Region of Pregnant Women

Student: Annelie Ciantar / Supervisor: Dr Owen Falzon

Introduction

Thermography's use in the biomedical field is becoming increasingly popular as it offers a safe and non-invasive way of obtaining information about the human body by means of skin surface temperature analysis. This project investigates the temperature variation of the abdominal region of both pregnant and non-pregnant healthy women across time.

Project Objectives

The project objectives were to find the acclimatisation period of the abdominal region of pregnant women and to predict the final temperatures across the abdominal region that would be expected following acclimatisation.

Project Methodologies

After the data acquisition process, which consisted of taking a series of images across time, two unforeseen circumstances were met. The first one was the challenge in thermal tracking, which is difficult partly due to the subjects' movement and partly due to homogenous patterns across the abdomen. The second one was the fact that most studies assume an acclimatisation period of 15 to 20 minutes, even though a decrease in temperature and other variations were still present after that period.

Two tracking methods were implemented. One consisted of monitoring the movement of the highest temperature pixel in each frame and shifting all areas according to this pixel's offset. The other method is the summation of squared differences (SSD), which consisted of scanning each image and comparing each area with a template based on the desired area from the previous frame. The area chosen consists of the best combination of pixel similarity and distance moved from the area of the previous frame.

Temperature variations for each individual varied greatly throughout the 100 minutes of data. Hence, a standard acclimatisation period could not be established. Since passive objects cool through an exponential decay, only exponential data was considered for the second objective of the project which was to reduce the amount of time that the subjects spend in front of the camera, as this would be of great advantage in a clinic.

Different mathematical models and algorithms were explored to provide proper curve fitting that satisfies both the dynamic characteristics of the data across time and the final temperature estimation. Once applied to the first few minutes of data, these curves would be able to predict the subsequent temperatures.

Results and Achievements

Through visual inspection, it was concluded that the SSD method provides the better result. A future improvement for thermal tracking would be an algorithm which varies the size and orientation of the region of interest to consider rotation and scaling.

The root mean square error for the dynamic characteristics and final temperature estimations is less than 0.1 and 0.05 respectively when considering between 70 and 100 minutes of data. Hence if these errors are acceptable for medical professionals, the data acquisition data could be reduced.

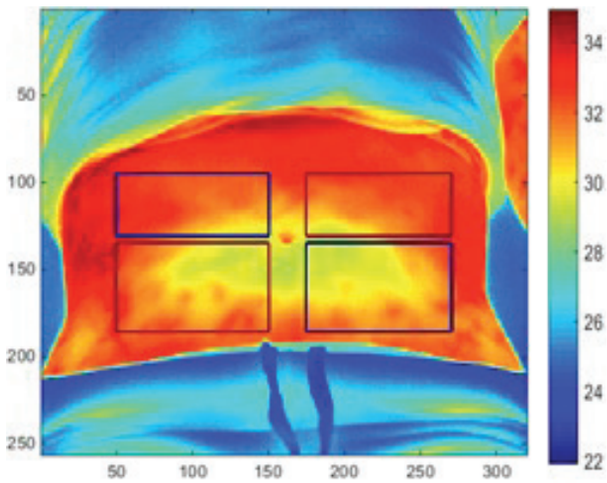

Figure 1: Thermal Image and the regions of interest

Most temperature differences between different quadrants across the abdomen shows statistical significant difference which suggests that the underlying structures of the abdomen clearly affect the abdomen's temperature.

This preliminary study shows that thermography can be a useful tool for future studies about foetal thermography.

System Integration and Control of a Mini Robotic Manipulator

Student: Marlon Galea / Supervisor: Prof. Simon G. Fabri

Introduction

A manipulator is an arm-like mechanism that consists of a series of segments, usually sliding or jointed, which grasp and move objects with a number of degrees of freedom.
The main aim of this project is thus to implement control algorithms for a small manipulator of five DOF available in the Control Systems Laboratory.

Project Objectives

This project summarizes the efforts undertaken to implement the control system for an anthropomorphic arm.
The objective of this project is thus to design, implement and test the electronic interface circuitry between the dSPACE board and the manipulator and a number of control algorithms had to be modelled, simulated, implemented physically and tested for this manipulator.

Project Methodologies

The following plan was formulated for the project:

- Getting to know what was done in previous related projects.
- Literature review on robotics and controllers.
- Research on control algorithms for the close loop control of the manipulator.
- Familiarization with the dSPACE DS1104 board and Control Desk.
- Evaluation of the motors and their sensors/ shaft encoders.
- Design of the electronics that interface the dSPACE controller with the manipulator.
- Modelling and simulation of the Direct and Inverse Kinematics for the five DOF manipulator.
- Derivation, modelling and simulation of the Direct Kinematics and Jacobian Kinematics, and the Inverse Jacobian Kinematics for the robotic manipulator.
- Derivation, modelling and simulation of the dynamics of the manipulator.
- Design and simulation of the inner torque loop for the motors.
- Design and simulation of the outer position loop for the motors.

Results and Achievements

The results obtained when controlling the angle of each joint vary when compared to with the motors unloaded are different from the ones when the motor is loaded. This is because when designing the controllers, no consideration was given to the non-linear dynamics of the manipulator links, as is standard independent joint control due to the large gear ratio of the gearbox used. The step response of the system was quite fast, i.e. when applying firstly positive reference angles and then negative reference angles of 45^{o} it was observed that the system rise time was of around four seconds.

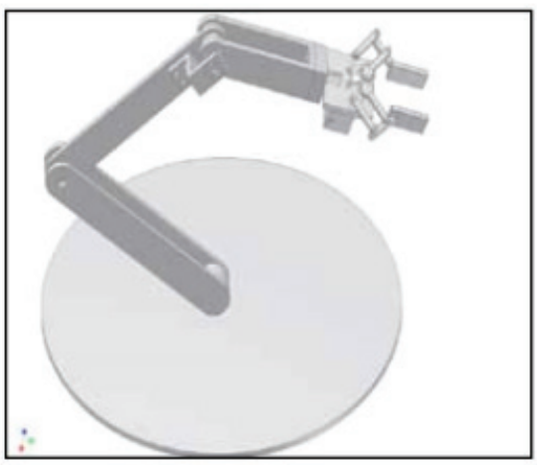

Figure 1: Model of the manipulator

Proportional and Simultaneous Myoelectric Control of a Robotic Arm

Student: Christian Grech / Supervisor: Dr Tracey Camilleri / Co-Supervisor: Dr Ing. Marvin Bugeja

Introduction

Human machine interfaces (HMIs) are a vital tool for people with mobility impairments, giving them the possibility of controlling a machine remotely. One possible control interface is through biosignals which are continuous signals recorded from the human being. This project focuses on the use of muscle activity, known as electromyography (EMG), for the control of a HMI system.

Project Objectives

The main objective of this project was to develop a model which could translate the EMG signals recorded from the upper limb of a human subject into corresponding shoulder and elbow joint angles and use this to control a robotic arm. The project focused on proportional and simultaneous control, where more than one joint could be controlled at any point in time.

Project Methodologies

The first part of this project focused on identifying the different techniques which make use of EMG signals in order to control a robotic arm. Three types of models that are typically used for continuous translation of EMG signals to joint angle position are the state space model, the linear regression representation and the multi-layer perceptron (MLP). From these three, the MLP was found to give the best representation and was thus used to model different single and simultaneous movements of the subject's shoulder and elbow joint angles.

A real-time application was then developed where the Catalyst-5T robotic arm, shown in Figure 1, was made to mirror the position in two dimensional space of the subject as he pointed to one of three objects placed on a horizontal plane.

Results and Achievements

When testing the single joint movement models for the shoulder and elbow, the average root mean square error (RMSE) cross-validated results varied from 5.43° to 15.16°. On the other hand, the best performing simultaneous joint movement model resulted in an average cross-validated RMSE result of 9.03° $\pm$ 0.33° for the elbow angle estimation and 7.30° $\pm$ 0.85° for the shoulder angle estimation.

When testing the simultaneous movement in real-time, the user's wrist position was replicated using a robotic arm. For the real-time implementation the accuracy of the x and y positions in mm was evaluated. An average RMSE of 12.86mm $\pm$3.06mm and 48.59mm $\pm$14.64mm for the x and y end effector trajectories respectively were obtained. The average correlation coefficient value in the x direction was 0.908 $\pm$ 0.043 while that in the y direction was 0.951 $\pm$ 0.015. These results demonstrate the ability of the real-time robotic arm in replicating simultaneous human arm movement as was the objective of this dissertation.

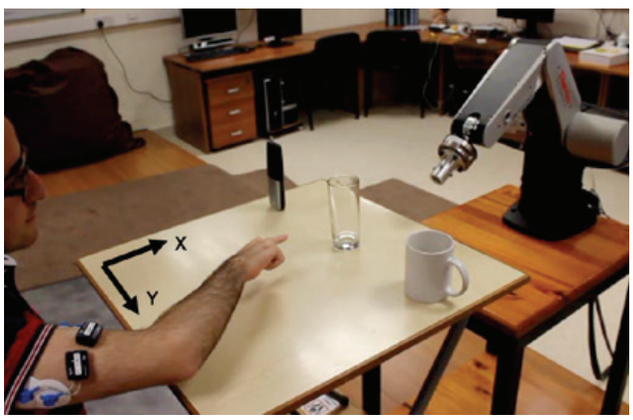

Figure 1: Controlling the wrist position of a robotic arm using muscle activity recorded from the human subject

An EEG-Based Biometric System

Student: Andrea Lia / Supervisor: Dr Owen Falzon

Introduction

Electroencephalography (EEG) is the non-invasive way of recording the electrical activity in the brain by placing electrodes on different parts of the human scalp. Recent studies contributed in the use of EEG as a biometric trait. A biometric system refers to a system which can identify or verify the identity of a person. This is done by uniquely identifying one or more biometric features. The EEG is unique making it a good candidate to use as a biometric trait.

Project Objectives

The main objective of this project is to use steady state visually evoked potentials (SSVEPs) [1], which are responses elicited in the brain when a person looks at a flickering stimulus to discriminate between six subjects.

Project Methodologies

The EEG data used in this study was acquired from six participants. All the subjects were aged between 20 and 25 years and included five males and one female. The subjects were seated half a meter away from the stimulation unit. The stimulation unit was designed using a four by four green LED matrix programmed to flicker at different frequencies and duty cycles. The stimulus frequencies used in this study were the 10Hz, 17Hz, 27Hz at two different duty cycles of 25 and 50 per cent. Figure 1 shows the setup used to acquire the data during the experiment.

Since SSVEPs in biometry has never been used so far, the appropriate frequencies and duty cycle had to be analysed within each individual before discriminating between the subjects. After selecting the best frequencies and duty cycle which performed best across all the six subjects, the discrimination of the six subjects follows using different frequency combinations.

Results and Achievements

Comparing the results of the 25 per cent and 50 per cent duty cycle, the 25 per cent duty cycle performed slightly better than the 50 per cent and thus was used to extract the features for discrimination. The frequency combination of 10Hz and 17Hz obtained a statistical significant difference in performance when compared to the 17Hz and 27Hz. The best classification accuracy of 65 per cent was obtained when using the 25 per cent duty cycle and the stimulus frequency combination of 10Hz and 17Hz. This result can be further improved by implementing other feature extraction methods and classification algorithms.

Figure 1: Experimental setup used to acquire the EEG data

References

[1] F.B. Vialette, M. Maurice, J. Dauwels and A. Cichocki, “Steady-state visually evoked potentials: Focus on essential paradigms and future perspectives,” *Progress in Neurobiology,* vol. 90, no. 4, pp. 418-438, 2010.

Voice Commanded Mobile Robot for Search and Follow Operations in Unknown Environments

Student: Clare Saliba / Supervisor: Dr Ing. Marvin Bugeja

Introduction

We are increasingly becoming accustomed to living and working side by side with robots. Robots are becoming indispensable in a number of industries. Most mobile robots implement a speech interface to enhance their interaction with humans. On the other hand, autonomous mobile robots are becoming more robust and self-efficient, hence requiring less intervention by human operators.

Project Objectives

The main goal of this project was to integrate human-robot interaction with autonomy. A system was to be developed that would allow the Khepera III mobile robot to be commanded, via speech, to autonomously search for, and follow a specific target in an unknown, obstacle-cluttered environment.

Project Methodologies

A speech interface was developed using Google speech recognition together with eSpeak speech synthesiser. Due to the computational requirements by these systems, the speech interface was developed and implemented on a Linux-based computer. A communication framework was developed in order to communicate with the mobile robot.

Due to the limitations of the Khepera III mobile robot, a search algorithm, that did not need a pre-defined map of the environment it was going to be used in, was designed. Since most algorithms make use of maps, a novel algorithm had to be developed. One of the Braitenberg vehicles proposed in [1], was modified and implemented. This algorithm makes use of the five ultrasonic sensors mounted on the Khepera III mobile robot in order to direct the mobile robot. Once the target is detected by the CMUcam5 smart camera mounted on the robot, the robot approaches the target using an algorithm based on the Dynamic Window Approach presented in [2]. The search and follow algorithms, which are governed solely by ultrasonic and vision sensors, were finally implemented on the mobile robot.

Results and Achievements

Different speech recognisers were tested. However, Google speech recognition was implemented, mainly due the accurate and repeatable results it produced. The speech interface was successfully integrated together with the algorithms implemented on the Khepera III mobile robot. The system was tested by uttering different commands and presenting different objects for the robot to find and follow. Figure 1 shows the motion of the mobile robot when it encountered obstacles during searching.

However, further work can be implemented to make the current system more efficient. This includes implementing a servomechanism that allows the camera to pan independently of the robot's motion to search more efficiently for the target. Moreover, swarm robotics can be introduced to explore large areas in less time. Finally, an object recognition algorithm can be implemented to work in parallel with the colour recognition. This would allow the robot to detect objects based on the shape, size, and colour.

Figure 1: The trajectory followed when the Khepera III mobile robot encountered some obstacles during a search operation

References

[1] Valentino Braitenberg, *Vehicles: Experiments in Synthetic Psychology*. London, England: The MIT Press, 1986.

[2] Dieter Fox, Wolfram Burgard, and Sebastian Thrun, "The dynamic window approach to collision avoidance.," *IEEE Robotics & Automation Magazine*, vol. 4, no. 1, pp. 23-33, March 1997.

Locality Preserving Projections in Affective Electroencephalogram Analysis

Student: Jurgen Seychell / Supervisor: Prof. Ing. Kenneth P. Camilleri

Introduction

Over the past few years, an area that is gaining more importance is the area of emotion recognition. This area's main aim is to have a computer system that can react to the different emotional states. For example, in Computer Aided Learning if the computer knows the emotion of the students, it can change the method of learning

Project Objectives

The aim of this project was to design a system that could classify emotions in the 4 quadrants of the valence-arousal space. In this study feature selection and dimensionality reduction was implemented in order to classify emotional data.

Project Methodologies

In order to classify emotional data, Welch's method was used to obtain the power in specific spectral bands for each channel. The data obtained from Welch's method had a lot of features and thus a feature selection algorithm was implemented. Fischer's Linear Discriminant, similar to the one implemented by Koelstra [1] was used for feature reduction.

Apart from feature selection, dimension reduction was also performed. Dimension reduction in supervised learning using Locality Preserving Projections (LPP) was computed. The data obtained was used for 2 class classification and 4 class classification.

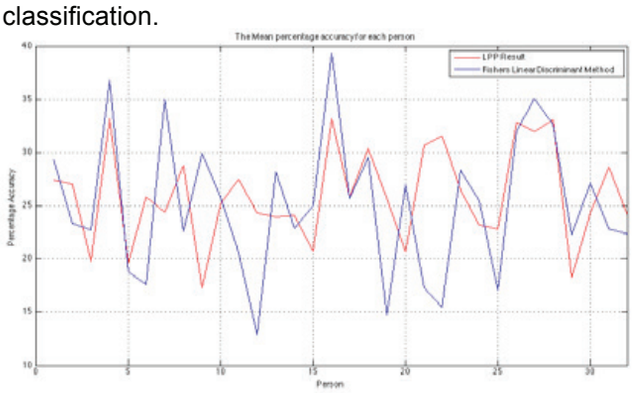

Figure 1: A graph for each participant's accuracy for the 2 different algorithms

Results and Achievements

The accuracy results from each person for each algorithm are shown in Figure 1. The mean accuracy for 4 class classification for Fischer's linear discriminative method was of 25.17% ± 6.82%, for Low/High Arousal was 48.36% ± 10.73% and Low/High Valence is 51.48% ± 8.40%. On the other hand, the accuracy for 4 class classification for LPP was of 26.03% ± 6.15%, for Low/High Arousal was 51.89% ± 7.30% and for Low/High Valence was 50.39% ± 8.51%.

The last achievement was to check if the valence-arousal space is isomorphic to the reduced dimensionality data. The top graph in Figure 2 shows only major points in the 4 quadrants marked in different colours. The bottom graph showed the data in 2 dimensions obtained from the LPP. As can be seen from Figure 2 the cluster effect was lost and the points were spread over the new space. Thus the valence–arousal space was not isomorphic to the EEG data.

References

[1] S. Koelstra, "Deap: A database for emotion analysis; using physiological signals," *Affect. Comput. …*, vol. 3, no. 1, pp. 18–31, 2012.

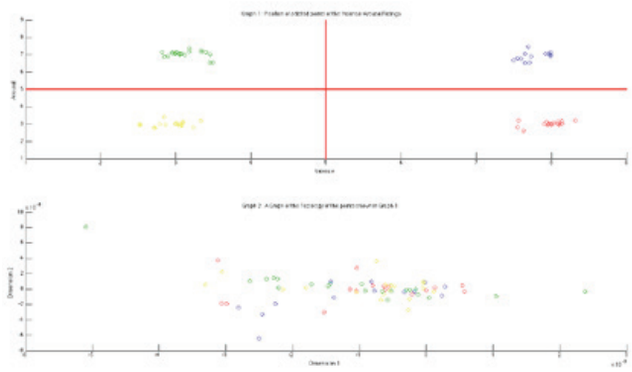

Figure 2: The reduced dimensionality of EEG data

Non-Photorealistic Rendering of Scenes

Student: Kenneth Terribile / Supervisor: Dr Alexandra Bonnici

Introduction

Non-photorealistic rendering (NPR) has been an established field within the area of computer-graphics for several years. The aim of NPR is to create appealing and expressive stylized illustrations from an image, which offer a human-drawn representation of a computer-generated render.

Project Objectives

While there are several styles of NPR techniques that are described in literature, the project focused on a painterly style, whereby the image was rendered in such a way that it mimics a painting.

Project Methodologies

For an artistic representation of a photographic scene an image was divided into two categories, obtaining a sketch-like representation of the scene and obtaining a colourised representation of the scene. Two edge detection algorithms, from which a sketched representation of the scene is obtained will be discussed. These are the Gabor filter [1], and an extension to the Kuwahara filter [2]. For the colourised representation of a scene, two different ways of adding a textured stroke to an image are looked into, by adding a textured stroke directly on the edges within the image, and by adding texture to the whole image and enhancing the edges within the image.

Results and Achievements

Given that NPR is a form of art, and art cannot be evaluated mathematically, results were evaluated using three different methods, these being; visual inspection, quantitative analysis, and qualitative analysis. For the qualitative analysis, a user study was carried and the results obtained matched the quantitative results, verifying the NPR process correctly.

The results show that people perceive rendered scenes as a hand-drawn illustration of an image, however for each image a different approach needs to be considered depending on the elements found within the image.

References

[1] Papari, G., Petkov, N., and Campisi, P. Artistic Edge and Corner Enhancing Smoothing. IEEE Trans. on Image Process., 16(10):2449–2462, Oct 2007. ISSN 1057-7149.

[2] D. Gabor, "Theory of communication. Part 1: The analysis of information," in *Electrical Engineers - Part III: Radio and Communication Engineering, Journal of the Institution of*, vol. 93, no. 26, pp. 429-441, November 1946.

Figure 1: Original Image

Figure 2: A watercolour representation of Figure1

Autonomous Robot Navigation in a Populated Environment

Student: Danica Theuma / Supervisor: Dr Ing. Marvin Bugeja

Introduction

To perform autonomous navigation successfully, a robot must excel in four main tasks. The first of which is perception, which is the ability of a robot to extract meaningful data pertaining to itself and its environment, by interpreting the information obtained from its sensors. The second task is localization. This is the ability of a robot to determine its position and orientation within its environment. Another important task is that of cognition, where a robot makes decisions on how to act in order to reach its goals. Lastly, a robot must also have good motion control in order to follow the planned trajectories successfully. The robot used in this project is a commercial research robot named PowerBot™ which was developed by Adept MobileRobots. This robot was installed with the Robot Operating System (ROS), which is an open-source, meta-operating system for robots, and it encompasses a set of tools that facilitate the development of robotic applications.

Project Objectives

The main objective of this work was the design, implementation and testing of a system based on the ROS framework, that allows PowerBot™ to autonomously navigate the dynamic indoor environment of the Engineering Building without colliding with obstacles and people along its course. This had to be achieved using a preloaded map acquired by the robot itself.

Project Methodologies

In order to reach this objective, a thorough analysis of: 1) the algorithms that can be used to generate a map of the environment, 2) the methods employed for the robot to be able to localize itself within the map, and 3) the actual path planning and obstacle avoidance algorithms that are required for the robot to find its way to a goal destination, was required.

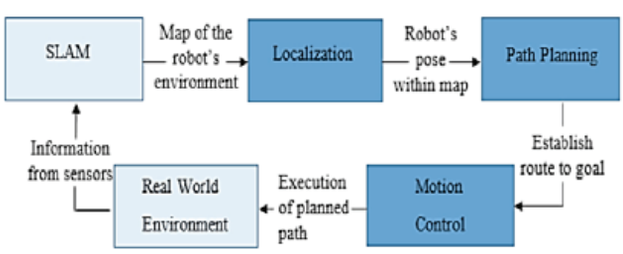

Figure 1: Block Diagram of the Designed System

This was followed by the choice of a Simultaneous Localization and Mapping (SLAM) algorithm, based on a particle filter in the mapping stage, and the use of the Adaptive Monte Carlo Localization (AMCL) approach to localize the robot within the map. Finally, Dijkstra's algorithm was used in the path planning stage, and was coupled with a local planner, the Dynamic Window Approach (DWA) for dynamic obstacle avoidance. The designed system is depicted in Figure 1.

Results and Achievements

The most important achievements of this work are:

1. The successful use of ROS to build a good map of the environment and to design an autonomous robotic navigation system.

2. A confirmation that autonomous navigation in a dynamic indoor environment such as that presented by the Engineering Building, is possible and can yield good performance even in the absence of absolute localization technologies, like GPS. As can be seen in Figure 2, the current results show that PowerBot can successfully navigate autonomously on paths that are over 100m long over an area of around 500m^2, whilst avoiding collisions with both static and dynamic obstacles.

3. The whole autonomous navigation system can be initiated in an easy-to-use method by using a launch file. The user then only has to input the robot's start and goal position for the autonomous system.

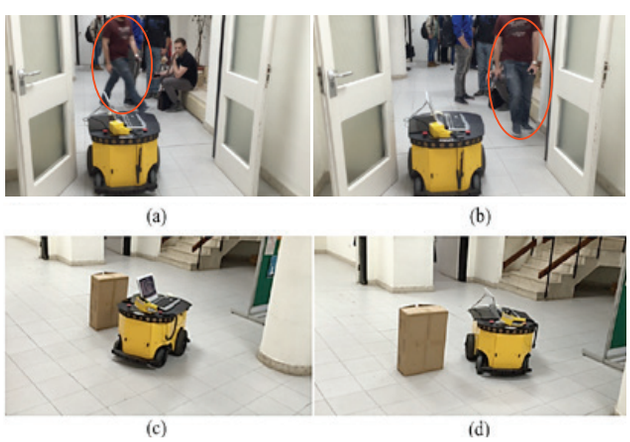

Figure 2: Mobile robot's successful autonomous navigation in a populated environment

Finger Movement Detection Using the Electromyogram

Student: Glen Mark Zammit / Supervisor: Prof. Ing. Kenneth P. Camilleri / Co-Supervisors: Dr Tracey Camilleri, Prof. Ing. Michael A. Saliba

Introduction

Myoelectric control, that is the use of the electrical potential acquired from the muscle innervation, has recently been receiving increasing attention. Amputees who suffer from upper limb amputations find it extremely difficult to rehabilitate and live a comfortable life without the functionality that the fingers can provide in their daily routines. Therefore dexterous control of fingers is essential such that advanced arm prostheses would be developed to provide the opportunity for these people to interact with their daily lifestyle.

Project Objectives

This project focuses on the detection of finger movements, through the use of Electromyographic (EMG) signals. A literature review of myoelectric finger movement detection and control was required in order to develop which methods are used to achieve this goal. Following that, existing databases of relevant myoelectric signals were analyzed in order to select and implement state-of-the-art methods of myoelectric signal processing, feature extraction and finger movement detection.

Project Methodologies

It was observed that for finger movement detection, there are two main approaches. The first approach is that of classifying discrete finger movements, whilst the second approach detect finger movements by estimating finger kinematics. The classification approach has been widely because it can successfully decode discrete finger movements.

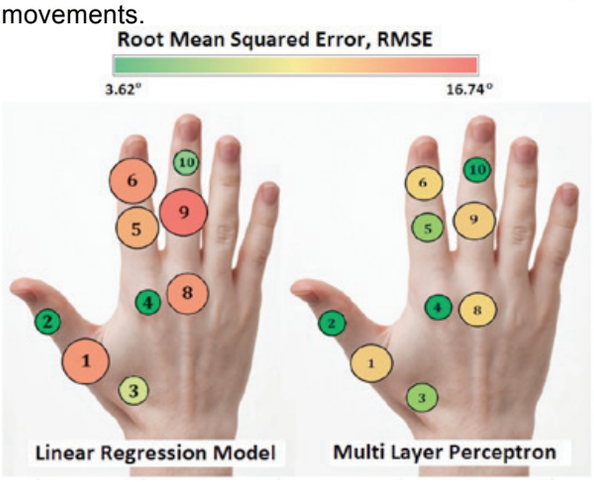

Figure 1: A visual representation of the root mean square Error (RMSE) results of Figure 2

However, finger movements are not limited to discrete movements but they also include continuous gestures. Even though the finger kinematics estimation approach has been under developed, it permits the proportional control of a particular finger movement or gesture, which is essential for advanced arm prosthesis and dexterous robotic hands. Therefore by using linear regression models (LRMs) and a multi-layer perceptron (MLP) neural network, finger joint angles were estimated for seven different movements, by extracting input features from the myoelectric signals, provided by the *Ninapro* Database [1].

Results and Achievements

The estimation results for both methods were compared and analyzed, as shown in Figure 1 and Figure 2. It was concluded that the MLP was superior to the LRMs since it produced better finger kinematics estimation. The system's performance was assessed through the coefficient of determination (R^2), the root mean square error (RMSE) and correlation coefficient (CC) measures, which for the MLP they were found to be on average, R^2= 0.72, RMSE = 6.84° and CC = 0.85, as seen in Figure 2.

References

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Performance Comparison - RMSE			
Glove Sensor	Linear Regression Model		MLP
	Joint/Sensor	RMSE (°)	RMSE (°)
1	MCP Thumb	15.88	10.39
2	DIP Thumb	4.42	4.04
3	Abduction	7.74	6.09
4	MCP Index	4.58	3.62
5	PIP Index	11.26	6.39
6	DIP Index	12.64	8.78
8	MCP Middle	13.14	8.31
9	PIP Middle	16.74	9.98
10	DIP Middle	4.80	3.94
Overall Performance		10.13	6.84

Figure 2: The root mean square error (RMSE) results obtained from the LRMs and the MLP respectively, with glove sensor reference to Figure 1

FINAL YEAR
ENGINEERING PROJECTS
MECHANICAL STREAM

An Exploratory Study on the Automated Sorting of Recyclable Domestic Waste

Student: Dilan Bonello / Supervisor: Prof. Ing. Michael Saliba / Co-Supervisor: Prof. Ing. Kenneth Camilleri

Introduction

The material recovery facility (MRF) present on the Maltese Islands does most of the sorting from the commingled waste manually. The targeted materials sorted in the particular material fractions are paper, cardboard, LDPE, HDPE, PET clear, PET colour, ferrous and non-ferrous. Automated technology, involving machines and robots is present and has the potential to be utilised in such a facility [1], [2].

Project Objectives

-The generation and selection of conceptual solutions for the automation of the waste separation process.
-The generation and selection of conceptual solutions for the sensing and material handling aspects of part of the sorting process. Focusing on material handling.
-The design and development of the material handling of part of the sorting process.

Project Methodologies

Literature review was carried out on the available automated recycling system technologies present. The process design specifications were pursued together with the quality function development and generation of the conceptual designs. The selection of the final conceptual design was carried out. Choice was then made on which part of the proposed process was to be delved into, resulting in the robot handling and sensing part of contaminant material from stream of sorted material. Literature review again was carried out on the robot gripper technologies available. Conceptual solutions followed, together with the final conceptual solution. Embodiment and detailed design followed, Figure 1. The gripper was later tested on various materials.

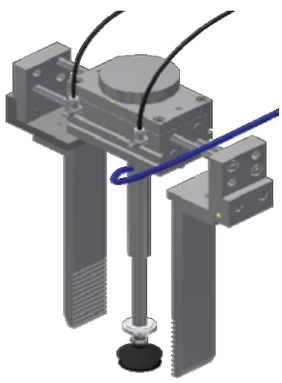

Figure 1: A CAD drawing of the final proposed gripper

Results and Achievements

The proposed gripper was constructed and rigorously tested on target and even non-target materials, Figure 2.
The results obtained where all positive, where the gripper, as long as the exact position and orientation of a particular point on the material to be handled is identified, handled all the various materials without a problem.
As could be seen the developed gripper has a huge potential in not only the material recovery facility present in Malta, but also recovery facilities worldwide. This is only possible with a closed loop autonomous system using near-infrared spectroscopy (NIR), 3D imaging, inductive sensors, and artificial intelligence (AI) to formulate the best location for the contaminant material to be grasped [3].

References

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Figure 2: The various materials having different shapes and sizes handled by the gripper

Design of a Proof-of-Concept Prototype for Open Cardiac Surgical Delivery System of a Vascular Plug Device

Student: Michael Borg / Supervisor: Dr Ing. Philip Farrugia / Co-Supervisor: Mr David Sladden

Introduction

A paravalvular leak (PVL) is a common complication that arises after a surgical heart valve replacement [1]. It can be described as a 'leaky valve' which causes the heart to work harder to compensate for the loss of blood pressure. Most PVLs are not life threatening however in some minor cases 1% – 3% [1] these PVLs can become large enough such that they cause severe heart complications including failure [2].

Project Objectives

The aim of this project was to design an innovative delivery device for the Amplatzer Vascular Plug (AVP), to be used for the closure of an aortic PVL (refer to Figure 1) via an open cardiac procedure called Mini – Sternotomy.

Project Methodologies

Following initial problem background research, an in depth literature review underlining the problems related with current delivery methods and state - Of - the art instruments was conducted. A problem analysis was then carried out to define the Product Design Sheet (PDS) of the device. Using various Synthesis design tools, six working principles were originated, of which, one was selected for further design development.

Further implementation of multiple design tools including; Design For 'X' studies and a detailed Failure Mode and Effect Analysis (FMEA) led to the development 3D CAD model and detailed engineering drawings. A full scale prototype was then built and used for to collect qualitative feedback from medical professionals at Mater Dei Hospital.

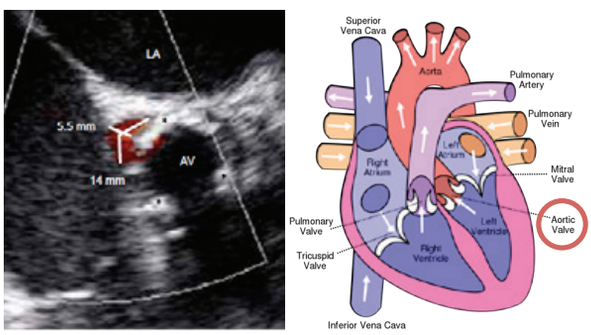

Figure 1: Circled in red, indicating the size and location of an aortic PVL. LA – left atrium, AV – aortic valve [3], [4]

Results and Achievements

Prototype evaluations indicated positive feedback. Ergonomic, easily manipulated adjustment options, dedicated fine adjustment mechanism for additional accuracy and an overall stable structure, all contributed to reach the high expectations of the Stakeholders.

Constructive criticism indicated that further design refinements and testing will be needed for the device to successfully make it in the market. Nonetheless the Prototype highlighted the importance and the benefits of this delivery device as it opened a new and a more reliable treatment for patients in need for the closure of an aortic PVL.

References

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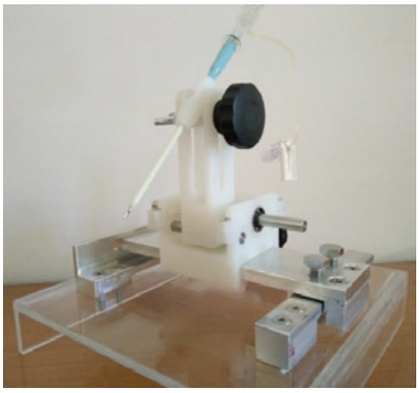

Figure 2: Functional Physical Prototype

Machining Miniature Components on the Sodick AP3L EDM

Student: Kristabel Borg / Supervisor: Dr Ing. Pierre Vella

Introduction

Various industries are investing in micromachining due to an increasing demand in miniaturisation of parts for numerous industries, including aerospace, automotive and even biomedical implants. However, the required production volume of these parts has increased drastically mainly due to the high demand for having small products with high functionality and micro size features. Micro-Electrical Discharge Machining (micro-EDM) has become increasingly popular due to its capabilities in the micromachining industry. It is a non-conventional machining process whereby material is removed by a discrete number of sparks and no contact between the tool and workpiece is experienced[1]. One of the major advantages of EDM is its ability to machine any conductive material, irrespective of its hardness. This dissertation focused on micro-EDM milling which does not require any expensive and complex tooling[2].

Project Objectives

EDM has a wide range of process parameters which can be altered by the operator, such as current, voltage and rotational speed. The main objective of this project is to conduct a number of experiments using Sodick AP3L EDM to investigate the behaviour of different rotational speeds on output parameters. Furthermore, the capability of the machine and the quality of component produced were also studied.

Project Methodologies

Two main sets of experiments were conducted. In the first set of experiments, nine different rotational speeds were studied; having 0rpm the minimum and 2,000rpm the maximum. The output parameters investigated were material removal rate(MRR), tool wear rate(TWR), surface roughness and surface quality. The results obtained at different speeds were compared to one another. In the second set of experiments, the quality and dimensions of the pockets obtained were studied using an optical microscope and surface profilometer.

Results and Achievements

As the rotational speed increased, more material was removed from the workpiece and the tool worn at a faster rate. This is compatible with literature because as the rotational movement was introduced, centrifugal forces were generated [3]. Molten material from the electrode and workpiece were removed and thus new underlying material was exposed to be machined. The wear experienced on the rotary electrode was more uniform rather than the stationary electrode which had one side more eroded than the other, as can be seen in Figure 1.
The bigger the electrode diameter, the more material was removed from the workpiece and the lower was the tool wear. A finer surface finish was obtained on the workpiece at low speeds, however after exceeding certain speeds, the surface became rough again[3].

In the second set of experiments, it was noted that due to the tool's wear, the pockets obtained were of smaller size and even having tapered walls. The obtained repeatability of the machine had an average error of 36µm.

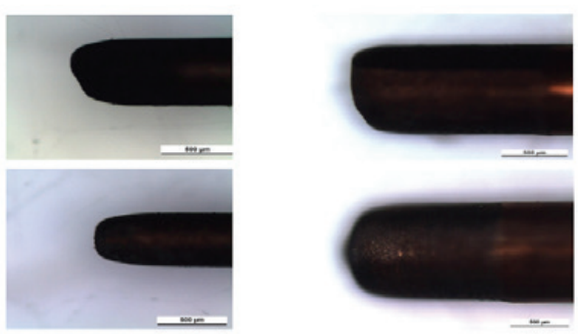

Figure 1: Electrode Wear: Top- Stationary electrodes

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Camera Inspection Process Improvement in Banknote Printing

Student: Brady Briffa / Supervisor: Dr Ing. Pierre Vella

Introduction

The cost of quality performance for a banknote printing company is a major strategic concern. The quality of a banknote is quintessentially important for the world's economy due to the public's confidence in its authenticity. [1]

Project Objectives

The first objective was to reduce the overall amount of non-value adding work in inspecting the quality of banknotes. The second objective was to reduce the false positive errors from the camera inspection system.

Project Methodologies

The lean six sigma methodology for process improvement was followed in this project. The five stages of the DMAIC cycle include Define, Measure, Analyse, Improve and Control. Lean Six Sigma is a data-driven approach in which several quality tools are used in each stage to ensure an effective problem analysis to deliver tangible results in the industry. [2]

Results and Achievements

From the first two stages of the DMAIC cycle, standardization and equipment reliability were the main areas needing improvement.
Small stops in banknote production were correlated with a significant quality loss. Furthermore, the automatic camera inspection set-up was not in line with the extent of the variability found in the processes. Through the implementation of the Total Productive Maintenance program, a 50.69 % reduction in small stops was achieved during a trial run and the quality loss from the Intaglio process was reduced by 2.1 % as illustrated in Figure 2.

References

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Figure 1: The Intaglio print on the portrait giving distinctive tactile and visual security features [3]

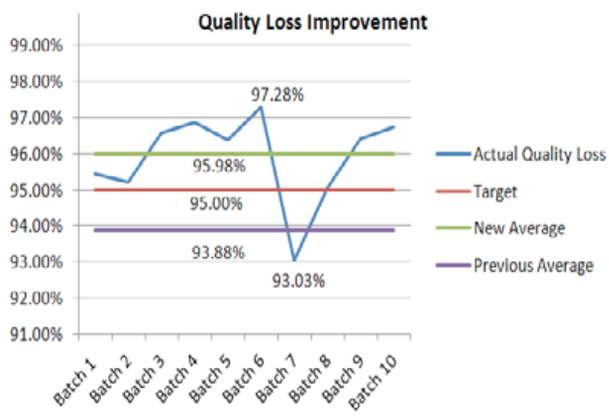

Figure 2: The 2.1% improvement in first pass yield from adapting the camera system set-up

Application of Process FMEA at Playmobil Malta Ltd.

Student: Kimberly Busuttil / Supervisor: Prof. Ing. Jonathan C. Borg

Introduction

Downtime is a concern to many factories in industry, as it ultimately leads to losses in different forms. Having excess downtime within a manufacturing process, hinders process efficiency. In this respect, finding solutions is crucial to reduce unnecessary downtime. This project concerns a study on how to reduce downtime at a plastics toy-manufacturing firm.

Project Objectives

The objective was to increase the process efficiency of the *printing process* at Playmobil Malta Ltd. by identifying the root causes of *stoppages* and *excess changeover time*, through fault analysis methods, such as PFMEA.

Project Methodologies

Throughout this dissertation, factors effecting the printing process efficiency in terms of stoppages and changeover time, were investigated profoundly. With respect to the *stoppages,* Ishikawa diagrams were used to acquire a thorough perspective of the different categories of the stoppages and an FTA to identify the root causes.

It can be seen in Figure 1 that more than half the stoppages occurred because of injection moulded defective parts, which were the input of the printing machine. A PFMEA was then conducted to quantify the different stoppages in terms of RPN values, thereby identifying which failures contributed the most to the stoppages. A Pareto chart was then applied in order to select which failures to tackle in the revised PFMEA.

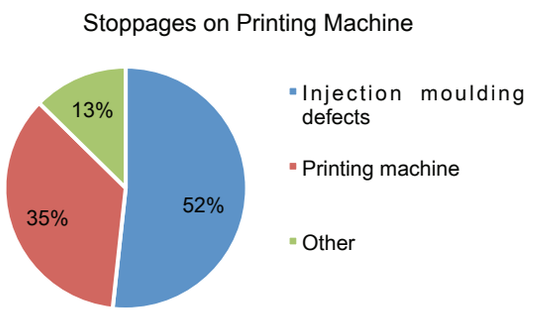

Figure 1: Pie Chart representing the Main Categories of Stoppages

An Ishikawa diagram was also applied to the *changeover*, in order to recognise areas where the changeover time could be shortened. The SMED methodology was employed to bring the changeover time from approximately 18 mins to a single digit minute. This tool reduces the tasks performed whilst the machine is down, by distinguishing between internal and external tasks and by then converting as many internal tasks as possible, to external ones.

Results and Achievements

The implemented action in the revised PFMEA, which was aimed to reduce the *stoppages* was replacement/repair of the injection moulding moulds. This was done in order to improve the quality of the injected parts. This action led to a 6.3 per cent increase in OEE. The RPNs of the PFMEA encountered significant percentage decreases of up to 83 per cent. A video simulation of how the good and bad parts pass through the rails of the machine was generated. The modifications to cut down on changeover time, that were developed through the SMED methodology, were demonstrated on site. The number of tasks performed whilst the machine is down was decreased from a total 11 tasks to 5 tasks, as shown in Figure 2. The 6 tasks extracted from the changeover included all the walking time, resulting in a 50.9 per cent decrease in changeover time, saving ~13 hrs per month, time which could be put into production.

In relation to the Theory of Disposition, this dissertation has shown that once the moulds of the injection moulding machines were repaired/replaced, there was indeed an improvement in the efficiency in its subsequent process i.e. the printing process.

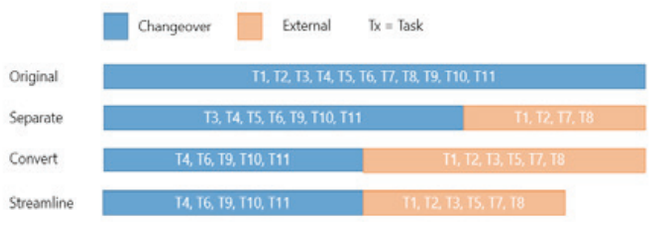

Figure 2: Applying the SMED Methodology to the Case Study Changeover

A Kansei Engineering Tool for Handling Customer Emotions

Student: Zachary Cassar Torreggiani / Supervisor: Prof. Ing. Jonathan C. Borg

Introduction

The market is being bombarded with hundreds of new products everyday. The affect a product has on the customer may just be the key-determining factor to success. Kansei Engineering (KE) is a form of affective engineering, whereby the use of design tools, aiding design engineers in order to develop products tending to the desired emotional affect [1]. An established approach is by analysing in the use of the senses [2]. However there is in fact a lack of tools, to aid designers in this process.

Project Objectives

The overall objective was to create a KE tool, by identifying a set of case studies, analysing the key senses used, the emotions elicited and the responsible product characteristics the eliciting of the emotions. The improvement of existing products was to be established and presented along with virtual designs. Furthermore evaluation of the proposed tool by means of validation by experienced professionals.

Project Methodologies

By analysing the user-product interaction life cycle, market research was conducted in order to analyse the use of the senses in product appraisal. It was found that the use of sight and touch were the common. A survey was conducted in order to further analyse particular influential factors of characteristics, pertaining towards the success of a product.

Results and Achievements

Whilst also confirming previously attained results, the affects of social influence were found to be influential to the success of a product and where therefore included in the approach.

This was applied towards the creation of the Product Element Interaction (PEI) Tool. This Excel based tool, comprises a design model and a rating system. Founded upon the affect analysis of individual design elements of a product.

In order to test the use of the tool, two case studies were produced. That of a pen made specifically for university students and also the improved design of a drip chamber.

The PEI Tool was validated by a number of evaluators who are well experienced in the field of product design and research and development. The evaluations outline both the potential use of the tool within the industry and some possible improvements, which would enhance the tool for use within the industry.

References

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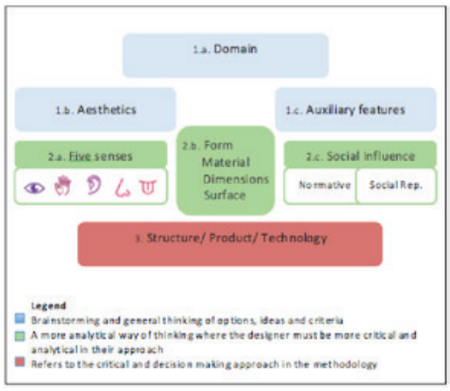

Figure 1: PEI design model

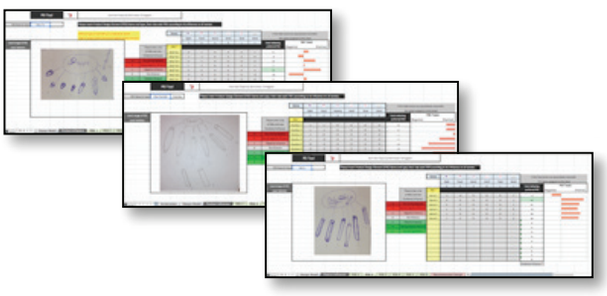

Figure 2: Integrated analysis & rating system

Application of LCA for Sustainable Product Development

Student: Raphael Coppini / Supervisor: Dr Ing. Paul Refalo / Co-Supervisor: Prof. Ing. Jonathan Borg

Introduction

Life Cycle Assessment (LCA) is a method used to analyse the life cycle of a product or service and identify the resulting impacts on the environment. This method can be used to develop a sustainable product. Designing a product to be sustainable involves considering the environmental, social and economic environment in which the product or service exists [1].

Project Objectives

The main objectives of this project were as follows:
-To select a suitable case study to illustrate the application of a Life Cycle Assessment to Sustainable Product Development
-To redesign an existing product with improved sustainability metrics.

Project Methodologies

Apart from the LCA method, an experiment designed to study the average water use of a Maltese person was carried out along with a survey. The survey was intended to gather information regarding hand washing habits of the Maltese population. The survey and the experiment were used in conjunction with Eco Materials Adviser which is an LCA software to analyse the various life cycle stages of a liquid hand wash dispenser. These stages included the material extraction phase, the manufacturing phase, the transportation phase, the use phase and the disposal phase.
Three different products' life cycles were compared. These were; a plastic disposable dispenser, a glass permanent dispenser and a stainless steel permanent dispenser. The LCA was applied to each of these products using what is called a comparative LCA where the three products were compared based on a number of sustainability metrics. These metrics were Carbon Footprint (kg of CO_2), energy (MJ) and water (L).
The results of this analysis were used to determine the product with the highest impacts and the product part with the highest contribution to these impacts.
The redesign was carried out on the product with the lowest impact. The part with the highest contribution turned out to be the bottle and so this part was the focus of the redesign process.

Results and Achievements

The resulting product was a plastic hand soap dispenser with a 68% reduction of the weight of the bottle. This lighter bottle resulted in a reduction of 90% in the energy required to manufacture the bottle and a 71% reduction in the energy required to extract the material for the bottle. The improvements of the ecodesign over the standards product in terms of energy use can be seen in Figure 1.
The results from the water use experiment showed that the amount of soap dispensed correlates directly with the amount of water used to wash ones hands. Based on these results the eco-designed product was designed to dispense 50% of what a standard liquid soap pump would normally dispense reducing the water associated with one wash from 0.9L to 0.76L.

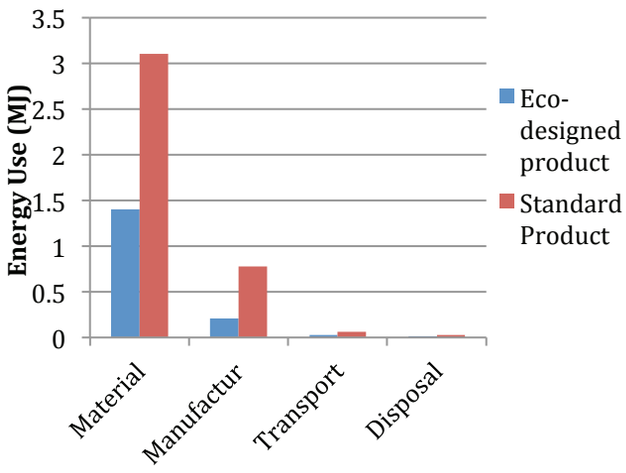

Figure 1: Energy comparison between standard product and Ecodesigned product

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Life Cycle Analysis of a Cosmetic Package

Student: Paul Jaccarini / Supervisor: Dr Ing. Paul Refalo

Introduction

Preserving the natural environment has become more of a priority in recent years in response to mankind's unsustainable interaction with the natural world over the last century or so. Cosmetic packaging is one of many other factors that are contributing to environmental exploitation throughout the various stages in such a package's life cycle [1].

Project Objectives

The main aims of this study were to evaluate the environmental impact of three cosmetic packages manufactured by Toly Products mainly in terms of energy use and global warming potential (GWP). Identifying the contribution from each life cycle phase to each impact category was also given importance.

Project Methodologies

Eco Materials Adviser was the LCA software package chosen to carry out this study. LCA is typically, a four-stage process. The first stage requires the goals and scopes of the study to be defined. The goals were mentioned above while these also include the goal to design the packages in such a way that will yield a lower environmental footprint than the current scenario. The life cycle phases evaluated include those of material extraction, manufacturing, transportation, use and disposal. Material sourcing was based on the current suppliers used by Toly, while manufacturing in Malta and China was considered. Transportation from one geographical location to another was carried out by a combination of sea or air transport and various modes of land distribution, while the use phase considered the package to be carried by the user in a vehicle while commuting to work.

The second stage required an inventory analysis, which involved the use of estimated material data from Granta's database and the calculation of travel distances in each package's life. The energy consumption, water use and cost of materials for all compacts were obtained from the inventory analysis. Impact assessment is the third stage and the GWP of the compacts was evaluated from this stage. The results of the LCA study were then presented and interpreted in the final stage of this LCA process.

Results and Achievements

As shown in Figure 1, the Mary Kay compact contributes roughly three times more to energy consumption than the Gemini and six times more than the Halo, throughout their entire life cycle. Raw material extraction is shown to be the highest contributing life cycle phase for energy use for all three compacts, ranging between 60-70%. The manufacturing and use phases are the second largest contributors to energy consumption for all three compacts. On the other hand, the transport and disposal phases have a negligible contribution to energy consumption, in this case when the package is being manufactured and used in Malta.

Other notable findings include the fact that manufacturing these packages in China will yield roughly 4% and 8% increases in life cycle energy use and GWP respectively, due to the larger distributing distances and higher carbon emissions associated with the production of electricity in China when compared to Malta.

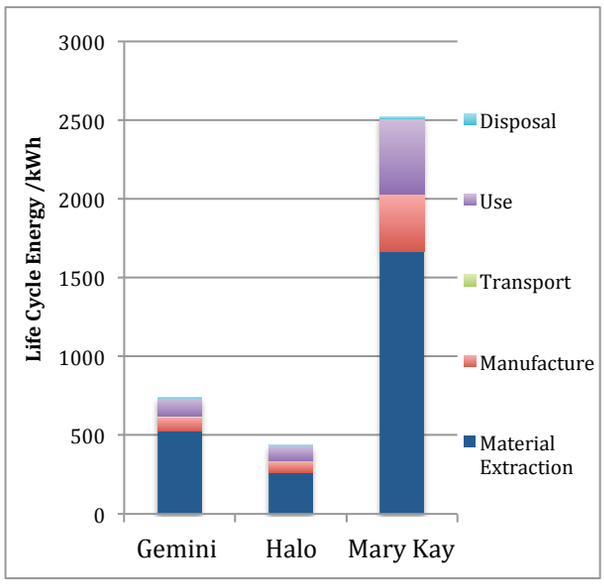

Figure 1: Life Cycle Energy Use for the Gemini, Halo and Mary Kay Compacts

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Design of a Universal Lacquering Fixture

Student: Luke Micallef / Supervisor: Prof. Ing. Jonathan C. Borg / Co-Supervisor: Mr Olaf Zahra

Introduction

Numerous firms in the manufacturing industry are opting for flexible tooling since there is a trend towards higher product variety and shorter lead times. Hence flexible tools such as fixtures are required to respond quickly to a wide variety of parts. *Toly Products Ltd*, is searching for such a tool, to minimise changeover times and storage.

Project Objectives

The industrial objective of this project is to design a universal lacquering fixture, for *Toly Products Ltd*. As a spin-off, the academic objective of this project contributes a design approach that can be used by industrial practitioners to generate universal tools.

Project Methodologies

Engineering design problems utilise a model in order to solve problems. In this case a model referred to as *The Basic Design Cycle* [1] acted as a guide and provided suitable direction. This cycle consists of four main activities – problem analysis, solution synthesis, solution analysis and evaluation. After understanding the problem well, solutions are generated and are analysed. Finally, the best solution is evaluated in order to check if it is a feasible solution. Various design tools were utilised during each stage of the design cycle, to provide a systematic way to generate solutions.

Results and Achievements

The designed universal fixture made use of a new smart material – micro-suction tape. This material makes use of millions of micro sized cups packed tightly together [2] to hold a part into position as reflected in Figure 1. Such a fixture would lead to shorter changeover times, less storage required, less manufacturing costs and also produce less impact on the environment. Moreover, RP models of the fixture were produced to test it on the lacquering process and positive results were obtained. The designed fixture caters for a wide variety of cosmetics which possesses a flat inner surface, as shown in Figure 2. Moreover, the directions taken to produce the universal fixture, were used to establish a design approach to design universal tools.

References

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[Website:]
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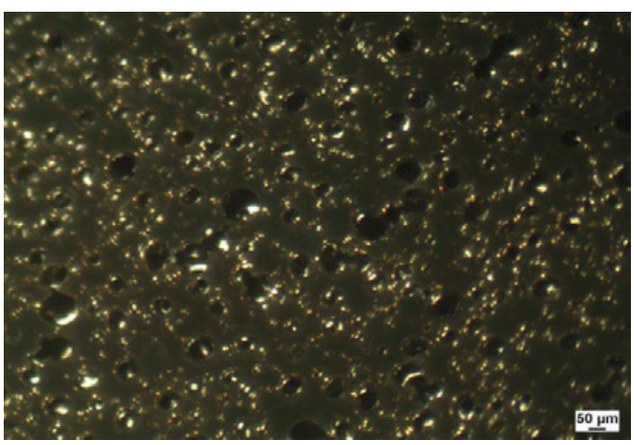

Figure 1: Micro-suction cups

Figure 2: The fixture and various parts it caters for

Performance Analysis of Pattern Heated Thermoforming

Student: Benjamin Mifsud / Supervisor: Dr Arif Rochman

Introduction

One of the largest problems with regards to thermoforming is the lack of control over the wall thickness distribution of the finished product. This project attempted to address that problem by applying a technique known as pattern heating, which involves the use of a patterned screen to manipulate the temperature profile during thermoforming in order to achieve more even material distribution [1][2].

Project Objectives

The purpose of this project was to design and optimize a pattern heated thermoforming process and compare the resulting products' wall thickness and part geometry with traditional forming methods.

Project Methodologies

In order to design an effective pattern heating process, it was first necessary to investigate the performance of standard vacuum forming techniques, not only to obtain a benchmark, but also to identify critical areas with regards to wall thickness.

Research was first carried on the material characteristics of amorphous polyethylene terephthalate (A-PET), the thermoplastic used in this study, to determine the optimal temperature window for thermoforming.

With this in mind, a series of heating tests were carried out using the thermoforming machine available at the Department of Industrial and Manufacturing Engineering (DIME) laboratory, after which further experiments were carried out in order to determine the wall thickness and stretching behaviour of the resulting parts.

Based on this information, critical areas of the samples were identified and series of patterns were designed and tested and the resulting temperature profile analysed. Following this, further tests were carried out in order to optimize parameters such as heating time and pattern distance. Finally wall thickness and stretching behaviour experiments were again carried out in order to draw a comparison to the original results.

Results and Achievements

Wall thickness measurements were taken along three sections of the part, and the results showed dramatic improvements in the identified critical areas.

While originally thicker sections were subjected to greater material stretching, critically thin areas showed improvements in wall thickness of up to 300%, as can be seen in the figure below.

Furthermore, analysis of the material stretching behaviour revealed that a more even distribution along the part geometry was achieved by the application of pattern heating techniques.

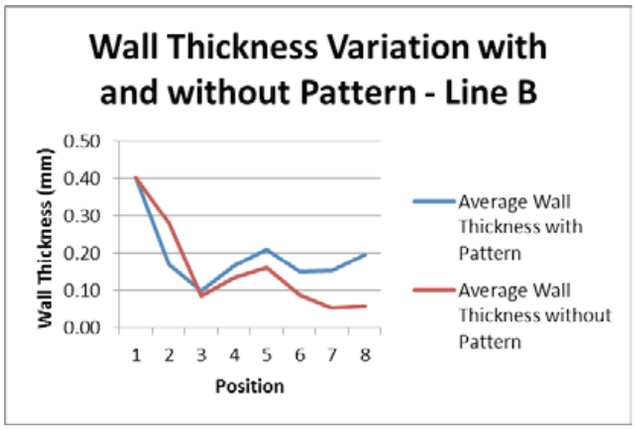

Figure 1: A comparison of the variation of wall thickness along a thermoformed part prior to and after the implementation of a patterned screen

References

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[2] J. L. Throne, 'Understanding Thermoforming' Hanser, Munich, 2008.

Design of a Universal Mirror Separation Device for the Cosmetic Industry

Student: David James Sciberras / Supervisor: Dr Ing. Philip Farrugia / Industrial Partner: Toly Products Malta Ltd.

Introduction

Toly Products Malta Ltd. is a cosmetic company that has produced compacts for over thirty years. The mirror used in the compact is produced by a complex cutting process. This project deals with the way the variously sized and shaped mirrors are separated after they are scribed. The manual method currently in use is the most effortful part of the process.

Project Objectives

The aim of the project was to create a proof-of-concept physical prototype of a universal mirror separation device. Another aim was to generate concepts of the system and to model the chosen solution using Computer Aided Design.

Project Methodologies

The Basic Design Cycle [1] was used to generate the solution to the problem. The current manual process was broken down into tangible steps to analyse the motion closely. A patent search and literature review helped view the current state of the art.
Data collected from Toly Products Ltd led to the creation of a QFD and product design specification. To synthesise a solution [3], a function-means tree, SCAMPER [2] and morphological chart were used. DFx [4] and material selection [5] exercises were then carried out, followed by a detailed CAD drawing. A functional prototype of the working principle was then created.

Results and Achievements

The working principle was proven successful in separating a variety of mirrors as required. This was demonstrated by a working physical prototype shown in Figure 1. Furthermore, the design facilitated an overall improvement of the process by incorporating a heat-treatment aspect proven to increase the quality of cut by Toly Products Ltd. A CAD model of the full process was created as seen in Figure 2.

An in-depth cost analysis proved that the designed machine would have a payback period of 1.42 years, and a very low running cost and energy footprint.
A time study also showed that the machine would have a minimum output of 5,280 mirrors per hour, surpassing the product design specification.

References

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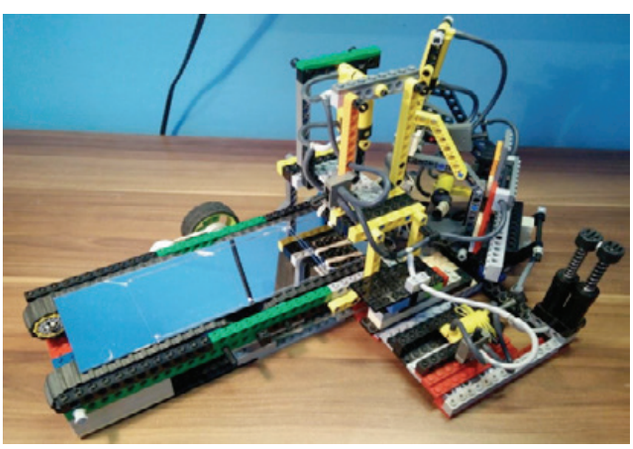

Figure 1: Working Prototype

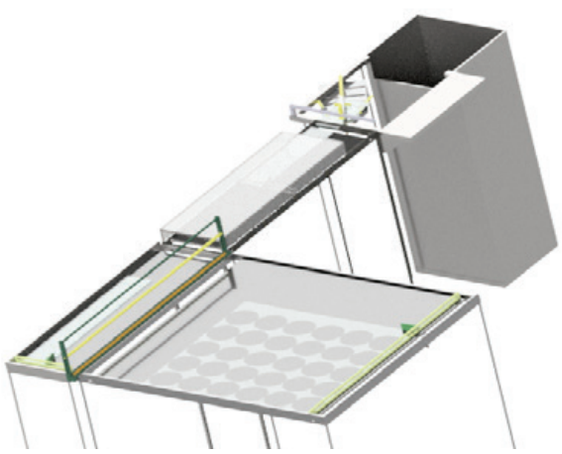

Figure 2: CAD model of the assembled machine

Sustainability Analysis of Cooling in Industry

Student: Keith Tanti / Supervisor: Dr Ing. Paul Refalo

Introduction

Energy and water resources are facing significant pressures worldwide. The need for sustainable manufacturing is urgent, and it is believed that a collective effort by all industries, irrelevant of size, can lead to sustainable development. This project is a typical practice of sustainable manufacturing that looks into the improvement of industrial cooling systems.

Project Objectives

The aim of this project was to analyse the feasibility of introducing a more sustainable cooling technology within Playmobil Malta Ltd's mould cooling system. The feasibility study included aspects related to both technical performance and most importantly the three pillars of sustainable manufacturing: the environmental, societal and financial pillars.

Project Methodologies

The feasibility study set off by the understanding of the current mould cooling system, the objectives and the available cooling technologies on the market. Following the selection of a sustainable technology, a new system setup that eliminated the use of a cooling tower (CT) and introduced a dry cooler (DC) (Figure 1) was devised and analysed in comparison with the current cooling system (System CT). The proposed system was studied with two different configurations (System DC 1 and System DC 2) defining the order of how the equipment within the system operated. The analysis was based on calculations for technical feasibility of both the equipment and the system in Malta's climate conditions and was followed by a sustainability assessment of the proposed system.

Results and Achievements

Results for the proposed setup proved the dry cooler technically feasibly with a higher effectiveness during the colder season. The proposed system showed a significant improvement with both configurations. Over an entire year, electricity consumption (Figure 2) was reduced by 46% with System DC 1 and by 20% with System DC 2. The more effective of the two (System DC 1) would also reduce carbon dioxide emissions by 263 tonnes and eliminate water consumption completely, saving up to 275 m^3 of fresh water every year. With the implementation of the dry cooler, Playmobil Malta Ltd would also benefit from annual savings on maintenance and operational costs amounting up to around €4,800 and over €30,000 respectively.

References

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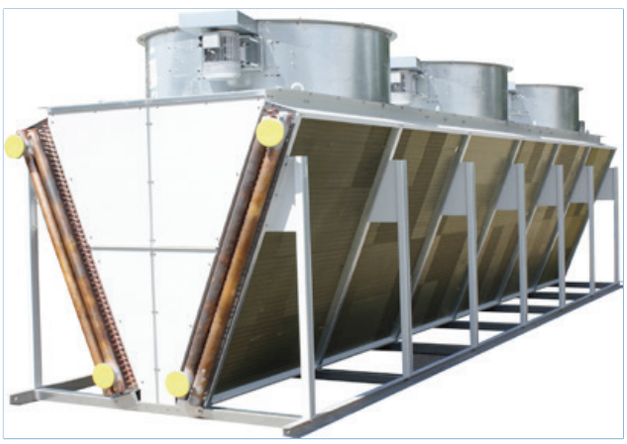

Figure 1: Dry Cooler [1]

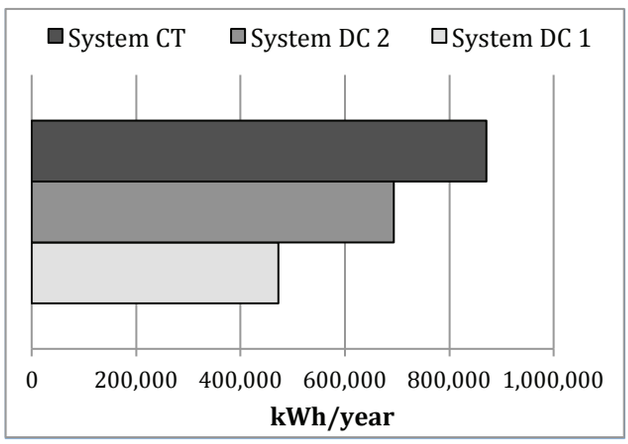

Figure 2: Yearly Electricity Consumption

Sustainability Analysis of Plastic Injection Moulding

Student: Jack Tranter / Supervisor: Dr Ing. Paul Refalo / Co-Supervisor: Dr Arif Rochman

Introduction

Injection moulding is a popular polymer manufacturing technique that is capable of producing high value added products at high output rates. It is very energy intensive; hence, measures must be taken to increase its energy efficiency, whilst simultaneously maintaining production of high quality parts [1].

Project Objectives

This project sought to determine the effect of selected process parameters on the energy consumption of the injection moulding process and quality of the moulded parts. This was done to find an optimal trade-off between the two responses, thus maximizing process sustainability.

Project Methodologies

To obtain a solution the sustainability objective, the design of a bottle opener as a case study part was conducted, shown in Figure 1. Upon finalization of the part design, the mould design was tackled, including simulations of the cavity fill and quality predictions.

Figure 1: Case study part

In order to identify the relationship between he selected process parameters, seen in Figure 2, and the energy consumption and part quality, a 2-level fractional factorial design was utilized to generate an experimental schedule that was followed to collect the relevant energy and quality data required. The energy data was collected by connecting power loggers to the injection moulding machine and its ancillary equipment. The criteria evaluating sample quality were the part length, part mass and a visual inspection of the surface.

The generation of the energy profiles allowed determination of the respective impacts of the phases of the injection moulding cycle. Data analysis utilized ANOVA, upon which the impacts of the process parameters on energy consumption and part quality were determined. An optimization was conducted, upon which the process energy was successfully reduced, whilst maintaining part quality [2].

Results and Achievements

The results, shown in Figure 1, determined that the holding time and the cooling time acquired the largest impacts on the injection moulding process. The part length and surface quality were largely affected by the mould temperature, indicating shrinkage variations and the holding pressure largely affected the part mass.

The optimization of the process parameter configuration acquired a 16% reduction in energy consumption per cycle, at 50Wh per cycle. This means that significant reductions in energy costs on the larger scale are achievable with simple adjustment of the process parameters.

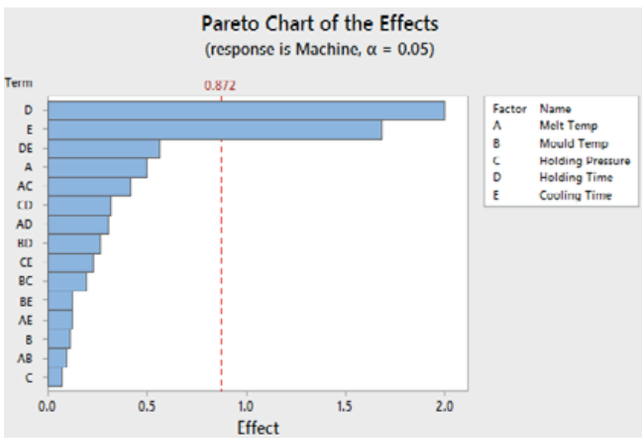

Figure 2: Effects of the process parameters on energy consumption

References

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[2]: Ribeiro, I., Henriques, E, 'Assessment of Energy Consumption in Injection Moulding Process', Proc. of the 19th CIRP Conference on life Cycle Engineering, University of California, Berkeley, USA, 2012

Rapid Tooling Development for Low Volume Injection Moulding of a Cosmetic Compact

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

Introduction

Rapid tooling (RT) is the use of additive manufacturing (AM), which is a layer by layer manufacturing technique using one machine, to manufacture a required tool. AM altered the way innovative engineering designers look at intricate designing processes, inevitably also changing the way companies do business. AM reduced product development time, whilst still maintaining high levels of quality, making it one of the most important technologies in today's and tomorrow's manufacturing.

Project Objectives

The aim of this dissertation is to explore the use of affordable and relatively cheap AM technology like fused deposition modelling (FDM) and stereolithography apparatus (SLA), which are normally used for rapid prototyping, rapid manufacturing and indirect soft tooling, for the production of hard direct rapid tooling which is then used in low volume injection moulding of custom cosmetic compacts.

Project Methodologies

Information was collected from recent published work and gathered in a literature review. A specific cosmetic compact was selected as a case study part. Subsequent to the design of the injection moulding tool and its inserts, the AM technologies and the corresponding polymeric materials were selected to manufacture the AM tool inserts. The printed polymeric AM tool inserts, Figure 1 (right), were fitted in the cavity plate pockets as shown in Figure 1 (left).

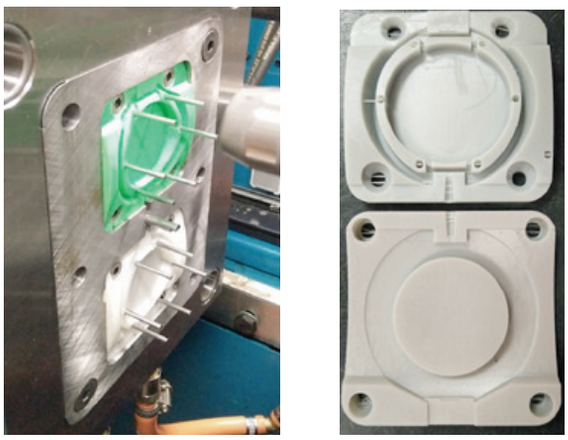

Figure 1: AM tool inserts fitted in IM base machined pockets (left) and SLA printed inserts (right)

Following this, the IM runs were carried out in order to test the tool inserts that were manufactured using different available AM technologies and materials.

Results and Achievements

The results obtained on the two final injection moulding runs were very good. No flashing and a good surface finish was obtained. The tool inserts printed on a PolyJet 3500 multi-jet modelling (MJM) printer had excellent thermal properties. Apart from HDPE, ABS (which has a considerably higher processing temperature) was also successfully injected, using these MJM inserts, for a couple of cycles. Inserts printed on a Viper Si2 stereolithography apparatus (SLA) printer, were considerably less thermal resistant, but a total of 27 cycles where easily accomplished producing 54 good quality parts, some of which are shown in Figure 2.

The maximum number of parts produced was eighty cosmetic bases with the rapid tool inserts manufactured using MJM technology. This proved that, using advanced polymeric materials available today, some of the AM technologies which are normally used for rapid prototyping, rapid manufacturing and soft indirect rapid tooling applications, can also, successfully be used, in hard direct tooling. In this project, FDM, SLA and MJM technologies were used to manufacture mould tool inserts (made out of polymeric materials) which were successfully used in actual injection moulding experiments.

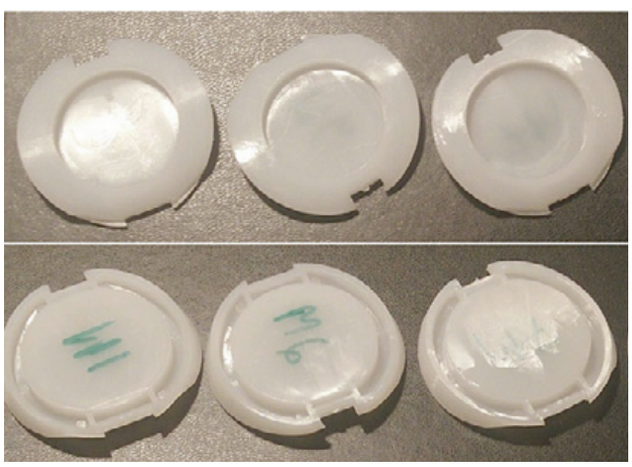

Figure 2: Cosmetic compact bases manufactured using polymeric SLA printed inserts

Performance Measurements on a Micro – Pelton Wheel Setup

Student: Luke Aquilina / Supervisor: Prof. Ing. Tonio Sant / Co-Supervisor: Mr Daniel Buhagiar

Introduction

The University of Malta is currently conducting research on the possibility to change the design of offshore wind turbines to use a positive displacement pump to pump sea water at high pressure to a hydropower plant. The idea behind this is to avoid using the heavier and costlier system that uses a gearbox and generator system. A Pelton wheel is ideal to then collect the power from the sea water pumped from the wind turbine since this type of turbine is well suited for high head water supplies.

Project Objectives

The objectives for this dissertation involved setting up the Pelton wheel located in the Fluids laboratory with an electrical sensor and data logging system. Experiments would then be carried out on the Pelton wheel and result obtained would were then compared with theoretical models.

Project Methodologies

For the experimental setup, the Pelton wheel was first attached to a dynamometer to help measure the torque output, along with an industrial 3 phase power-wash to provide pressurised water flow. The Pelton wheel was equipped with four sensors to measure its performance characteristics; a pressure transducer and a flow meter to measure the pressure and the flow rate of the flow supplied, a load cell to measure the torque output and a magnetic pickup sensor to measure the rotational velocity of the Pelton wheel.

Figure 1: Pelton wheel used during the experiments

Experiments were then carried out on the performance of the Pelton wheel. These included steady state testing where the pressure and load settings were left constant during runs, and deceleration runs where the deceleration characteristics of the Pelton wheel when the power-wash was switched off were measured.

Results and Achievements

Results obtained from the experiments have shown that the overall efficiency of the system implemented was quite low. However, this may be attributed mainly to losses in the nozzles. Since these were mainly intended for industrial cleaning purposes, these were not as efficient as nozzles intended for hydraulic testing. In fact, estimates derived from the experimental results for the nozzle efficiency were as low as 18% for one of the two nozzles used. Using such estimates, the Pelton wheel efficiency was then estimated to be around 60%. Theoretical models using these estimations were then compared to the experimental results and these were shown to be in line with each other as shown in figure 2.

Deceleration tests were also conducted to examine the variation of the Pelton wheel performance with time once the power-wash was switched off. However, calculations on the dynamic system of the Pelton wheel are out of the scope of this Pelton wheel and are left for future work on the subject.

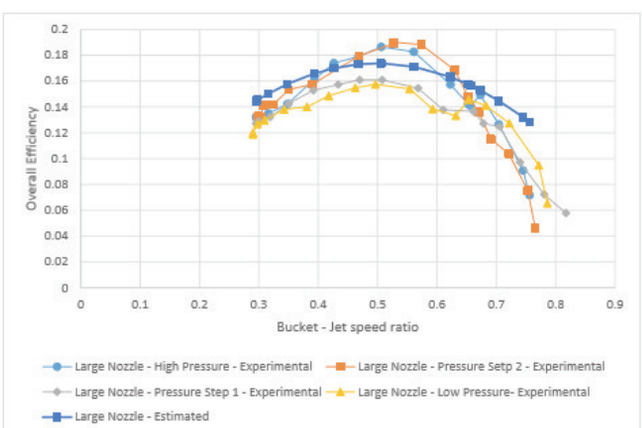

Figure 2: Experimental results compared to theoretical models

Waste Management - Refuse Derived Fuels

Student: Matthew Aquilina / Supervisor: Prof. Robert Ghirlando

Introduction

Biogas is a promising energy source that can be used as renewable energy. The main problem with the use of biogas is, that it contains a number of other gas constituents which hinder effective and efficient use of the biogas energy potential. This dissertation looks into the potential of Pressure Swing Adsorption for the Għallis Landfill. [1]

Project Objectives

- Analyse various biogas upgrading methods
- Select an appropriate biogas treatment technology for the Maltese Islands
- Set-up a physical biogas purification system
- Conduct initial and final biogas analysis

Project Methodologies

A system for gas purification was designed and set up as shown in Figure 1. It consists of a pressurized tank filled with biogas. The biogas flows to a small tank and through a pressure regulator. Then the gas proceeds to pass through two adsorbent filled pressure vessels. Each pressure vessel adsorbs different gas constituents. Pressure gauges and valves offer better control the process.

Figure 1: System for Biogas Purification

The test was conducted for pressures, ranging from 1 to 10 bar with 1 bar increments. After each test the gas composition of the feed and final gas was determined by using a gas meter.

Results and Achievements

32 % average increase in Methane purity was achieved in the biogas final product, shown in Figure 2. While CO_2 volumetric percentage was decreased from 47 % to an average of 19 %. The calorific value of the biogas was also increased by an average of 259 %, as mainly CO_2 and H_2O were decreased.

This system can be easily implemented on the Maltese Islands, as it is robust, relatively efficient and does not require complex equipment. It will also increase the life expectancy of various machinery and equipment.

References

[1] Q. Zhao, E. Leonhardt, C. MacConnell, C. Frear, and S. Chen, 'Purification technologies for biogas generated by anaerobic digestion', Climate Friendly Farming, 2010

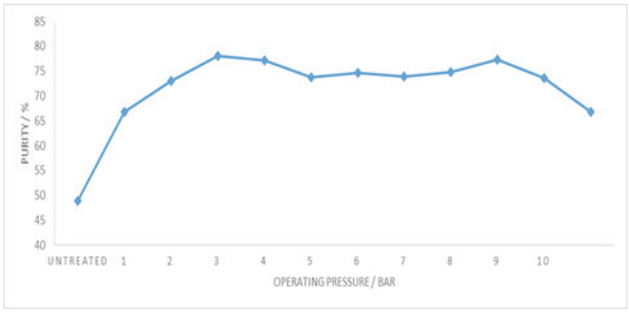

Figure 2: Methane Purity Increase

Continuation of the Analysis of the Diesel Particulate Filter Blockage Problem in Malta

Student: Robert Axisa / Supervisor: Dr Ing. Mario Farrugia

Introduction

The Diesel Particulate Filter forms part of the exhaust after treatment system that is found in modern diesel engines. Its job is to stop the produced Particulate Matter from going into our atmosphere, as it is a harmful exhaust gas. Locally, many diesel vehicle owners are facing problems with their clogged DPFs as regeneration seems to be problematic.

Project Objectives

The aim of this study was to understand this problem in more detail and what are some of the key factors that cause this problem. Another objective was to learn more about the DPF soot that clogs up the DPF.

Project Methodologies

An online survey was carried out amongst local drivers and included both Petrol and Diesel owners. Through the help of Transport Malta, 4600 letters were sent to owners of Euro5 and Euro6 diesel vehicles which notified them of this study. Furthermore, the survey was also sent out through social media. Questions regarded different topics such as the use of vehicle, vehicle problems and the vehicle itself. Collected data was then statistically analysed.

As regards the DPF soot, experiments which aimed to find the Calorific Value and Hydrogen to Carbon ratio were performed. Other materials were also tested which were then used as benchmarks.

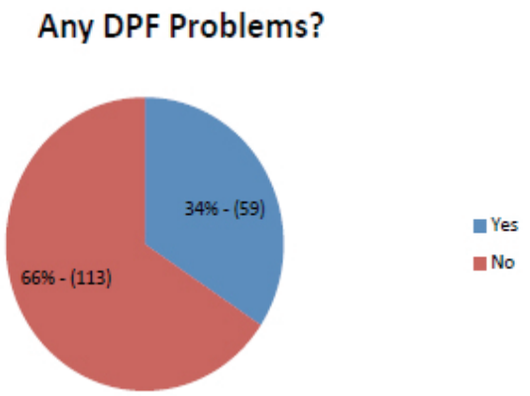

Figure 1: Problematic DPFs

Results and Achievements

A total of 310 participated in the survey, with the majority of them being diesel owners. It resulted that 34% of the diesel respondents had experienced DPF problems with their vehicle (Figure 1). There are many local remedies but costs can range from below €400 up to more than €1250. Success of these remedies also varies. It also resulted that most people knew about the DPF's job but were not aware of how their behaviour can affect it.

More advanced statistical tools (Logistic Regression Analysis) were used to identify some of the most important parameters which affect the DPF's performance. Results are shown in Figure 2, were the strongest parameter was 'Pay attention to revving' and 'Hours spent in traffic daily' was the weakest (from Sig. Column) .

From the DPF soot experiments, it resulted that it has a high percentage of Carbon content. Calorific Value for the soot was comparable to that of Hard Coal [1], and had an H:C ratio of 0.0962. The other tested materials were Diesel and Printer Toner.

References

[1] - T. Trus, IEA Coal Data Systems, 1st ed. International Energy Agency - Energy Statistics Division, 2010, p. 11.

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	170.508[a]	.000	0	.
Year of Manufacture	179.649	9.141	7	0.243
Origin of Vehicle	174.300	3.791	3	0.285
Engine Capacity	175.941	5.433	3	0.143
Hours of driving per week	177.239	6.731	4	0.151
Hours spent in traffic daily	173.899	3.391	5	0.640
Duration of most frequent drive	177.187	6.678	3	0.083
Gear-box type	172.178	1.670	2	0.434
Pay attention to revving	174.247	3.739	1	0.053
Gender	170.818	0.309	1	0.578

Figure 2: Results of Statistical Analysis

Structural Analysis on a Wind Turbine

Student: Paul Joseph Borg / Supervisor: Prof. Martin Muscat

Introduction

The driving force behind the Għammieri wind turbine was a need for cleaner energy. The traditional multi-bladed Chicago-type wind-driven turbine was used for a number of years for its water pumping uses, yet nowadays the Maltese landscape has become dotted with abandoned and decayed turbines, since the introduction of more efficient electrically powered water pumps has completely taken over.

Project Objectives

The objective of this dissertation was to conclude this eight year project, where measured forces due to wind were compared to the theoretical equations that have created the turbine in the first place. Fatigue analysis for critical areas were also conducted to check the expected life of the system.

Project Methodologies

The project was split into two parts – to determine the forces acting on the turbine due to wind, and to determine the expected turbine's lifetime by means of fatigue analysis.

Forces due to wind were acquired by means of sixteen strain gauges that were attached to the mast, which is a two metre long tube on which the nacelle yaws during operation, shown in figure 1. Wind forces would create moments on the mast, where the strain gauges would pick up the subsequent strain created.

There was a need to distinguish between moments created by forces due to wind, and moments created by the nacelle's off-centre weight. After the forces due to wind were obtained, they were compared with respect to the static equations that had created the turbine in the first place [1].

The oscillating wind forces due to fluctuating wind speeds were sources to potential fatigue failures. Fatigue analysis was therefore carried out by means of finite element analysis on the mast and its welds, which are the areas that undergo most stresses, when compared to the rest of the structure [2].

Results and Achievements

Static wind forces on the turbine were more than 10 times lower than the design equations that spawned the turbine in the first place. On the other hand, fatigue analysis proved that neither welds, nor the mast itself would fail due to fatigue stresses, unless the turbine was intentionally operated under heavy winds, and generally bad weather conditions.

Figure 1: Wind turbine during operation

References

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[2] Farrugia A, "Conversion of the Chicago Type Wind Pump to Generate Electricity – The Structural Aspect". B.Eng. dissertation, University of Malta, Malta, 2011.

Simple Solar Still Kit

Student: Michaela Buttigieg / Supervisor: Prof. Ing. Robert Ghirlando / Co-Supervisor: Dr. Ing Paul Refalo

Introduction

The project was a continuation of work carried out to optimise the simple solar still [1] (Design 1 shown in figure 1a). The unit utilises solar radiation to distil water. The vapour condenses against the glass surface and collects at the side channels.

Design 1 interested missionaries for application in developing countries. This required a design iteration to produce a kit.

Project Objectives

The initial objectives of the project were:

Design a kit for a simple still, based on Dr. Paul Refalo's work that is easy to ship and build.

To design a simple solar still that can be easily built with materials available in developing countries.

Quality assurance objectives were added:

Build a prototype utilising food-grade materials.

Project Methodologies

Problem analysis was carried out following 'Human centred design' [2] with the aim of understanding the market actors and the constraints of implementing the product. This involved speaking to missionaries and operating Design 1. Other solar still kits were investigated in terms of yield, cost, assembly and manufacturing method. A Product Design Specification (PDS) was carried out prior to solution analysis. Solution analysis was carried out by utilising the Analytical Hierarchy Process to rank criteria prior to assessing concept designs through a Pugh decision matrix. The final concept design was assessed through a Design Failure Mode and Effects Analysis to give the final design. The packaging design followed the packaging code BS 1133[3]

A prototype was fabricated and used to test ease of assembly and operated to ensure that the design maintains high water yield.

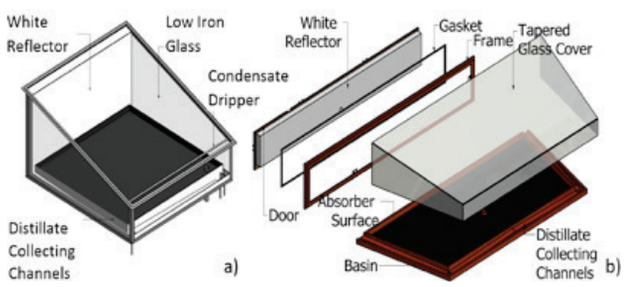

Figure 1: CAD model of a) Design 1 b) Revised Design

Results and Achievements

A kit containing 10 units was designed each maintaining the same footprint of design 1 (1 m^2). The kit is 1.4 m high and sits on top of a stevedore pallet (1.6 m x 1.2 m). The revised design was frameless and divided into 3 subassemblies: glass cover, basin and frame and door. Assembly would involve sealing the glass cover to the basin and then sealing the door and frame to the two. The design targeted easier maintenance by changing point of access. The new design opened from the back door by clamp-latches. Water quality tests [4] carried out on design 1 at the Water Services Corporation laboratory suggested that the distillation process eliminates coliforms present in feed water. Food-grade silicone was utilised for the prototype. The yield achieved was 20-25 per cent lower than design 1 for similar weather conditions. Leaks were detected at the basin.

Various manufacturing methods were recommended based on batch size of kits.

References

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[2] T. W. Brown, Jocelyn, "Design Thinking for Social Innovation " *Stanford Social Innovation Review,* vol. Winter 2010, 2010.

[3] BSI, "BS 1133-8:2011," in *Packaging code Part 8: Guidance on wooden boxes, cases and crates*, ed. London: BSI Standards Limited, 2011, p. 124.

[4] *on the quality of water intended for human consumption,* T. C. o. t. E. Union 330/32, 1998.

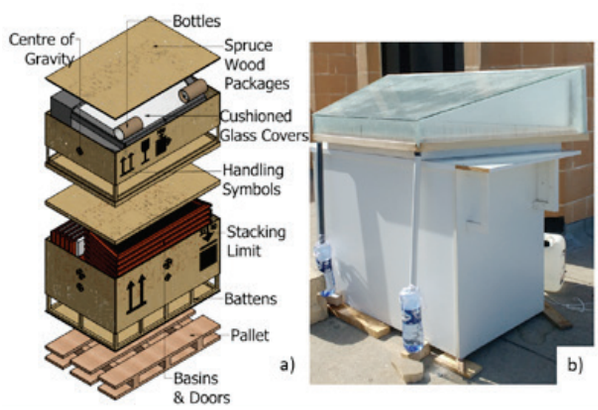

Figure 2: a) CAD model of packaging b) Prototype

Development of a Common Rail Diesel Engine Control Scheme and Experimental Investigation on Exhaust Gas Recirculation

Student: Carl Caruana / Supervisor: Dr Ing. Mario Farrugia

Introduction

Compression ignition engines have become increasingly popular in the private car sector and industrial equipment. Several advancements were made in this sector, mainly in the aim to reduce harmful emissions whilst retaining the rated power output. Such compromise is possible through the precise control of injection parameters for the optimisation of combustion and introduction of exhaust gas after-treatment.

Project Objectives

This project regarded a progressive study on a common rail diesel engine, mainly through development of a control scheme implemented with a programmable ECU, together with benchmarking of the Exhaust Gas Recirculation system.

Methodology and Results

The flow rate of fuel through a pilot-operated diesel injector is dependent on both duration of injection and rail pressure. Common rail diesel engines are characterized with a variable fuel pressure, which can vary between 300Bar and 1600Bar to improve the atomization of fuel. In this project a control scheme was devised whereby the pressure in the fuel rail was proposed to be a function of the torque requirement and engine condition represented by the driver request and mass air flow reading respectively. The control scheme developed was implemented through a prototype version of the Reata Engine Management.

In support of the pressure control scheme development, several tests on the injection system were performed. These included the flow testing of the injectors on a flow bench and engine benchmarking using the OEM engine management. Further testing using OnBoard Diagnostics (OBD) also followed.

The second aim of this project was to study the principles of the exhaust gas recirculation system fitted on the engine used in this project. Benchmarking of the system was carried out using LabVIEW data acquisition.

The behaviour of the EGR solenoid valve, together with the EGR mass flow rate were acquired at different engine conditions for future progression on the prototype engine management. The flow rate of EGR was measured with an orifice plate method, following a prior error analysis for determination of optimum EGR line and orifice diameters.

To analyse the effectiveness of the exhaust gas recirculation system, a UniNOx sensor was sponsored by Continental-Corporation and a complementary CAN module was kindly sponsored by Methode Electronics. This enabled further research and evaluation of the NOx emission reduction through the EGR system.

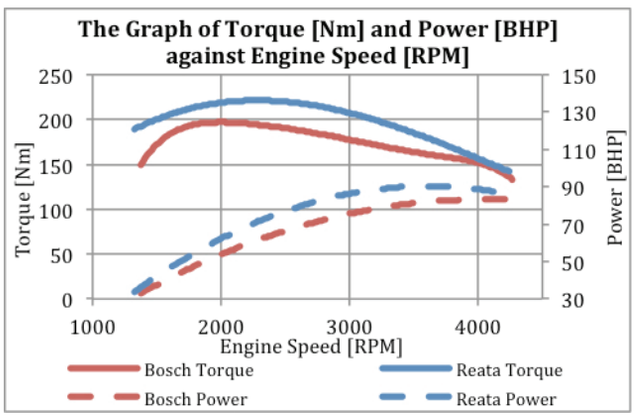

Figure 1: The graph of torque and power developed by the Reata and Bosch calibrations against engine speed

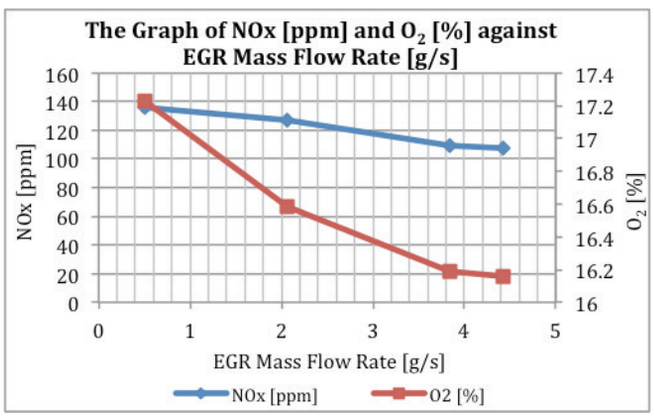

Figure 2: The graph of NOx [ppm] and O_2 [%] against EGR mass flow rate [g/s]

Open Field Testing of a Micro Wind Turbine

Student: Cecille Marie Cassar / Supervisor: Prof. Ing. Tonio Sant / Co-Supervisor: Ing. Robert N. Farrugia

Introduction

Once a prevalent method of pumping up water in rural Malta, Chicago wind pumps are quickly being replaced by electric pumps or left to deteriorate. The University of Malta hence developed a 9-bladed micro wind turbine (see Figure 1), with the aim of designing an aesthetically similar, but more efficient system to replace these damaged pumps. [1]

Project Objectives

This project was intended to carry out the first phase of performance testing for the installed turbine prototype. An analytical model of the turbine was also created to allow for comparison between predicted and actual performance results.

Project Methodologies

XFOIL was used to analyse aerofoil characteristics and corrections were subsequently applied to them. This data was used for the blade element momentum theory which had been previously coded in MATLAB. The existing code was simplistic, thus it was modified to improve steady-state modelling accuracy. Tip losses, hub losses, the Glauert correction and the cosine cubed approximation were all integrated.

Approximately eighteen and a half hours of data were logged at a frequency of 1 Hz and averaged over one minute intervals. The Method of Bins was employed to split it into categorised yaw angle, wind speed and tip speed ratio bins of fixed ranges. This allowed for wind site analysis, and the generation of power and C_P-□ curves at different yaw angles.

Figure 1: Installed 9-bladed turbine

Results and Achievements

The wind site analysis revealed the non-ideal nature of the turbine location. Conditions experienced during testing classified the site as non-flat with very high turbulence levels and significant yaw errors. Barely any collected data fell into low (0°-10°) yaw error bins. These unsteady flow conditions prove to be challenging to accurately predict and model.

The power curves from testing data show an expected decrease in power at higher yaw angles, alongside an increase in power with increasing wind speeds. Good comparison was achieved to the cosine cubed approximation. The C_P-□ curves obtained through data manipulation show the expected curved shape, but differ in the optimal tip speed ratio value when compared to analytical predictions (see Figure 2). An interesting observation was that there was no decrease in the power coefficient with increasing yaw errors up to 40°. This can be the result of dynamic stall and unsteady flow conditions.

Overall, the designed turbine is efficient; producing higher power than predicted, in a non-ideal location even at high yaw angles.

References

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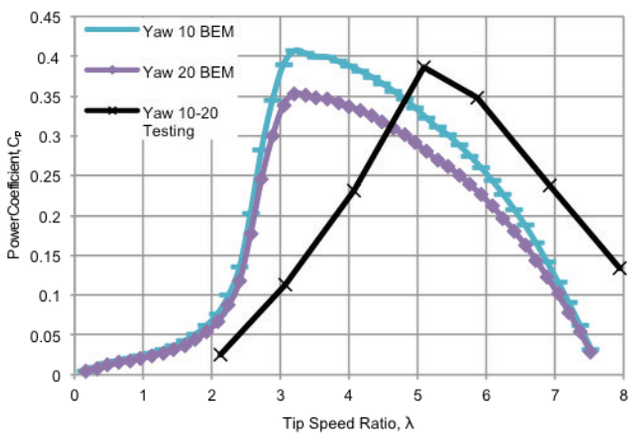

Figure 2: Comparing C_p-□ curves for yaw 10°-20°

Monitoring the Limb Motion

Student: Christina May Cefai / Supervisor: Dr Ing. Zdenka Sant

Introduction

The complex movement of the human body is facilitated by joints. With an aging population, wear and tear injuries in these joints are becoming more common, leading to an increase in knee and hip replacements. After the surgery, rehabilitation, both with a physiotherapist and at home, is essential to gain the maximum potential of the new artificial join.

Project Objectives

The main objective of this final year project was to design, assemble and program a mobile device which is able to monitor the patient's progress of the rehabilitation of knee and hip replacement. The created device had to be tested and verified to confirm its reliability.

Project Methodologies

The created device named the 'Mobile Motion Capture' (MMC) uses surface electromyography (sEMG) to measure the activity of the muscle while a triple axis accelerometer is used for motion capture, in conjunction with a goniometer and camera. The device is also able to save the data collected from the sensors onto a microSD memory card which could then be easily transferred to a computer for further analysis.

The 'Muscle Sensor V3' [1] is a sEMG that records the electrical potential of muscle, while a 'SparkFun ADXL335' [2] is the triple axis accelerometer capturing the motion. The measured data is saved on a microSD memory card by means of a 'SparkFun MicroSD Shield' [3]. All these components are connected to an 'Arduino UNO – R3' [4], which is a programmable microcontroller for the MMC.

After the device was assembled and programmed, it was tested simultaneously with the VICON system in the Biomedical Engineering Laboratory at the University of Malta. The test involved measuring the activity of the vastus medialis and capturing the motion of the tibia while extending the knee in a seated position, keeping the femur as static as possible. The Newton-Euler and Lagrange method of dynamical analysis were performed on the tibia using the motion capture data from the MMC and the VICON system.

Results and Achievements

The device was verified by comparing the MMC measured and compute data to that obtained from the data collected by means of the VICON system. A comparison was made between the Newton-Euler, Lagrange, and sEMG computed data from the MMC and VICON system. The results of both methods of mechanical analysis were also compared to each other to prove that the method of analysis was correct.
It was concluded that the MMC produced accurate and reliable results and is a positive step forward in better monitoring of patient's rehabilitation progress and limitations. It will create the opportunity to record muscular activity in the patient's natural environment.

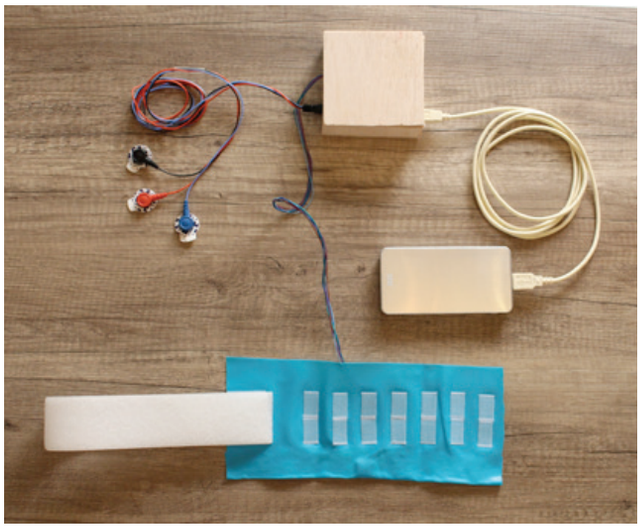

Figure 1: The Mobile Motion Capture device

References

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Finite Element Modelling of the Hole Drilling Technique for Residual Stress Analysis in a Joint of Dissimilar Materials

Student: Sarah Ciappara / Supervisor: Dr Ing. Pierluigi Mollicone

Introduction

A Finite Element Modelling (FEM) strategy based on a residual stress measurement experiment was implemented with the scope of identifying the residual stresses that are present between E36 Ultra-low carbon steel component and aluminium 1050-H14 specimen, joined together in their solid state through Friction Melt Bonding [1], which is not yet governed by established standards.

Project Objectives

The first objective of this study was to investigate if it is possible to reproduce the hole drilling experiment though FEM techniques, after which the model was extended to cover the dual material specimen in an attempt to obtain a better understanding of the resulting residual stress.

Project Methodologies

Initially, the modelling procedure of the hole drilling technique was validated by modelling a single material spot welded AISI Mild Steel specimen with known residual stresses, governed by established standards.
Progressively, this model was extended to cover the dual specimen which was subjected to a tentative residual stress, taken from literature, with the intention of comparing the extracted model strain relief, with the experimentally derived relationship. The aim of this methodology is to obtain an understanding of the magnitude and direction of the initially applied residual stress that would drive the model extracted strain relief closer to that which is derived experimentally.

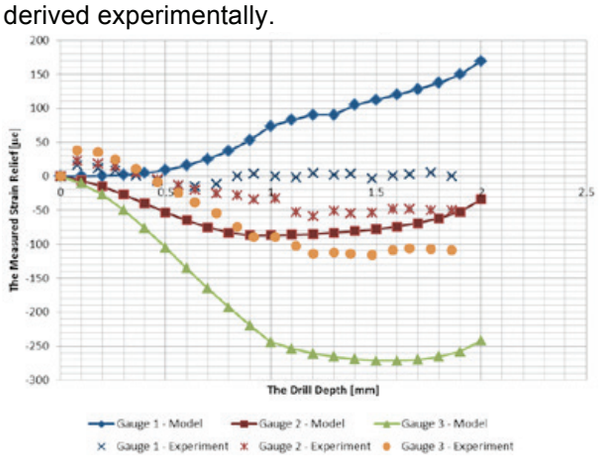

Figure 1: Strain Relief [μe] vs. Drill Depth [mm] with $\sigma_y = 230\ MPa$

Results and Achievements

From the modelled single material spot welded steel specimen it was concluded that the residual stresses obtained from the model were comparable to the ones from the experiment and the comparison of the strain relief against drill depth relationship between the model and the experimental set-up resulted accurate in the longitudinal and transverse directions. Therefore, for these directions the model could be validated as a credible system to reproduce the hole drilling experiment.
In the Friction Melt Bonded specimen when the yield strength of steel was applied in the longitudinal direction along the length of the weld (gauge 3), the strain relief relationship in *Figure 1* was obtained which clearly shows a large discrepancy between the model and the experimental relationship.
Therefore, in an attempt to reduce this deviation half the yield strength of steel was applied instead which resulted in the strain relief relationship illustrated in *Figure 2*.
It can hence be concluded that on welding an E36 Ultra-low carbon steel specimen with aluminium 1050-H14 through Friction Melt Bonding, the residual stress is closer to half of that present in a welded steel specimen.
In conclusion, it is hoped that this study proves fruitful for other researchers interested in this field.

References

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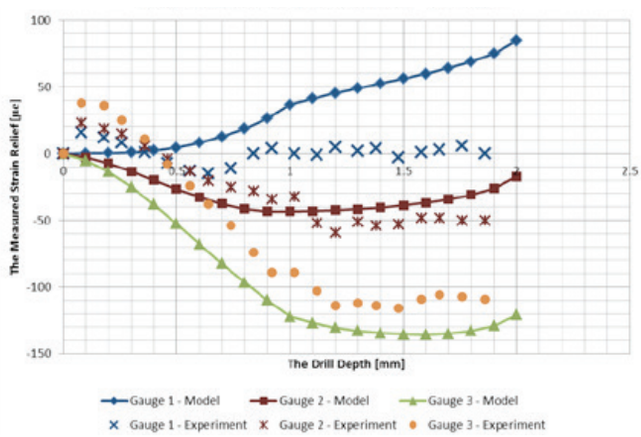

Figure 2: Strain Relief [μe] vs. Drill Depth [mm] with $\sigma_y = 115$ MPa

Investigation of Two-Phase Closed Thermosyphons

Student: Braden Cutajar / Supervisor: Dr Ing. Christopher Micallef

Introduction

Two-phase closed thermosyphons are widely used in industry as passive heat exchange devices. They make use of the latent heat of vaporisation of the working fluid in order to transfer heat from evaporator to condenser against the gravitational field. Their benefits include very low thermal resistance and their function as a thermal diode.

Project Objectives

The aim of this project is to investigate the change in thermal resistance with change in heat input, inclination, diameter, fill ratio and adiabatic length as well as a qualitative study on the boiling and flow regimes as observed in the adiabatic section.

Project Methodologies

Thermocouples were attached to the evaporator and condenser to record their temperatures. The temperatures along with the heat input were used to calculate the total thermal resistance. An experiment for each combination of; five inclination angles, five heat input levels and three diameters was carried out. Three fill ratios and two adiabatic lengths were tested with all other variables constant. Ten readings for each thermocouple over a period of twenty minutes were taken. During all experiments, the glass adiabatic section was used to investigate the boiling and flow regimes inside the thermosyphon (Figure 1).

Figure 1: Exposing glass adiabatic section

Results and Achievements

It was observed that total thermal resistance of the thermosyphon decreased with increasing heat input (Figure 2) and diameter. Previous literature unanimously reported this result. This observation also agreed to a relatively good extent to the theoretical values, although there was a divergence between these two values with increased heat input.

Inclination angle and adiabatic length did not have a significant effect on thermal resistance. Fill ratio seemed to affect how thermal resistance responds to varying heat input and may hint at the existence of an ideal fill ratio for temperature regulation.

A phenomenon known as Geyser Boiling Phenomenon (GBP), studied by Sarmasti Emami et al. [1], was observed to occur at a certain heat flux range. Outside this range and for large diameters GBP was not observed. It is hypothesized that plug flow in small diameters is the cause of GBP.

References

[1] M. R. Sarmasti Emami, S. H. Noie, M. Khoshnoodi, M. T. Hamed Mosavian and A. Kianifar, "Investigation of Geyser Boiling Phenomenon in a Two-Phase Closed Thermosyphon," Heat Transfer Engineering, vol. 30, no. 5, pp. 408-415, 2009.

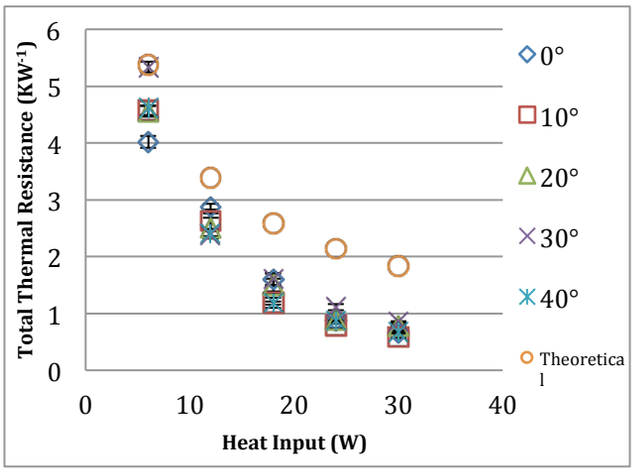

Figure 2: Plot of heat input with thermal resistance

Low Velocity Impact Response of Composite Sandwich Panels

Student: Daniel Dalli / Supervisor: Dr Ing. Claire De Marco

Introduction

Sandwich panel construction is increasingly being implemented in structural applications requiring high strength- and stiffness-to-weight ratios. Impact damage on sandwich panels has received a great deal of focus, particularly the low velocity impact response that the structures exhibit when subjected to impacts such as dropped tools or debris. [1,2]

Project Objectives

The main objective of the project was to investigate the different impact responses exhibited by single layer and multi-layer sandwich panels. Analytical models were applied to predict the impact response, including contact law relationships, the spring-mass model and the energy balance model.

Project Methodologies

In this project, sandwich panels were fabricated using facesheets of chopped strand mat and woven roving E-glass fibres and Polipol™ polyester matrix, bonded to DIVINYCELL® H100 polyvinyl chloride foam core, using a hand lay-up procedure, cured under vacuum bagging. The panels were subjected to dropweight tests, according to the ASTM D7136/D7136M-05 [3]. An integrated electronic piezoelectric force sensor was used to measure the force-time history of the impact.
Two types of panels were fabricated; a traditional single layer panel and multi-layered structure. The multi-layered panel was constructed using less resistant facesheets and the extra reinforcement of the intermediate layer.

Figure 1: Multi-Layer Sandwich Panel

Results and Achievements

In both types of panels, the typical damage characteristics included extensive matrix cracking, delaminations and fibre breakage in the facesheets as well as core crushing. The intermediate layer in the multi-layer panel contained the damage in the upper half of the panel. On the other hand, the single layer sandwich experienced deeper indentation of the indentor.
Contact law relationships and the spring-mass model were used to model the impact, focusing on the contact, bending, shear and membrane stiffnesses. The energy balance model was used to predict the maximum load sustained by the panels.
When using the standard size indentor (16mm diameter), a good degree of accuracy was obtained from the energy balance models. The proposed model, incorporating damaged stiffness of the multi-layer also achieved good results.

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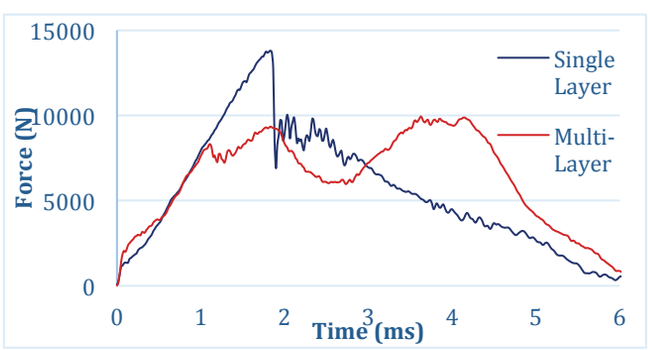

Figure 2: Typical Force-Time Histories

Preliminary Design and Analysis of a Multi-Hulled Ship

Student: Julian Debono / Supervisor: Dr Ing. Claire De Marco

Introduction

Multi-hull ships are a type of marine vessel that are dynamically progressing with regards to performance and production growth. Advancements in these marine vessels have been introduced due to a remarkable growth in the technical papers being published discussing multi-hulled ships and their benignant features.

Project Objectives

The main project objectives were to design a suitable hull design for the trimaran (tricore), selecting a suitable material for the hull, perform a stability and resistance analysis on different tricore configurations, selecting a final tricore configuration and obtaining power requirements for the final configuration.

Project Methodologies

Initially a research about the advantageous features present in multi-hulls was performed and an analysis on current multi-hulls was tackled. Following the research, a study on the resistance and stability features of multi-hulls was performed. After the theoretical research was completed, a tricore (trimaran with 3 identical hulls) hull was designed using the naval architecture software, Maxsurf Modeler [1]. A suitable tricore hull was designed so as to obtain good slenderness features. Additionally, a material selection procedure was carried out so as to determine the most suitable material for the hull to be used in a marine environment. From the chosen material an estimate for the weight of the hull was obtained and several weights were allocated on the tricore configurations for testing purposes. During the testing stage, the tricore configurations were tested in both Maxsurf Stability [2] and Maxsurf Resistance [3] so as to be able to analyse the behaviour of the tricore with varying hull placements. The features that were modified for each hull configuration were the separation, stagger distance and draught of the tricore. In the resistance analysis, the tests were performed at the correct draught determined from Maxsurf Stability [2]. From the stability and resistance results obtained, a suitable tricore configuration was determined ensuring it satisfies the HSC 2000 criteria [4]. The configuration will have good stability and resistance properties overall.

Results and Achievements

From the testing performed, several results were attained. With regards to the stability analysis it was determined that with an increase in separation and stagger distance, both the transverse and longitudinal stability features will be improved. With regards to the resistance analysis, it was determined that with increasing speeds and separation and stagger distances, the overall interference resistance will be reduced along with weaker hump/hollow effects. Therefore it was concluded that a suitable separation and stagger distance should be present in a tricore configuration so as to enhance both stability and resistance characteristics without hindering the ship's operation at sea.

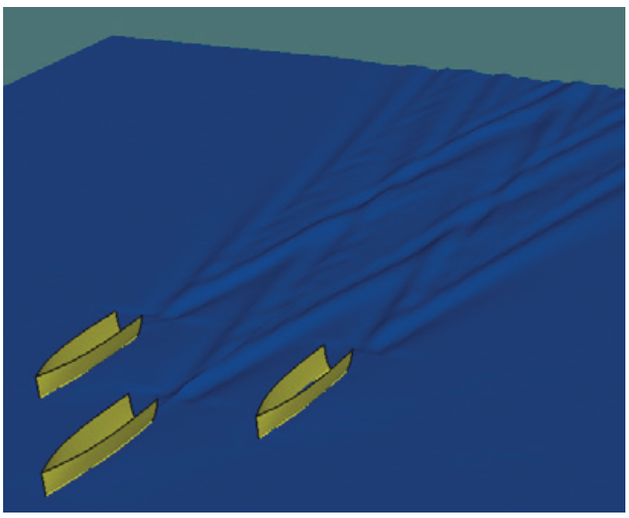

Figure 1: Final tricore configuration

References

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Design Improvements on an Underwater Vessel

Student: Christopher Dimech / Supervisor: Prof. Martin Muscat

Introduction

A towfish is an underwater vessel that can be used for monitoring sea pollution. It is equipped with the necessary sensors and cameras which are able to monitor pollutants, jellyfish and plankton population. The towfish is towed behind a surface ship and hydroplanes and elevators are used to control the depth of dive. Several designs have been done over a number of years by students within the Department of Mechanical Engineering. The latest design which stems from the project BIODIVALUE incorporates all the required features but suffers from excessive loading on the main flanges. These flanges allow access to the inside of the towfish in order to affect repairs or change its payload.

Project Objectives

The main objective of this project was to re-design the towfish incorporating the necessary modifications keeping the depth of dive to be 50 meters below sea level and the towfish to be positively buoyant so that when it is not being towed, it rises to the surface of the sea. Workshop drawings for the main body were also produced in order to implement the modifications.

Project Methodologies

The towfish was considered as a pressure vessel which consists of three shells: a hemisphere, a cylinder and a cone as shown in Figure 1.

The material chosen for the towfish was structural steel S235 having suitable mechanical properties, yield and tensile strength.

The design of the towfish was carried out according to EN13445-3:2009 (European Standard for Unfired Pressure Vessels – Design). Design by Rule was used to calculate some of the dimensions and nominal thicknesses of the major components, including the required modifications in the main cylindrical shell. An obround opening flush with the surface was introduced as shown in Figure 2. Design by Rule was mainly used to prevent buckling in any of the three main shells. Some of the clauses in EN 13445-3 were adapted in such a way that they suit the proposed design.

Following that, Design by Analysis was carried out to check for the structural integrity of certain components. It acts as a complement to Design by Rule wherever this does not cover the required design.

Results and Achievements

The results showed that Design by Rule was used correctly for modifying the towfish main body since the FEA analysis did not show any yielding in the material.

The connections between the cylinder and the hemisphere as well as that between the cylinder and the cone were no longer plastically deformed. This was achieved by eliminating the flange connections, increasing the shell thickness by 1mm and welding the three shells together.

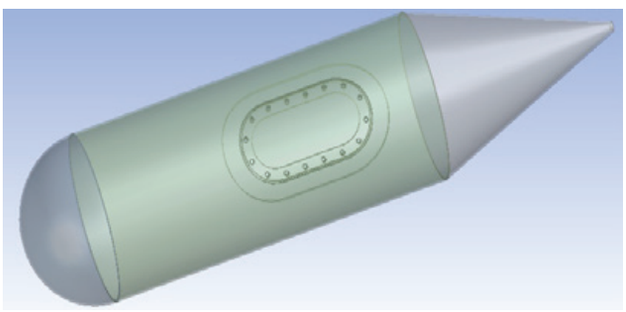

Figure 1: Main body of the newly designed towfish

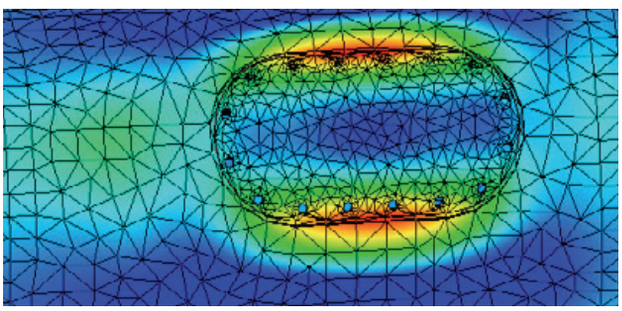

Figure 2: Maximum deflection of 0.04mm at the opening

Solar Cooling

Student: Dean Farrugia / Supervisor: Prof. Robert Ghirlando

Introduction

In this project, several models of an existing solar cooling plant were developed and tested using the software simulation package *Insel*. Since the system was over-designed to enable operation even on overcast days, excess thermal energy is generated by the plant on clear days with high irradiation values, leading to hazardous vaporisation and pressurisation within the system piping.

Project Objectives

To construct a model using environment simulation software and to include several modifications to the current design with the aim of exploring options on how to manage the excess thermal energy developed at the plant.

Project Methodologies

The solar cooling plant is composed of five main components, as follows: an array of solar thermal collectors, a hot water storage tank, a vapour-absorption chiller, a dry re-cooling unit, and a cold water storage tank. Components were simulated individually by utilising dynamic models of the equipment available through the simulation software. The tests were carried out under constant input conditions in order to analyse both transient and steady state responses. The models were then validated by comparing the results to those found in literature.

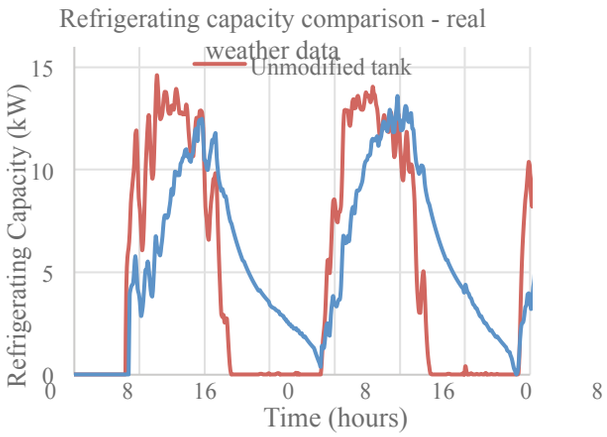

Figure 1: Refrigerating capacity variation

The models were combined to simulate the complete solar cooling system under constant environmental conditions. Subsequently, simulations were performed using real weather data over a four-day timespan, obtained through meteorological reference software, *Meteonorm*. The weather data simulations provided insight into plant behaviour during all parts of a given day, including periods of little or no insolation. Modifications were added to the existing plant design and were then simulated under identical conditions to the previous tests. Modifications include varying the dimensions of the hot water storage tank and selectively operating sections of the collector array.

Results and Achievements

For each system modification, the variation in temperature at the inlet and outlet of all hydraulic circuits was analysed, in addition to component specific data such as refrigerating capacity developed by the chiller and solar collector efficiency. The volume of the hot water storage tank was varied between $0.2m^3$ to $3m^3$ along with corresponding pump flow rates. The four most viable solar collector array configurations were also tested and a notable increase in collector efficiency was noted for a reduction in collector area. The results suggest that by increasing the size of the hot water tank and exploiting the effects of thermal stratification, overall system performance may be improved.

References

[1] Schumacher J., '[Insel 8 Tutorial', Doppelintegral, Stuttgart/Germany, 2012.

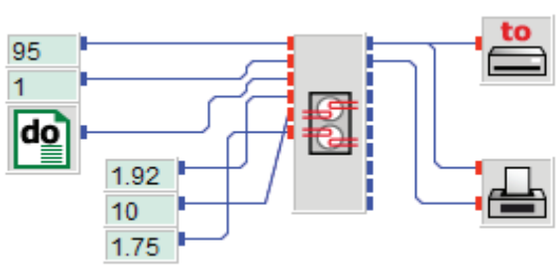

Figure 2: Workspace for the simulation of an absorption cooling machine, from *Insel8* [1]

Robust Design Methodology for Displacement Vessel Hull Optimisation

Student: Jean-Paul Farrugia / Supervisor: Dr Ing. Simon Mizzi

Introduction

Efficient hull design is the goal of any today's ship owner. With stricter environmental regulations and a finite fossil fuel supply, means of reducing power requirements of any vessel are adopted from the earliest design stages.

Project Objectives

The aim of this study is to analyse an existing hull design and through the use of Robust Design strategies, reduce its resistance at cruising speed.

Project Methodologies

To perform a Robust design study, it is essential to perform a number of experiments on the object under study in order to find its response towards changing parameters. [1] The first step was therefore creating an automated system to generate a number of hulls and record their hydrodynamic performance.
This automation process was achieved using an *Excel VBA* code which can access and alter designs in *Maxsurf Modeler* as well as obtain resistance from *Maxsurf Resistance*. *ANSYS* workbench was then used to create a design of experiments (DoE) which communicates with *Maxsurf* through the *Excel VBA* code. The control points of the vessel's hull were set as the input factors and the resistance and block coefficient were set as the response parameters.
Using this setup, an initial DoE was generated using fourteen control points evenly spread along the hull to find the most sensitive regions of the hull. The data was exported to *Minitab* and analysed using a Pareto chart displaying up to two term interactions. On identifying the most significant regions, an additional fourteen local control points were selected as the input factors for another DoE. The resulting data was analysed using both *ANSYS* and *Mintab* to obtain an optimum design. Two resistance methods were selected, Series 60 and Slender body and two optimization strategies were followed, one maximising the block coefficient and the other keeping it constant.

Results and Achievements

The initial observation was that the significant regions of a vessel's hull varied when using the different resistance methods. Using Series 60, the most significant regions were found to be amidships, while using Slender body, these regions shifted towards aft and fore of the vessel. The most reliable resistance method of the two was the Slender Body and optimisation using both *Minitab* and *ANSYS* yielded significant resistance reduction. Figure 1 shows the resistance curve of the optimised hull using *ANSYS*, keeping the block coefficient at its initial value. A 15% resistance reduction was observed at cruising speed at the expense of a slight increase in resistance at higher speeds, with the effect of humps and hollows significantly reduced.

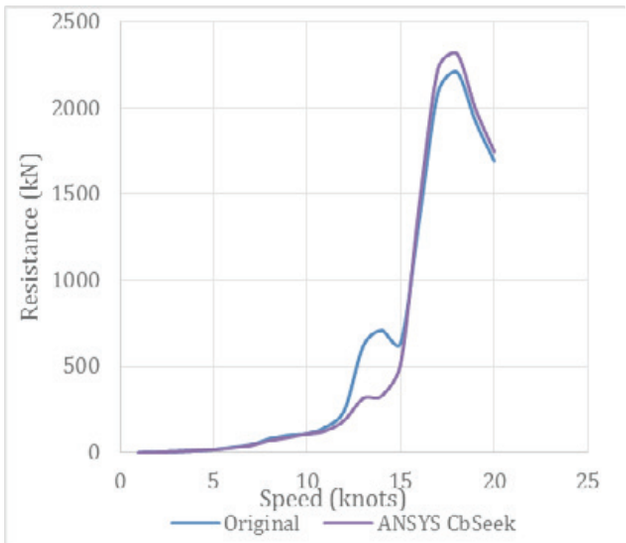

Figure 1: Optimised Resistance curve using Slender Body

References

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Analysis of Vehicle Dynamics Applied to Formula SAE

Student: Karl Farrugia / Supervisor: Dr Ing. Mario Farrugia

Introduction

Vehicle Dynamics is a vast subject which encompasses multiple engineering areas in a single entity. It is a subject that involves all major factors contributing to a response a vehicle might experience through an external or internal force. This response can be studied and appropriately predicted for vehicles having different configurations through a mathematical model of the vehicle.

Project Objectives

The objective of this dissertation was to present a methodology by which testing could be performed on the Formula SAE vehicle. Handling characteristics were the main aim objective, encompassing most of the variables describing it. Vehicle "anti" features were also derived from first principles.

Project Methodologies

The vehicle centre of gravity location was the first variable that needed to be found. This was done by using a method obtained from Milliken [1] to find the distance from front axle to centre of gravity, from rear axle to centre of gravity and to find the height of centre of gravity.

The steering ratio was also found. The steering ratio is the ratio between the steering wheel rotation and the actual wheel angle. Thus a correlation was found between these two rotations. This was done by using lasers and measuring tape from which measurements were taken and used in equations obtained geometrically.

The Ackerman angles of the vehicle were then found. This Ackerman steering is referred to by Gillespie [2] as when having the outer wheel turning less than the inner wheel when driving round a circular path with no scrub at the tires. Thus this angle was then compared to the previous actual steering angle.

The vehicle was then subjected to steady-state cornering around a skid pad. Readings were taken of the steering angles and lateral accelerations. An understeer coefficient can thus be obtained by plotting these two. Slip angles at the tires and side slip angles at the centre of gravity were also obtained.

Results and Achievements

It was found that the centre of gravity's location ratio between front and rear axle was 0.46:0.54. This is almost ideal for a vehicle which is designed to understeer.

The vehicle's actual steering only slightly differed from Ackerman steering, and the most noticeable difference occurred between 3 to 14 meter radius of curvatures.

The understeer coefficient was also determined using graphs as shown in Figure 1. It resulted that its value is zero, thus the vehicle is neutral steer. This was slightly changed when adding a ballast to the nose of the vehicle. To negate neutral steer without building a new vehicle, new a-arms can be designed to move the tires 2.3cm backwards. Slip angles and side slip angles were also obtained together with graphs of lateral force vs front slip angle. This yielded a cornering coefficient of 215N/°.

Anti-dive equations were also derived for motorcycles, outboard and inboard brakes.

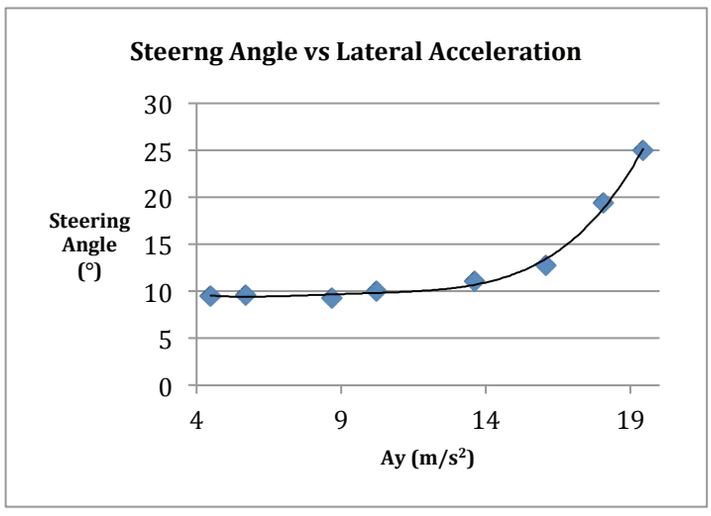

Figure 1: Steering Angle vs Lateral Acceleration

References

[1] Thomas D. Gillespie, Fundamentals of Vehicle Dynamics, Warrendale Pennsylvania, Society of Engineers. Inc., 1992,

[2] William F. Milliken and Douglas P. Milliken, Race Car Vehicle Dynamics, Warrendale Pennsylvania, Society of Engineers. Inc, 1994,

Stress-Strain Analysis of a Hip Joint

Student: Raina Galea / Supervisor: Dr Ing. Zdenka Sant

Introduction

The hip joint is a distinctive and vital ball-and-socket mechanism. Osteoarthritis is a common joint adversity, which potentially may lead to impaired mobility. These pathologies are ordinarily treated through hip replacements and other methods. Research for improvements in orthopedic technology through newly developed models and materials, is on-going.

Project Objectives

The aim of this study was to investigate the stress-strain distribution for a hip joint, through the simulation of a subjects' physiological state, for a single-leg stance. This was targeted to obtain the contact stresses between the joints' articulating surfaces.

Project Methodologies

A three-dimensional, finite-element model of a hip joint, constituting of the pelvic and femoral bones, were segmented from a computerised tomography data using Mimics software. Cartilages were modelled in ANSYS. Muscles and ligaments were modelled as links to mimic the physiological connection between the two bones, as shown in Figure 1. Linear, elastic and isotropic material attributes were set, together with the respective element types, SHELL 181 and SOLID 187 for the areas and volumes respectively. The contact between the articulating surfaces was set using CONTA 174 and TARGE 170. Analytical loads and boundary conditions were applied accordingly.

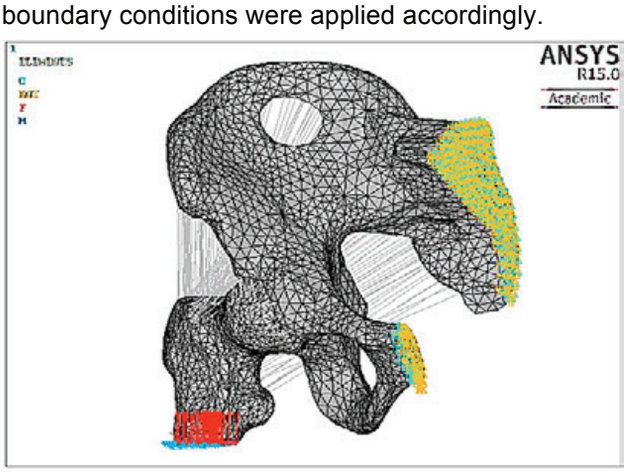

Figure 1: Hip Joint Bone and Tissue Assembly

Results and Achievements

Figure 2 displays the distribution of contact stresses for the simulated hip joint. A peak contact stress of 2.50 MPa was achieved at the inferior-lateral region.

Both bones displayed high stresses due to their resistance to deformation. The highest tensile bone stresses were observed at the ligament attachments since the latter tissues aid in a passive joint stabilisation through contractions, consequently inducing localised tensile stresses. As anticipated, high tensile stresses were also present at the distal femur, which is the location of load application.

The cartilage tissues displayed high strains and low tensile stresses. Yet, the compressive stresses were high, provided that body weight bearing conditions are attained through the transfer of compressive loads to the joints' cartilages.
The contact stresses of the joint and the biomechanical behaviour of bones obtained in this work were substantially similar to cited work, validating the credibility of this study.

This investigation was further recognised to cater for a pathological case, given that the individual had loss of bone at the iliac wing, and additionally showed pelvic dysplasia. The objectives of this investigation were achieved, and once again this proved the use of finite-element analysis to support specific abnormality cases, as the patient specific model can always be created.

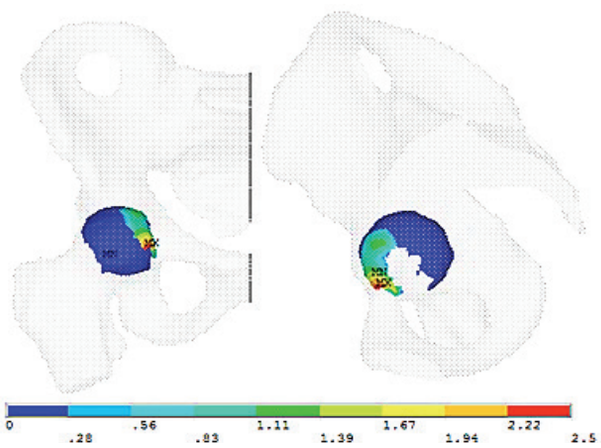

Figure 2: Contact Stresses (MPa) at the Hip Joint

Design and Structural Analysis of Unmanned Aerial Vehicle Wing

Student: Neil Hili / Supervisor: Dr Zdenka Sant / Co-Supervisor: Prof. Ing. David Zammit Mangion

Introduction

Unmanned Aerial Vehicles (UAV) are becoming a fundamental part of the transport industry. Aircraft design should aim at achieving the optimum design, in many cases this should be as light as possible to promote efficiency, but at the same time meeting all the engineering requirements and be safe to operate.

Project Objectives

To design a concept wing that will be attached to a UAV with properties specified by the Institution of Aerospace Technologies and structurally analyzed using a Finite Element Analysis(FEA), namely ANSYS® Mechanical software package for different aerodynamic loads.

Project Methodologies

After performing basic analytical calculations, initial dimensioning of the main components of the wing such as the skin, spars, ribs and aileron were produced. A 3D model of the wing was then created using Autodesk® Inventor, and later exported into ANSYS ® Mechanical APDL to analyse the stresses and strains in each component caused by the aerodynamic loads on the wing. These loads were simulated using the software package XFLR5 [1]. Analyses for a steady flight at 10,000 ft and for a 30 ° bank were conducted. Apart from this, buckling analysis on the skin of the final design was also carried out. The project involved a material selection process and a manufacturing plan which could be implemented in the production of the components.

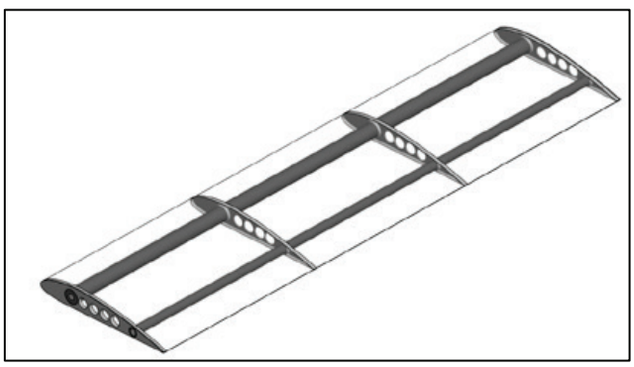

Figure 1: Final Concept of wing design

Results and Achievements

Figure 1 shows the final wing design from a total of nine. The stresses and strains, generated in the wing components due to simulation of the three different flight conditions show that such a design would be adequate.

The highest stresses are found in the third rib away from the fuselage. The highest value of stress registered is 143 MPa, which is equal to 76 per cent the yield stress of CFRP, this being 600 MPa. Figure 2 shows the contour plot for the von Mises stresses generated in the rib attached to the fuselage. This stress generated in this rib is equal to 32.5 MPa, this being 95 per cent below the yield strength of the material.

The design of an aileron was conducted in order to be able and simulate the aerodynamic loading during banking. Results obtained showed that the structure should not fail during a 30° bank. From the buckling analysis on the skin, it resulted that a pressure distribution of 12.9kN/m^2 is required to cause buckling, which when compared to the pressure distribution caused by the UAV flying at an angle of attack of 15°, this is 5 times larger.

The results obtained conclude that a wind composed entirely of a carbon fibre components should not fail under the three different aerodynamic loads which were analysed.

References

[Website:]

[1] XFLR5. 2015. XFLR5. [ONLINE] Available at: http://www.xflr5.com/xflr5.htm. [Accessed 26 November 2016].

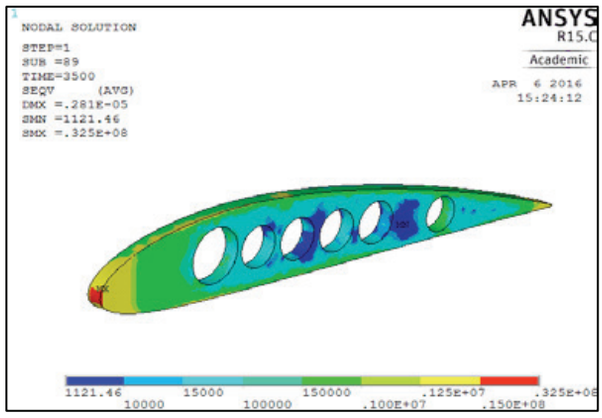

Figure 2: Von Mises stress contour plot on Rib

Design of a Towfish

Student: Martina Khan / Supervisor: Prof. Martin Muscat

Introduction

The aim of this project was to modify certain aspects of the latest design of the towfish produced within BioDiValue project [1]. The prototype of the project [1] incorporated all the required features but suffered from excessive loading on the main flanges. These flanges allow access to the inside of the towfish in order to effect repairs inside its main compartment. To minimize the excessive loading a modification on the design of the flanges was required.

Project Objectives

The project objectives were to decide on the modifications to be made on the BioDiValue [1] towfish design, design the towfish including modifications and produce workshop drawings showing the modifications that are to be made.

Project Methodologies

The main flanges (those connecting the cone to the cylinder and the cylinder to the hemisphere) were completely removed. An obround opening in the main cylindrical shell, was designed to access the inside of the towfish. The three main geometries will be welded together. Figure 1 shows the three main geometries of the modified towfish. The opening in the main cylindrical shell requires a reinforcement in the main geometries. The reinforcement was mainly obtained from increasing the thickness of the shells and adding reinforcement were necessary. The main dimensions of the vessel were calculated according to the Unfired Pressure Vessel Code EN 13445 Part 3 [2].

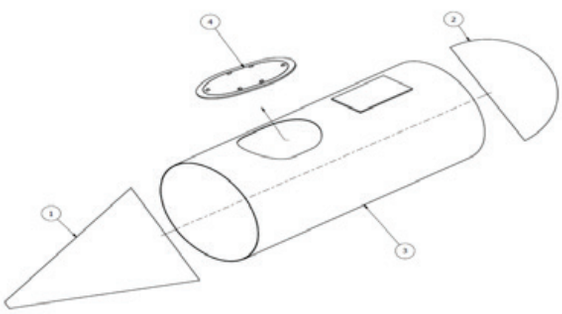

Figure 1: Image showing the modified design of the vessel (1 is the cone body, 2 is the hemispherical cap, 3 is the main cylinder body and 4 is the opening)

Results and Achievements

Autodesk Inventor [3] was used to ensure that the thickness of the shells is able to withstand the external pressure acting on the vessel. Also, strain analysis was carried out on the welded area between the hemispherical and cylindrical shell and the conical and cylindrical shell as shown in Figure 2.

The main achievement of this project was the reduction of deformation between the shell connections. The strain occurring at the flange region in the BioDiValue project [1] was that of 0.111 % which is greater than the one obtained in this project (0.089 %).

References

[Paper:]
[1] A. Cammarata, M. Formosa, M. Muscat, G. Salgado Martin, R. Sinatra, "Design of an Underwater Towfish using Design by Rule and Design by Analysis", in Proceedings of the ASME 2014 Pressure Vessels and Piping Conference, 2014

[**Standard:]**
[2] British Standard Institution, "Unfired Pressure Vessels - Part 3: Design", BS EN 13445-3:2009

[Software:]
[3] Inventor 2015, Mechanical Design & 3D CAD Software, Autodesk, Autodesk.com

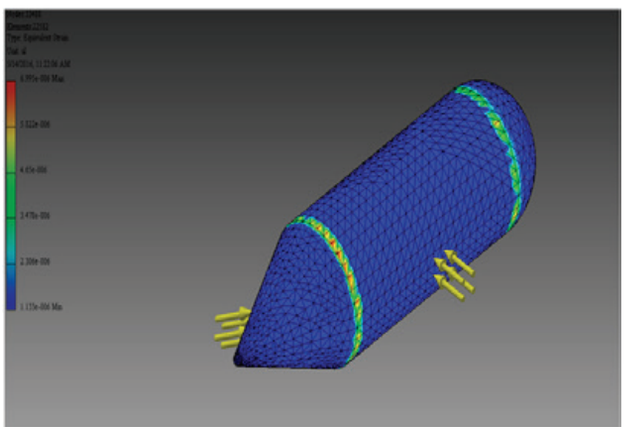

Figure 2: Equivalent strain acting on the edges between the hemispherical cap, the main cylinder body and the cone body

Design and Fabrication of an Apparatus to Demonstrate Buckling

Student: James Mamo / Supervisor: Prof. Martin Muscat

Introduction

If a thin walled structure is subjected to compressive loads, it is most likely to fail due to buckling. This is caused due to the loss of stability of the structural member and occurs after the member is displaced transverse to the load applied on it. A practical example of buckling is pressing on the edges of a cardboard as it deforms from the middle section.

Project Objectives

The main aim of this dissertation was to design and build an apparatus to be used to demonstrate buckling and show the effect the end conditions have on the critical buckling load.

Project Methodologies

The theory behind the buckling behavior of struts was analyzed, and different analytical methods used to find the critical buckling loads were studied and compared to each other. A market research was carried out to find out what similar products exist on the market. The apparatus was then designed using design tools such as sketching and a morphological chart, and then different computer models were generated using AUTODESK® Inventor® Professional [1] student version. The components were designed in such a way to facilitate fabrication, machining and welding while being as durable and functional as possible. A finite element analysis using ANSYS® [2] was carried out on the model to check if there are any stress concentrations and if the frame can support the loading. Struts were chosen as the structural member to demonstrate buckling, as they do not require large amounts of forces to lose stability.

After confirming that the apparatus can support the loading, the model was fabricated and assembled. When the apparatus was ready and undergone testing to ensure it is functional, experimental testing was carried out. A guide that can be used for the students to show them how to set-up and operate the apparatus is also given. In addition, a sample lab experiment was also carried out, together with a discussion on the results obtained.

Results and Achievements

The struts were considered to be in a buckled state when they reached a point where if the load was increased the struts would either become plastically deformed or become unstable. The apparatus worked as expected and all the struts that were tested reached the buckling stage. The process of designing and fabricating the apparatus gave a better understanding of the issues involved when designing components for welding, machining and fabrication. This apparatus aims to aid students in understanding the main principles of buckling theory by demonstrating them in a practical way.

Figure 1: Testing the buckling of struts apparatus

References

[1] AutoDesk Inventor Professional 2014, Student Edition, Autodesk, 2014

[2] ANSYS Academic Research, ANSYS, Version 15.0

Continuation of the Turbocharger Hot Gas Test Stand

Student: Samuel Mamo / Supervisor: Dr Ing. Mario Farrugia

Introduction

The need to reduce CO_2 emissions and fuel consumption have placed turbocharging and engine downsizing at the forefront of automotive power plant technology. Turbocharging utilises kinetic energy from waste exhaust gases to compress air into the combustion chamber, allowing higher power extraction from smaller cubic capacity engines. [1]

Project Objectives

• To improve the test stand developed in the year 2014/5 through inclusion of additional hardware such as an independent lubrication system and a fuel metering system
• To look into the difficulties of measuring turbine inlet/outlet temperatures and turbocharger speed and propose and make modifications to mitigate the errors
• To start implementing a LabVIEW® system to monitor and control the test stand to provide a test setup similar to what is already used for the engine dynamometers.

Project Methodologies

Work initiated on a hot gas turbocharger test stand in the year 2014/2015 was resumed. The test stand was ameliorated and automated, allowing for improved system monitoring and enhanced data acquisition capabilities. This was achieved by replacing the test stand's manual instruments by sensors connected to a National Instruments PCI-6221 card.

The turbocharger speed signal measured using a speed sensor was amplified, filtered, digitised and isolated allowing measurement by LabVIEW®'s counter/timer. Radiation shields were manufactured and installed, enabling investigation of the effect of radiation on thermocouple readings. Furthermore, additional hardware was designed and installed improving the test stand's performance and independence.

LabVIEW® was utilised enabling real-time data display and logging. Through LabVIEW® a PID control scheme was graphically coded, enabling

Tests were performed in order to obtain turbocharger performance maps. Validation of the test stand's performance was undertaken by comparing experimentally obtained turbocharger data, to data supplied by the turbocharger's manufacturer.

Results and Achievements

System improvements led to decreased testing time. Turbocharger lines which required hours to be mapped via the manual system can now be produced in minutes.

References

[1] N.Watson &. M.S.Janota, "Turbocharger Matching," in *Turbocharging the Internal Combustion Engine*, New York, The Macmillan Press Ltd, 1982, pp. 340-371.

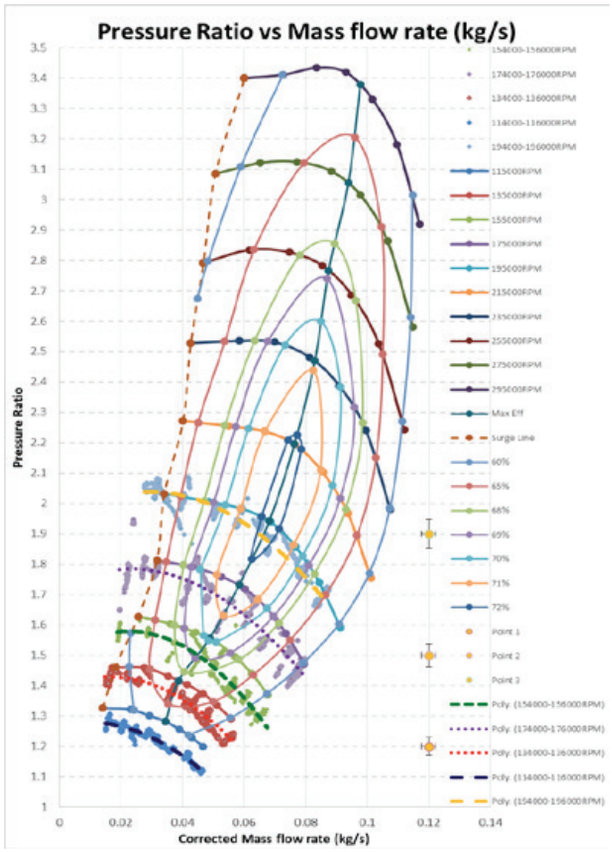

Figure 1: Compressor Map

Effect of Physiological Load on the Spinal Segment

Student: Louise Mifsud / Supervisor: Dr Ing. Zdenka Sant

Introduction

Pain in the lower back is a very common health problem and the use of finite element computational models may be highly effective in this medical field and in the manufacture of implants and prosthetics. It is a promising tool which can contribute to the understanding of the effect of physiological load on the spinal segment.

Project Objectives

- To create a 3-Dimensional (3-D) model of the L4 vertebra, IV disk, and L5 vertebra from computerized tomography (CT) scans.
- To obtain the muscular forces acting on the patient's L4 vertebra during walking by computing inverse dynamics through simulation.
- To analyse the stresses computed using two frames of the gait cycle ('heel strike' and 'heel off') by means of finite elements analysis (FEA) for three different FE models.

Project Methodologies

From the anonymous CT scans supplied, anatomically and geometrically accurate 3-D models were created. This was carried out through image processing by manual segmentation of the image data. Consequently Stereolithography (STL) models, finite element (FE) models and Initial Graphics Exchange Specification (IGES) files were developed through the use of Simpleware Scan IP Software.

The STL file of the L4 vertebra was then used as a geometrical template to obtain coordinates of certain prominent features. Through application of a series of scaling laws within AnyBody software, the shape of the generic AnyBody vertebra was morphed into that of the patient and a given gait cycle was applied to the whole human body model.

Two geometrical FE models of the L4 vertebra, IV disc and L5 vertebra were obtained from Simpleware while the third model was created from basic principles using ANSYS software. The boundary conditions and loads for the two instances 'heel strike' and 'heel off' in the gait cycle were obtained from the inverse dynamic analysis performed through AnyBody software. After the simulation was performed, values of stress and displacement were obtained through ANSYS software.

Results and Achievements

The results obtained show that physiological load causes the highest stresses during instance 'heel strike' (when the heel is in initial contact with the ground) as opposed to instance 'heel off'. Results also showed that creating a FE model from basic principles (as was the case with the third FE model) is more accurate than having it done through automated software. Finally, through a comparative analysis with previous work, it was also concluded that applying subject- specificity does yield more accurate results.

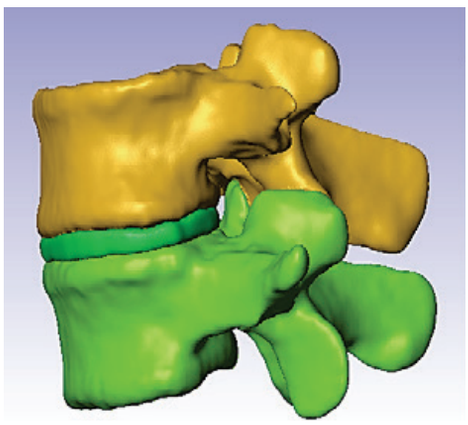

Figure 1: 3-D model of L4 Vertebra, IV disc and L5 vertebra completed

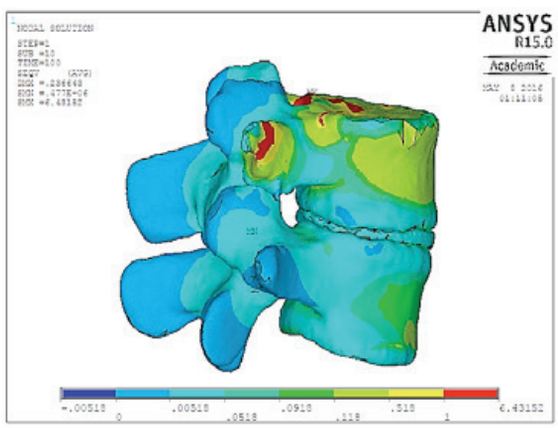

Figure 2: Contour plot of the Von-Mises stress on the third model at instance 'heel strike'

Continuation of the Analysis of an Industrial Cooling Tower

Student: Christopher Paul Mizzi / Supervisor: Dr Ing. Mario Farrugia

Introduction

Evaporative coolers form part of the cooling towers category. They are used in industry to discharge heat by cooling the process fluid [1]. In this analysis the inlet air mass flow rate was varied, and its effects on the thermal performance of the evaporative cooler was evaluated.

Project Objectives

The main aim of this dissertation was to analyse and compare the results, both analytical and experimental, available for Multigas' evaporative cooler, focusing on the thermal performance

Project Methodologies

A thermal performance analysis of the evaporative cooler was conducted based on the work done by Kröger and Merkel [2][3].

Several experimental parameters measured, such as the flow rates of air and process fluid, inlet and outlet process fluid temperatures, amperage of the motors, inlet and outlet air conditions such as temperatures and relative humidity, and the rate of the make-up water were compared with the analytical results obtained and the discrepancy observed between both, was analysed.

Furthermore, the results attained were analysed in order to obtain any relationships present, if any between the inlet air mass flow rates and the parameters being analysed.

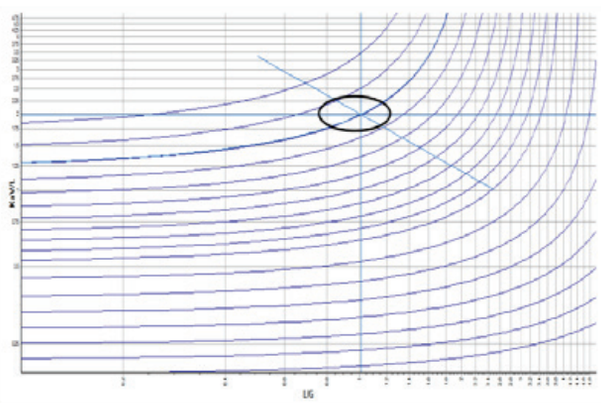

Figure 1: Cooling Demand Chart for the maximum air mass flow rate

Results and Achievements

From the analysis of the samples of data obtained, several relationships and correlations could be drawn.

As was expected, as the mass air flow rate increased, the heat transferred both from the process fluid and especially to air, increased.

Cooling Demand Charts were also plotted in order to evaluate how further away from the ideal conditions, the cooling tower is being operated.

Furthermore, it was concluded that as the air mass flow rate increases, the effectiveness or the performance of the evaporative cooler will be enhanced. Thus, higher fan power leads to a better performance of the evaporative cooler at the expense of an increase in the consumption of water

References

[1] W. Stanford and G. B. Hill, Cooling Towers Principles and Practice, Birmingham, England: Carter Thermal Engineering Limited, 1970

[2] [D. G. Kroger, Air-Cooled Heat Exchangers and Cooling Towers: Thermal-Flow Performance Evaluation and Design, Vol 1, Tulsa. Oklahoma: Pennwell Corporation, 2004.

[3] [N.J.Williamson, "Numerical Modelling of Heat and Mass Transfer and Optimisation of a Natural Wet Cooling Tower," Degree of Doctor of Philosophy Thesis, University of Sydney, 2008.

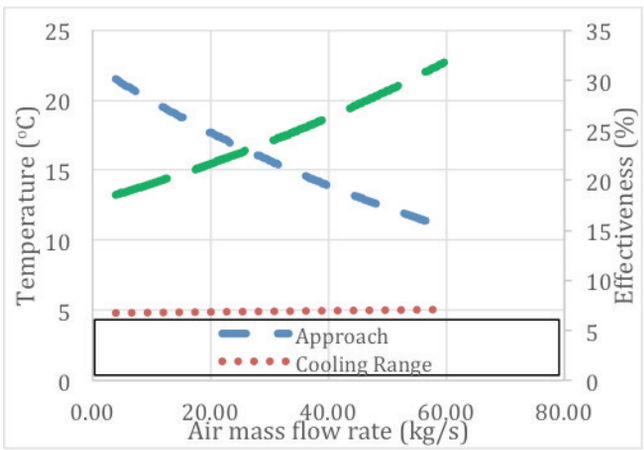

Figure 2: Performance Parameters against Air Mass Flow Rate

Characterization of Cavitation in Maritime Engineering

Student: Gabriel Pace / Supervisor: Dr Simon Mizzi

Introduction

Cavitation develops on a marine propeller when an area of low pressure is created due to an increase in the rotational velocity of the propeller blades. The region of low pressure acting on the blade suction side causes cold boiling to take place. This causes a reduction in the propeller performance which are the non-dimensional open water characteristics.

Project Objectives

The main objectives of the project are to obtain a complete set of data of a chosen propeller. To set up a fully functional CFD process including the correct y^+ values that can compare and contrast the results obtained in cavitation and non-cavitation conditions.

Project Methodologies

Throughout the course of this project the INSEAN E779A propeller was modelled, meshed and imported into the Fluent software. A domain study and a grid independence test was executed. The simulation was run at non-cavitation conditions at 25rps. Subsequently, the rotational velocity was increased to 50rps maintaining the non-cavitation conditions. The multiphase model was switched on for the 50rps keeping the boundary conditions identical as previously. The results from both the 25rps and the 50rps conditions were compared as well as the results from the single phase model and the multiphase model.

Results and Achievements

The model geometry shape was confirmed by superimposing the model blade outlines with those of the data set and a perfect match was obtained. A functional CFD process was set up producing the correct mesh resulting in the precise y^+ values showing the changes occurring at the boundary layer. It has been shown that it is possible to solve a sporadic and randomly natured phenomenon such as cavitation using CFD software such as Fluent. Although a cavitation model has been created there is a limitation because there is no validation of the model at this stage and further work must be done to verify the numerical results produced.

The computational results show that there was a better agreement with the experimental data when the rotational velocity was increased. The contours of several properties and the cavitation patterns on the blade are in accordance with theory and this has shown that if the rotational velocity is increased until the pressure is reduced to below that of the vaporization pressure, cavitation will be evident on the blade suction side.

The main reasons for the possible shortcomings are:

- Inadequate turbulence model
- Inadequate domain extents
- Inadequate cavitation model

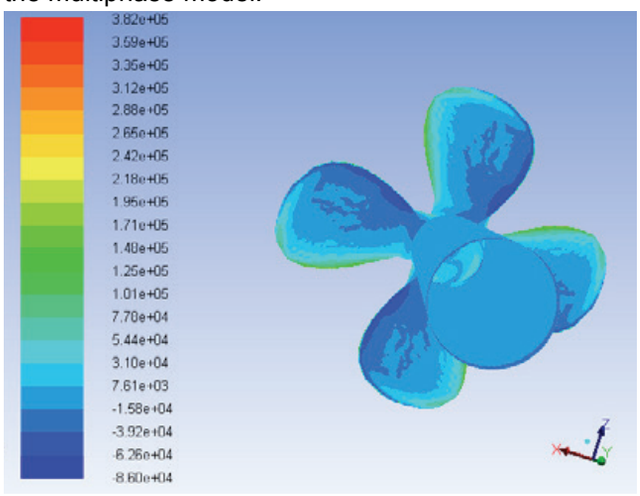

Figure 1: Contours of total pressure at 50rps in cavitation flow

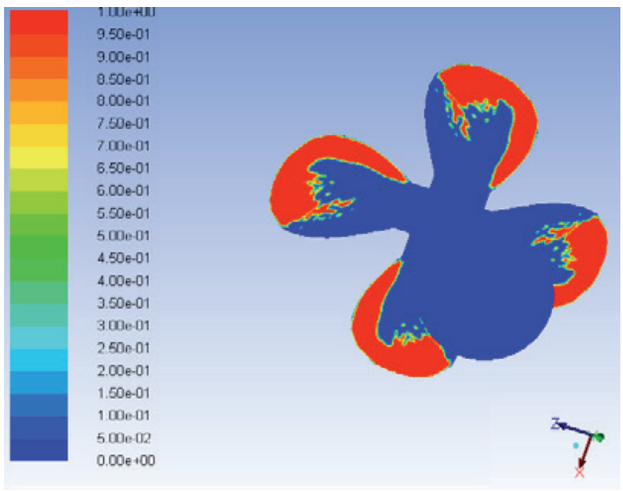

Figure 2: Water vapour contours showing cavitation at 50rps

Aerodynamic Performance Modelling of a Glider-Mounted Energy Recovery Ram Air Turbine

Student: Owen Parnis / Supervisor: Prof. Tonio Sant

Introduction

Aviation is an important sector in modern economy. [1] Despite this, it is also a major contributor to the global greenhouse emissions.[2] With the expected future growth in the aviation sector new renewable energy sources are being introduced to power aircrafts. Tests on sailplanes are being done on the viability of wind turbines (ram air turbines) to generate energy while soaring between thermals.

Project Objectives

The project objective is to analyse the viability of wind turbine energy generation on sailplanes. This is done by creating a numerical computational model for the sailplane and the operating wind turbine using MATLAB®. The energy yielding potential form this synergy is also analysed.

Project Methodologies

An analysis of the existing data in the fields of sailplane aerodynamics and flight mechanics coupled with high speed wind turbine characteristics was performed. This was done to create a numerical computational model using a time marching solution for the sailplane soaring between two thermals. The glide trajectory and glide ratio of the sailplane without wind turbine was computed. Next the computations were repeated for same sailplane with an installed wind turbine. The latter was assumed to have the characteristics of the MEXICO [3] wind turbine with a radius of 0.76m. The results obtained were compared to the results for the soaring sailplane.

Results and Achievements

Figure 1 shows the influence of the wind turbine integration on the flight trajectory of the soaring sailplane. As can be observed, the energy generating turbine reduces the glide ratio from 56.16:1 down to 6.78:1. The test also resulted in a total energy yield of 5.8761 MJ during the flight involving an altitude reduction from 4000m to 1500.

Moreover, the effects of changing the radius of the wind turbine on the sailplane flight trajectory were also investigated. Figure 2 shows the results obtained when the wind turbine's rotor radii was varied. As the wind turbine radius was increased the potential energy being generated increased whilst the time of flight and the glide ratio decreased. This was observed until reaching a radius of 1.25m.

References

[1]: Air Transport Action Group (2014). Aviation Benefits Beyond Borders [on-line]. Available: http://aviationbenefits.org/media/26786/ATAG__AviationBenefits2014_FULL_LowRes.pdf. (Accessed on: 10/05/2016)

[2]: Gençsü I and Hino M (2015). Raising Ambition to Reduce International Aviation and Maritime Emissions. [on-line]. Available: http://2015.newclimateeconomy.report/wp-content/uploads/2015/09/NCE-Aviation-Maritime_final.pdf. (Accessed on: 10/05/2016)

[3]: Schepers J.G et. al., "Final Report of IEA Task 29, Mexnet (Phase 1): Analysis of Mexico wind tunnel measurements", Energy Research Centre of Netherlands, 2012

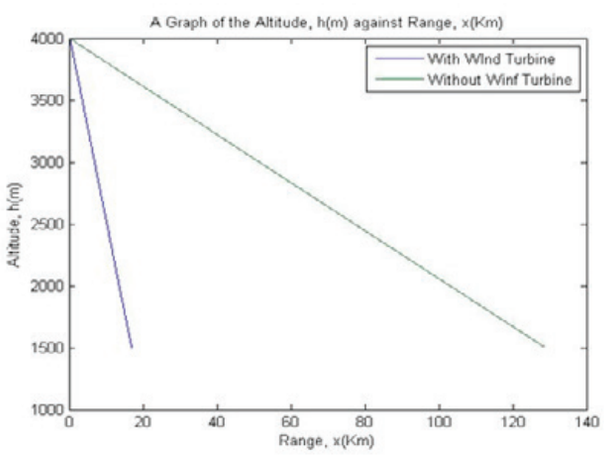

Figure 1: A graph comparing the trajectories of the sailplane with and without the wind turbine

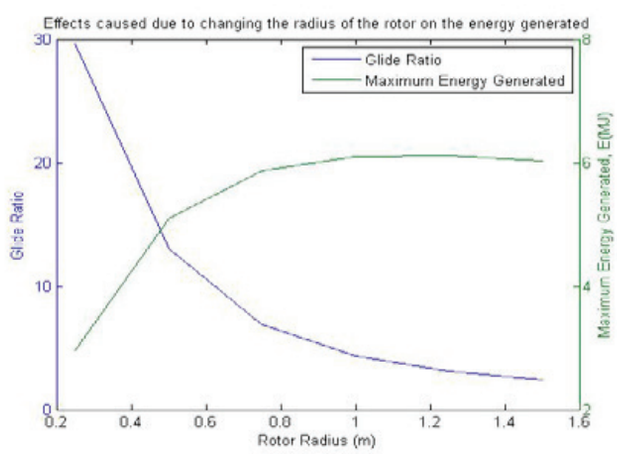

Figure 2: A graph comparing the Glide ratio and the total energy generated for different rotor radii

Wind Tunnel Testing and CFD Modelling of a Model Wind Turbine Rotor

Student: Kurt Portelli / Supervisor: Prof. Tonio Sant / Co-Supervisor: Dr Christopher Micallef

Introduction

Wind power is becoming ever more important, thus necessitating more research about the performance characteristics of HAWTs. Such data may either be obtained from experimental practice or through computational simulations and this project does both in an effort to validate the use of CFD in modelling such aerodynamic problems.

Project Objectives

- Power and thrust wind tunnel experimentation
- Modelling the same rotor using CFD, obtaining counterparts to the experimental data
- Verifying experimental data vs. previous work
- Validating CFD data vs. experimental

Project Methodologies

Wind tunnel experiments were performed to obtain data regarding both power and thrust characteristics of the model rotor shown in Figure 1. Equipment developed in previous works was used alongside some new equipment developed in this project. Raw data was obtained from a torque meter, an encoder and an electronic scale for different tip speed ratios.

A simplified version of the actual rotor used in the experiments was modelled in CFD. Simplifications were made to obtain good quality meshes. Power and thrust data were obtained for the same set of tip speed ratios as in the experiments after confirming grid independence and convergence.

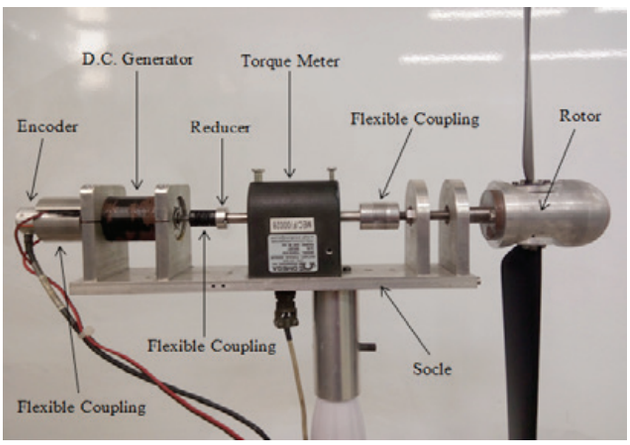

Figure 1: Model Wind Turbine used in Experiments

Results and Achievements

The raw data obtained in both the experimental and computational portions of the project was processed in order to obtain C_P vs. λ and C_T vs. λ plots which represented respectively the power and thrust characteristics of the model rotor used.

First, the experimental plots were verified against the results of previous works carried out by Bonnici [1] and Sant et al. [2] The three sets of data were found to be in close agreement with each other and thus the works mutually reinforced each other. The trends were basically identical, with some discrepancies only noticed in the actual values. Adjustments were made to correct for possible errors noticed in the power experiment, thus getting even closer results.

Next, the data obtained from the CFD simulations was compared to its experimental counterpart as shown in Figure 2 for the power results. Once again the trends were very similar with only some discrepancies in the actual values. Adjustments were once again carried out, this time in the thrust results to correct for drag experienced by the tower.

References

[1] D. Bonnici, “Experimental Analysis of a Model Floating Wind Turbine under Controlled Conditions”, Masters, University of Malta, 2013.

[2] T. Sant, D. Bonnici, R. Farrugia and D. Micallef, “Measurements and modelling of the power performance of a model floating wind turbine under controlled conditions”, Research Article, University of Malta, 2014.

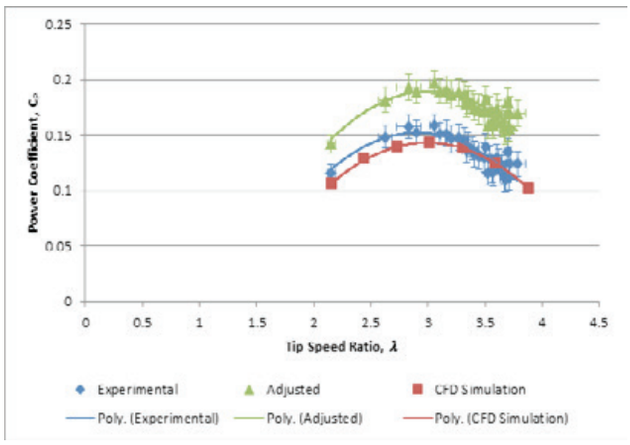

Figure 2: Power Results

Modelling the Energy Performance of the Maltese *Gallarija*

Student: Marcus Portelli / Supervisor: Prof. Ing. R. Ghirlando / Co-Supervisor: Dr Ing. C. Yousif

Introduction

The traditional closed wooden balcony, the Maltese *gallarija*, has been a feature in Maltese architecture for hundreds of years, yet little is known about its origins and the reasoning behind its design. This dissertation studies the energy performance of the Maltese *gallarija* and investigates how the *gallarija* affects the energy efficiency of a building through modelling and simulation using DesignBuilder software. [1]

Project Objectives

The aim of this dissertation is to model the Maltese *gallarija* and simulate various scenarios in order to observe its effect on thermal comfort levels, as well as determine how it can best be utilised to impart a positive effect on the energy performance of the building. Methods to improve the *gallarija*'s performance are also discussed.

Project Methodologies

The software DesignBuilder [1] was used to model the *gallarija* and its behaviour under various weather conditions and usage scenarios. The model dwelling consisted of two storeys, with the *gallarija* connected to the top floor room. The dwelling's external dimensions were taken as measuring 10×10×3 m^3. Two scenarios were simulated, a summer design week and a winter design week. These two weeks represent the worst case scenarios for these two seasons, for the weather data year of Malta. [2]

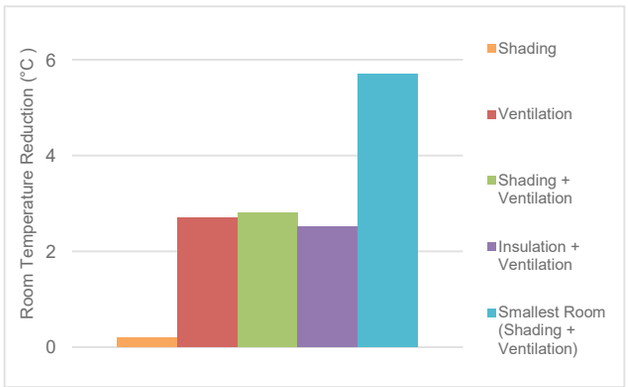

Figure 1: Room temperature reductions for the summer design week

Results and Achievements

The *gallarija* model was simulated under various scenarios, investigating aspects such as window opening schedules, internal and external shading, and material modifications such as additional insulating panels and the use of double glazing. The model was also compared to a model having a window flush with the exterior wall.

The results showed that the effects of the *gallarija* on the building itself were minimal, given the high thermal mass of the building. However, as seen in Figure 1, it does allow for some control of the indoor temperature when used in a scheduled manner, as it facilitates natural ventilation especially during summer nights. Other elements of the building envelope such as the roof, as well as the building orientation, had a greater impact on the indoor temperature of the building. When compared to a window flush with the external wall, as shown in Figure 2, it showed that the indoor temperature was affected negatively by the *gallarija*.

Nevertheless, the *gallarija* should not be simply treated as an architectural relic, but rather as an alternative environment to the dwelling – a space which connects the building with the exterior.

References

[1] DesignBuilder Software Limited, "DesignBuilder v4.7.0.027," Gloucestershire, UK, 2016.

[2] D. C. Yousif, "Weather Data (Malta)," University of Malta, Institute for Sustainable Energy, 2010.

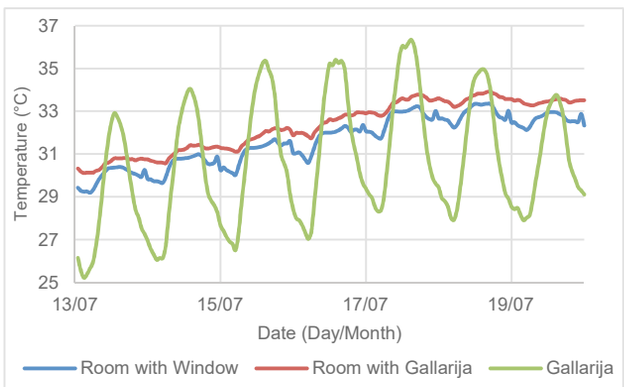

Figure 2: 'Room with Gallarija' and 'Room with Window' temperature comparison for summer week

Finite Element Analysis of Friction

Student: Peter Said / Supervisor: Dr Ing. Pierluigi Mollicone

Introduction

Friction Stir Welding (FSW) is a technique developed by The Welding Institute in 1991, which allows the welding of dissimilar materials, such as steel and aluminium. This welding technique is different because it joins materials without melting them. This produces residual stresses due to the thermal gradients and clamps used during welding. Numerous studies have been done to investigate the setup, experimentally as well as by finite element, using thermo-mechanical modelling.

Project Objectives

The aim of this project is to use the Finite Element (FE) method in the analysis and calibration of the model of a type of Friction Stir Welding (FSW) Process called friction melt bonding [1] together with the analysis of various parameters in the FE model of FSW.

Project Methodologies

The investigation started by verifying the FE model provided based on tests done by [1]. This was done by revising the sequentially coupled structural analysis to obtain the correct loads from the thermal analysis.

This was followed by the validation of the model. A calibration was carried out to compare and confirm the thermal model with data obtained from thermocouples from the experimental results of [1].

Once the model was verified and validated, data was extracted from particular load steps in the transient analysis. This data was used to construct secondary models with different input parameters to help in the investigation of the residual stresses and their effects on the lap jointed materials under test.

Numerous secondary FE models were constructed to compare and contrast the results obtained between each model, more specifically the estimated critical buckling load of the FSW setup.

From the data of the secondary models the FSW FE model was revised by unclamping in a different procedure than previous unclamping attempts [2].

Results and Achievements

Longitudinal stress data was extracted from the FE FSW model just before the unclamping procedure commenced. When analyzed using numerical integration, it was found that the residual stress exerted a resultant load of approximately 17800N on the plates.

From the constructed secondary FE models, it was found that the critical buckling load of the lap jointed steel and aluminium plates was approximately 850N.

With this approximated load it is clear that the resultant load from the residual stresses in the welded plates exceeds the critical buckling load and therefore it may be concluded that the plates buckle due to the residual stresses in the plates.

By removing the clamps from the edges first and the mid-plane of the plates last, the model can be successfully unclamped since there is a larger displacement at the edges than the centre of the plates due to the buckling effects.

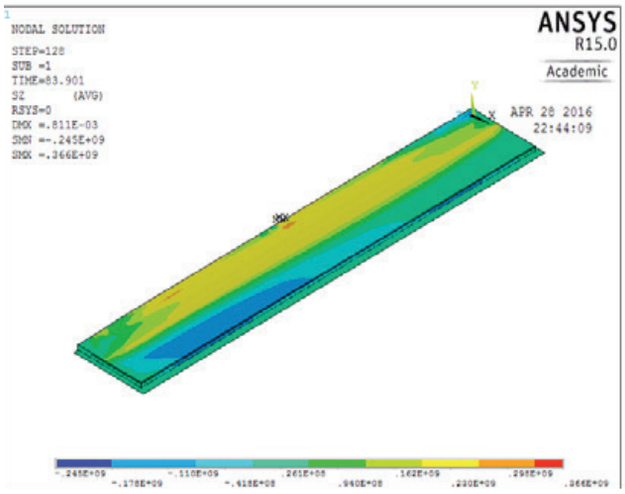

Figure 1: The longitudinal stress just after the spinning tool is raised

References

[1] Université Catholique de Louvain, “Lap joint welding of dissimilar materials,” 2014

[2] D. Scicluna Calleja, “Finite Element Analysis of Friction Stir Welding,” B.Eng. dissertation, University of Malta, Malta, 2015.

Measurements of Fluid Flow in Rotating Ducts

Student: Ezekiel Sammut / Supervisor: Dr Ing. Christopher Micallef

Introduction

In today's world, electronic components are being used in a wide variety of devices and equipment. Due to limitations in space and compactness, heat dissipation is often a problem. Methods to measure fluid flow are limited particularly when it comes to rotating ducts. The behavior of fluid flow in a rotating duct is different from one which is at rest. In this work fluid flow measurement theory is applied to real problems commonly encountered in industry.

Project Objectives

The objective of this project was to device a method to measure the fluid flow in a rotating duct. This method was then validated experimentally using a test rig built specifically in an earlier project which needed some modifications.

Project Methodologies

The first step was to familiarise with the work carried out in previous years and hot wire anemometry in general. A miniaturised anemometry system was built and tested successfully in a wind tunnel. Modifications to the test rig were performed to accommodate the miniaturised anemometer.
To be able to relate the readings from the anemometry circuit developed, a calibration process was carried out in the wind tunnel before and after the testing procedure. One setup is used to measure the fluid flow at the entry to the duct and the other setup was used to measure the flow inside the rotating duct, as seen in figure 1.

Results and Achievements

Results obtained at the horizontal entry to the duct showed that the flow, few millimeters away from the duct entry was experiencing high acceleration as it entered the duct. In fact measurements from the hot wire system showed that, the fluid flow velocity was doubling in magnitude. Tests were performed at different duct rotation speeds and this doubling in fluid flow velocity effect was constant throughout. As the rotational speed of the duct was increased the fluid flow velocity also increased in magnitude.
The method chosen for measuring the fluid flow inside the rotating duct was also successful. Measurements were obtained using a specially constructed hot wire, together with the use of the anemometer circuit developed, and fitted inside the aligning fixture, as shown in figure 2. The fluid velocities at this position were higher than at the duct entry, as expected.
This conformed to the theoretical results obtained in a previous project using computational fluid dynamics software. As the fluid gets close to the radial exit from the duct, which creates this flow affect, the flow velocity increases.

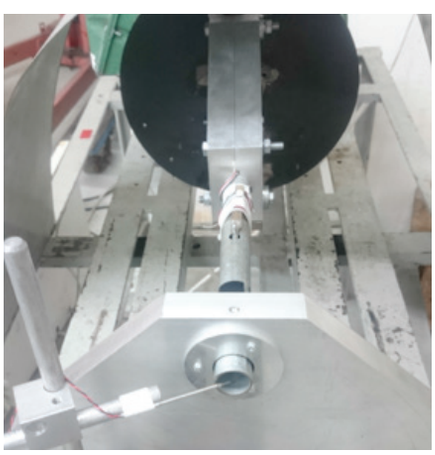

Figure 1: Experimental Setup

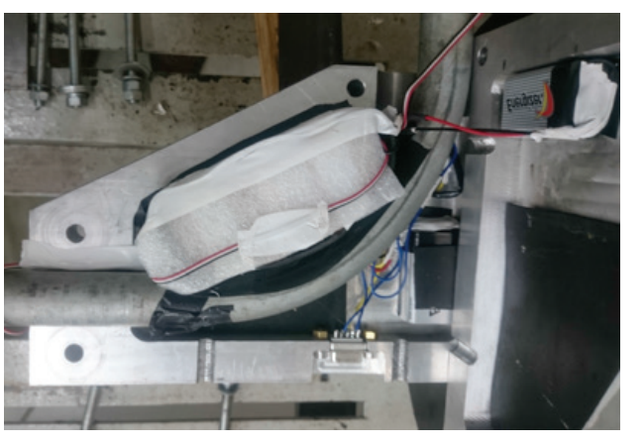

Figure 2: Anemometer Circuit inside Fixture

Structural Analysis of Welded Joints

Student: Thomas Sammut / Supervisor: Prof. Ing. Martin Muscat

Introduction

Mechanical joining techniques of components are used extensively and are extremely important in the engineering of a structurally robust product. Thus, it is necessary to have a thorough understanding of the performance of all the aspects involved in the joining technique, under all conditions of use and design.

This project aimed to investigate and validate the methods of structural connections of welded joints as specified in EN1993-1-8 (2005): Eurocode 3.

Project Objectives

The objectives of this project were to identify the design methods used by the standard EN1993-1-8 (2005): Eurocode 3 [1] and design different welded joints in accordance with it. The designs had to then be manufactured and tested, both experimentally and computationally using finite element analysis software. The maximum load carrying capacity results for each test was then compared to the calculations using the code available.

Project Methodologies

Two types of fillet welded joints were designed. These were chosen in line with the standard SM EN ISO 9018:2015 [2] which described parametrically the design and necessary procedure to destructively determine the capacity of the welded joints loaded transversely in tension. Steel plates of 3mm thickness with yield strength 397MPa and ultimate tensile strength 523MPa were machined and welded together to form multiple cruciform joint and lapped joint specimens. The manual metal arc welding (MMAW) process was carried out using the electrode type E6013 which boasted materials properties in excess of the plate (base) material. This among other technicalities was in line with that specified in EN1993.

Finite element analysis (FEA) software ANSYS 16.2 Student was used to perform von Mises stress analysis of the welded joints by using plate elements (APDL) and Workbench, to model quarter sections of the joint; taking advantage of symmetry along the y-axis and x-axis. The maximum load carrying capacity with respect to the maximum stress carried by the joint was investigated.

Results and Achievements

Following all the tests it was concluded that for thin plate, minimum throat thickness fillet welded joints loaded transversely in tension, the load carrying capacity was governed by the strength of the plate (base) material. Experimentally, all the welded joints failed at the plate rather than fracture at the weld throat area itself as shown in figure 1. The maximum loads were below the calculated allowable resistances as shown in table 1.

The reason was mainly due to the thickness of the plates which yielded at a lower stress state than that reached at the location of highest stress concentration (weld toe). In light of this, further testing is required on larger plate thickness' and higher steel grades in order to compare further with calculated allowable design resistance results.

Figure 1: Cruciform specimen after failure at the plate

Table 1: Ultimate load results (FEA, Exp., EN1993)

Joint	Numerical Analysis Ultimate Load		Experimental Ultimate Load	Eurocode 3 Allowable
	APDL approach	Workbench approach	INSTRON tensile machine	Directional Method
	kN	kN	kN	kN
Cruciform a = 3mm	47.0	72.0	60.5	88.8
Lapped a = 2.6mm	61.2	72.0	63.0	76.9

References

[1] C. The European Union - European Committee For Standardization, EN1993-1-8 (English): Eurocode 3: Design of steel structures – Part 1-8: Design of joints, The European Union, 2005.

[2] C. The European Union - Committee For Standardization, SM EN ISO 9018: Destructive tests on welds in metallic materials. Tensile test on cruciform and lapped joints, Malta Competition and Consumer Affairs Authority, 2015.

Performance Analysis of a Hybrid Offshore Floating Wind, Solar and Thermocline Energy System

Student: Daniel Sant / Supervisor: Prof. Tonio Sant / Co-Supervisor: Ing. Robert N. Farrugia

Introduction

The Offshore Wind and Thermocline Energy Production (OWTEP) concept has been proposed as a means of reducing the cost of wind energy by simultaneously also exploiting the cooling properties of deep seawater (DSW). This project investigated the effectiveness of adding solar PV energy to the energy mix of the OWTEP system to increase the flow of DSW, in turn increasing the electrical and cooling energies of the system. This Offshore Wind, Solar and Thermocline Energy Production (OWSTEP) concept is shown in Figure 1.

Project Objectives

The main objectives of this project were to:

- integrate a number of solar panels to the existing OWTEP concept;
- incorporate a realistic vapour-compression AC cycle to quantify energy consumption;
- carry out a parametric analysis on the OWSTEP system to observe the influence of different design variables on the overall system performance; and
- simulate the OWSTEP performance using local data to investigate the energy yield under Central Mediterranean conditions.

Project Methodologies

A detailed mathematical model was derived for the entire system. All the system parameters were then determined, based on preliminary calculations and available data. The mathematical model was modelled in MATLAB® and the program was then used to: (i) observe the system characteristics for different operating conditions and parameters; and (ii) investigate system performance locally.

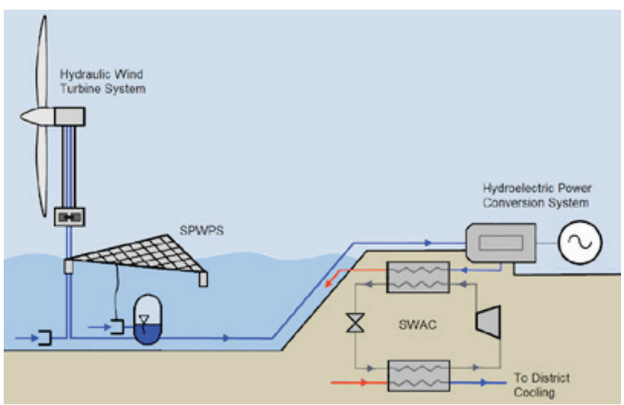

Figure 1: Illustration of the OWSTEP system

Results and Achievements

The OWSTEP system was found to perform favourably compared to the OWTEP system. For a typical year, the gross electrical energy, cooling and COP were respectively found to be 10.7%, 30.0% and 3.7% higher for the former system. As shown in Figure 2, the OWSTEP was especially found to be more effective in the summer period, in light of low speeds, yet high solar irradiation levels. The contribution of solar energy to the electrical energy generated in August is in fact of 35.7%.

An OWSTEP system with a flash chamber incorporated into the vapour-compression cycle was also compared to the 'standard' OWSTEP system. The cooling energy and COP for the former were found to be 12.4% and 13.4% higher respectively.

A conventional hybrid offshore wind turbine and solar PV system was found to generate 8.9% more in gross electrical energy than the OWSTEP system. This deficit was however found to decrease to 5.2% when considering the energy savings of the OWSTEP system compared to a seawater air-conditioning cycle in which the cooling medium is surface seawater. For the system with a flash chamber, the deficit in net electrical energy was further reduced to a mere 3.7%.

The OWSTEP system is bound to perform more favourably in regions with typically high wind speeds, due to the higher limiting velocity for the hydraulic turbine as opposed to a conventional turbine. This is due to the absence of the generator-gear train assembly. Then, the OWSTEP system is expected to render better energy yields than the conventional hybrid systems in such regions.

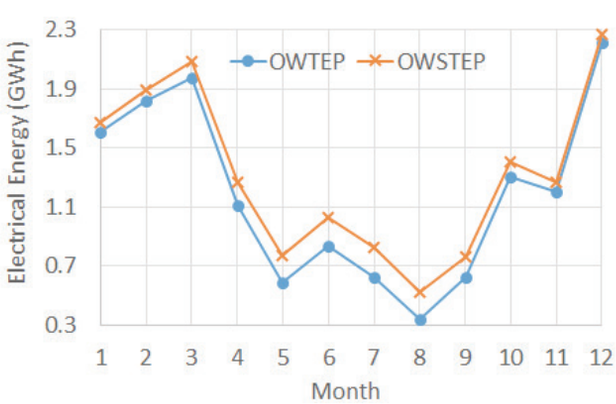

Figure 2: Plot of electrical energy (GWh) vs month

Non-Newtonian flow characterization of cardiovascular vessels

Student: Mark Anthony Schembri / Supervisor: Dr Simon Mizzi / Co-Supervisor: Dr Aaron Casha

Introduction

In today's world, cardiovascular diseases are one of the biggest causes of death worldwide [1]. Various fluid dynamists attribute haemodynamic characteristics to the pathogenesis of such diseases. This concern instilled the will in several researchers to investigate the blood flow patterns in the aorta and their impact on the surrounding walls, via computational fluid dynamics (CFD) simulations, this being the focus of this dissertation.

Project Objectives

The project objectives included the validation of a non-Newtonian model using a simple test case, specifically the fluid dynamics and characteristics of blood flow over a backward facing step. Having validated this simple test case via a non-Newtonian approach, the following steps included the segmentation and re-construction of a specific aortic geometry, generation of the respective meshes and blood flow simulation through the aorta using Newtonian and non-Newtonian fluid models.

Project Methodologies

CT scan images of a 77-years old male patient were obtained from Mater Dei Hospital (Msida, Malta); this enabled the segmentation and generation of the aortic geometry using the Seg3D software, which later required smoothing using MeshLab (see Figure 1). The aortic valve was constructed in ANSYS ICEM CFD 15.0 followed by the generation of various meshes using the same software, all of which were analysed. The mesh which offered the best quality and stability was later used for the ensuing blood flow simulations.

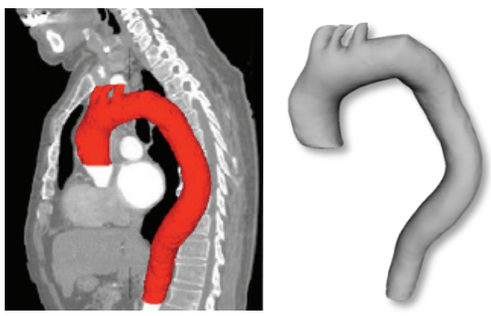

Figure 1: The final segmented (left) and smoothed (right) aortic geometry to which later the constructed aortic valve was attached and upon which the mesh was generated

A Newtonian and a bespoke non-Newtonian Carreau-Yasuda model were both implemented, thus giving the possibility to compare and contrast results between the two fluid constitutive laws.

Results and Achievements

The presented outcome shows that there is a difference in results when assuming that the fluid is either Newtonian or non-Newtonian. It was concluded that the shear-thinning effects are pronounced and cannot be ignored completely, unlike several existing studies. It was found that the highest WSS (wall shear stress) regions are located at the superior aortic arch wall, just under the bifurcations (see Figure 2). Of high importance is the fact that even though Newtonian and non-Newtonian WSS distributions are very similar, the non-Newtonian WSS magnitudes are higher even for areas of low WSS; this agrees with what Liu *et al* discussed in their study [2]. The descending aorta was the inferred region of choice where a surgeon could perform an incision, due to its low WSS characteristics.

References

[1] Mendis S., Puska P., and Norrving B. editors, 'Global Atlas on Cardiovascular Disease Prevention and Control', World Health Organisation, Geneva 2011, pp.2-14.

[2] Liu X., Fan Y., Deng X. and Zhan F., 'Effect of non-Newtonian and pulsatile blood flow on mass transport in the human aorta', Journal of Biomechanics, 2011, pp. 1124-1126.

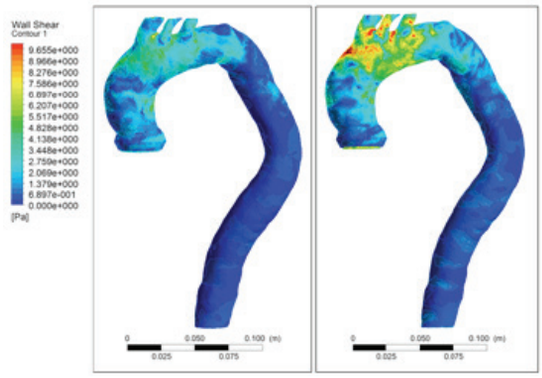

Figure 2: Wall shear stress distribution for the Newtonian flow simulation (left) and the bespoke non-Newtonian Carreau-Yasuda simulation (right)

Finite Element Analysis of UOM Racing Chassis

Student: Gabriel Scicluna / Supervisor: Dr Ing. Pierluigi Mollicone

Introduction

A pivotal component of a racing vehicle is the chassis itself. Its design determines the level of the driver's safety as well as the vehicle's handling and manoeuvrability. Therefore, computer software simulations coupled with actual physical tests are performed to make sure that the chassis is up to standard and is able to achieve its main objectives.

Project Objectives

The main objectives of this project was to perform a Finite Element Analysis of the University of Malta Racing Team chassis.

The torsional rigidity of the chassis was obtained through the Finite Element Analysis, and was then validated by means of experimentation on the chassis itself.

Project Methodologies

Tensile testing was performed on the tubes used to manufacture the FC-15 chassis to determine the Young's Modulus and Poison's Ratio. This was done for a number of test samples. These values were necessary for the simulations.

Following this, a test rig was specifically designed and constructed for the testing of the FC-15 racing vehicle. The FC-15 chassis was mounted on the constructed test rig as shown by Figure 1.

Figure 1: FC-15 mounted on test rig

To experimentally obtain the torsional rigidity value of the chassis, a torque had to be applied to the chassis.

This was applied by gradually adding weights on one side of the test rig. Each time, the deflection experienced by the chassis was recorded through dial gauges located at specific locations along the chassis.

These measurements, together with the torque applied, were used to obtain the torsional rigidity of the chassis.

This result was used as a benchmark for the results obtained through the simulations, shown in Figure 2.

Results and Achievements

Through experimentation and repeated testing, a value of 693.58 Nm/° was obtained for the torsional rigidity of the chassis. Furthermore, the simulated value for the torsional rigidity was of 632.92 Nm/°, implying an accuracy of 91% of the Finite Element model.

Therefore, the Finite Element model can be used by the University of Malta Racing Team to better design future chassis.

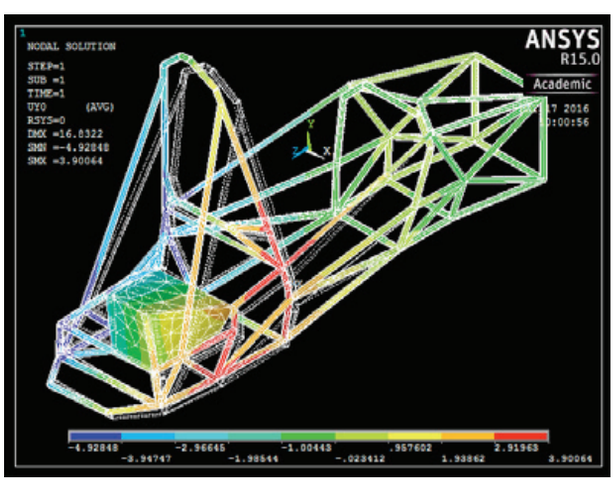

Figure 2: Displacement experienced by FE model (-4.93 to 3.9 mm)

Design of a Hull for a Small Craft in Accordance to Standardised Methods

Student: Luke Sciortino / Supervisor: Dr Ing. Claire De Marco

Introduction

One of the areas involved in ship and boat building is the design and construction of small craft typically characterised by a length overall ranging from 6 to 24 metres, depending on classification society. Construction not only involves the hull but also the internal structure which provides strength and serves as a support to the hull.

Project Objectives

The aim is to design a recreational small craft suitable for short journeys within the Mediterranean between Malta and Sicily. The ultimate goal would be to end up with a certifiable boat design, tested for compliance to standards and ready for commercial construction.

Project Methodologies

To reach all goals, various theories have to be applied. The resistance is estimated via three resistance prediction methods developed by Savitsky [1], Blount and Fox [2] and Savitsky and Brown [3]. Nonetheless, the second approach shall be considered given the applicability to craft characterised by a varying beam and deadrise angle. Determining the power would then enable the selection of a suitable propulsion system. As for the structural analysis, Gerr's [4] Scantling rules are adopted for the design of both the hull shell and internal structure. On the other hand, BS EN ISO 12215 [5] and BS EN ISO 12217 [6] are beneficial to ascertain the compliance of the craft with established standards.

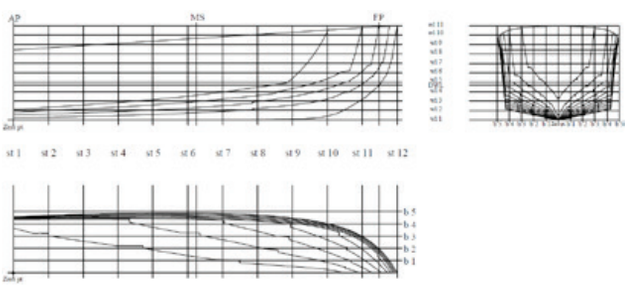

Figure 1: Hull Lines Plan

Results and Achievements

The theories were implemented in accordance with data corresponding to the hull designed illustrated in figure 1. Results were compared with the analogous values obtained through software. Resistance and power prediction led to the selection of a propulsion system composed of two waterjets and two engines. An internal structure was also designed via Maxsurf Structure [7] and the final outcome can be observed in figure 2 whereby the major components namely ring frames, bulkheads, plates and longitudinals are included. Lastly, a general arrangement was produced and subjected to testing via naval architecture software to assess stability and ensure safety.

References

[1] D. Savitsky, "Hydrodynamic Design of Planing Hulls," *Marine Technology*, vol. 1, no. 1, pp. 71-95, 1964.

[2] D.L. Blount and D.L. Fox, "Small-Craft Power Prediction," *Marine Technology*, vol. 13, no. 1, pp. 14-45, 1976.

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[6] International Standards, "Small Craft – Stability and buoyancy assessment and categorization – ISO 12217," The British Standards Institution, London, 2012.

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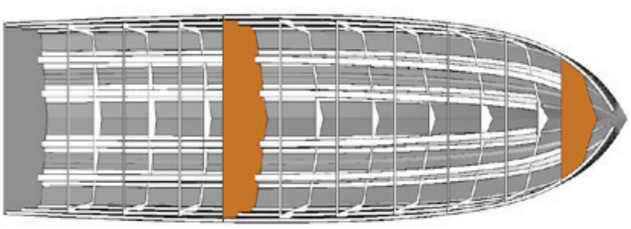

Figure 2: Internal Structure

Analysing the Stability, Strength and Floodability of a Bulk Carrier

Student: Glen Slattery / Supervisor: Dr Ing. Claire De Marco

Introduction

Bulk carriers are and have always been the workhorses of the sea, designed to carry large volumes of cargo in bulk across all seas. The foremost challenge in today's maritime transportation is to design a vessel which is safe whilst observing the classification society's standards and in addition of being capable of providing the specific requirements of its owner.

Project Objectives

- Research rules and regulations regarding the structure and stability of bulkcarriers.
- Design a 3D virtual model of a bulk carrier including its cargo holds, ballast tanks and the essential tanks and compartments of the vessel.
- Use maritime regulations to assess stability and strength by investigating the floodable length, longitudinal strength and intact stability.
- Verify that the results obtained conform to classifications society's requirements.
- Produce a stability booklet in compliance with the work undertaken.

Project Methodologies

A 3D bulk carrier virtual model, Figure 1, was created by MAXSURF [1] software and refined by augmenting additional tanks and compartments as detailed in established in-service bulk carriers, to include 5 cargo holds and 22 ballast tanks.

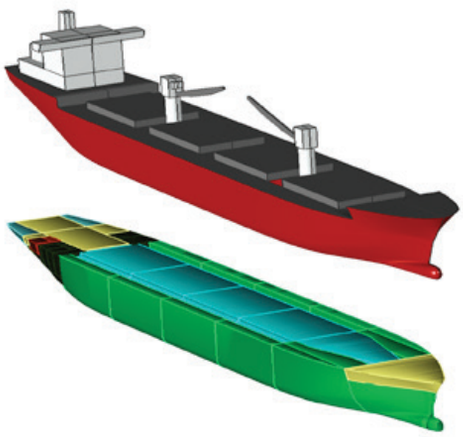

Figure 1: 3D Bulk Carrier Model

Results and Achievements

The virtual model was created according to regulations specified by the International Maritime Organisation (IMO) and the International Association of Classification Societies (IACS).

The floodable length for a bulk carrier is the length of compartment that when flooded causes the ship to sink to a margin line. The floodable length of the vessel, Figure 2, was found through simulations on the 3D model using MAXSURF [1] and validated through analytical calculations. The results show that the bulk carrier is able to withstand compartment flooding, whereby the vessel may immerse but is not considered lost. Longitudinal strength calculations resulted in values for the maximum shearing forces and bending moments the vessel must endure during its lifetime. The ship also satisfied the IMO's intact stability criteria for each regulated loadcase [2]. The vessel is therefore deemed seaworthy since a sufficient righting moment exists to return the ship to its original upright position if the vessel is forced to heel over.

References

[1] MAXSURF Enterprise. Bentley Systems, Incorporated.

[2] International Maritime Organisation (IMO), 'Resolution A.749(18)', in Code on Intact Stability for all Types of Ships covered by IMO instruments, London, 1993

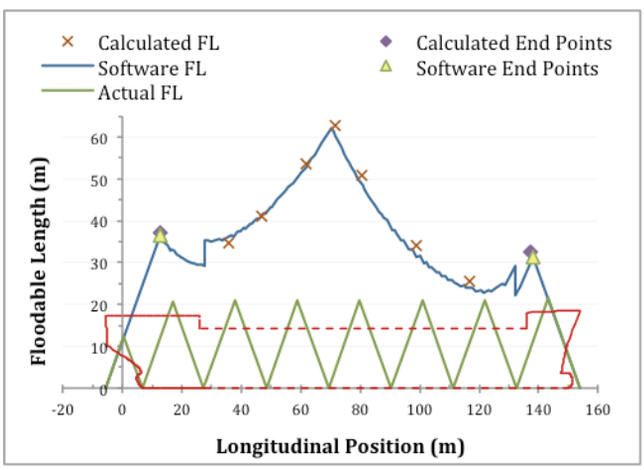

Figure 2: Floodable Length Results

Lightweight Maritime Structures

Student: Luke Anthony Spiteri / Supervisor: Dr Ing. Claire DeMarco

Introduction

Several materials have been used to build vessels throughout the years, with the objective that the naval engineer is to construct the lightest ship possible that can fulfil its purpose; that is where sandwich structures come in. Sandwich structures consist of two thin and strong skins adhesively bonded to a thick, low-density core via a resin.

Project Objectives

- To make use of a material selection procedure in order to select the best sandwich construction according to the different requirements.
- To outline the relevant theory associated with sandwich structures and incorporate it into a spreadsheet program along with the material selection procedure.
- To perform the necessary experiments in order to validate the results obtained from theory via the spreadsheet program.

Project Methodologies

A spreadsheet program was implemented, focusing on the material selection procedure and calculating the sandwich properties of any combination of skins and core. Two sandwich panel configurations were chosen for the scope of the study according to material selection procedure, and for each configuration six test specimens were manufactured by hand layup, in order to simulate the flexural performance of such panels. Long beam flexure tests were conducted, according to ASTM standard D7249-12 [1], on the manufactured specimens as shown in Figure 1.

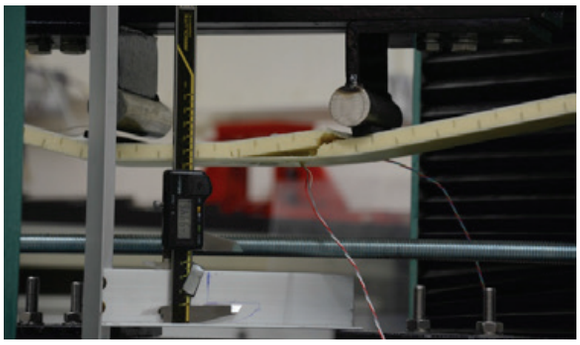

Figure 1: Flexure test setup

Results and Achievements

The first panel was chosen via the spreadsheet program according to the sandwich having the best weight to stiffness and strength ratios, resulting in a panel of a core of Divinycell H60, thickness of 20mm and three layers of woven carbon fibre of 200g/m^2 on each side. The second panel was chosen according to the sandwich having the best cost to strength ratio and second best cost to stiffness ratio and fabricated of a core of Divinycell H100, thickness of 10mm and one layer of quadraxial glass fibre of 1630g/m^2 on each side.

The experimental results found via the four point bending test, i.e. the flexural strength and flexural rigidity, agreed well with the theoretical data obtained by the spreadsheet program. Moreover, the experimental tests revealed, as expected, that the sandwich configuration with the carbon fibre face sheets, performs better for weight dependent applications, while the sandwich configuration with the glass fibre skins, is better suited for cost dependent applications. Furthermore, when compared to more traditional shipbuilding materials such as aluminium and steel, the tested sandwich panels proved to perform much better when the objective is weight reduction, as can be seen in Figure 2.

References

[1] ASTM Standard D7249, “Standard Test Method for Facing Properties of Sandwich Constructions by Long Beam Flexure,” ASTM International, West Conshohocken, PA, 2012.

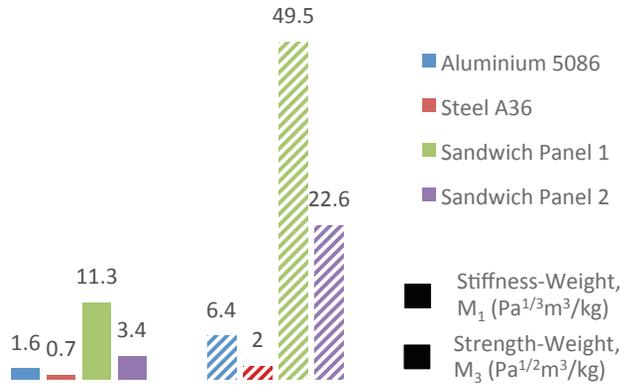

Figure 2: Comparison of materials for different material indices involving stiffness, strength and weight

Wireless Strain Measurement

Student: Jean Paul Sultana / Supervisor: Dr Ing. Pierluigi Mollicone

Introduction

The recent drastic improvements in the silicon microelectric industry have encouraged the capability of creating very flexible and adaptable micro-processors that have allowed the viability of various technological applications over the last decades [1]. The mechanical engineering field of study has taken up this technology to satisfy new applications that were too difficult or impossible to achieve prior.

The Mantracourt T24 Wireless Telemetry System offers a platform that is capable of transmitting data obtained from sensing devices to a remote base-station wirelessly, via a mode of radio frequency transmission.

Project Objectives

The objectives of this project were threefold. The first objective was the development and implementation of a Wireless Strain Network based on the Mantracourt T24 platform. Secondly, the development of a static test for the direct comparison of the wired and wireless strain measuring solutions. Finally, the third objective was the development of a dynamic procedure incorporating the wireless strain network.

Project Methodologies

Initially the *T24-Sai* transmission modules were understood and the Wheatstone bridge board for the adaptation to receive data from linear strain gauges was developed. Direct comparison of the wired Vishay Model P3 system and the developed one was performed by a Four-Point Bending procedure. The results of which were processed by the Bland-Altman [2] comparison technique for the acceptance of the newly developed measurement method. A Whirling of Shafts dynamic procedure was developed for the implementation of a strain measuring system in a fully-dynamic scope.

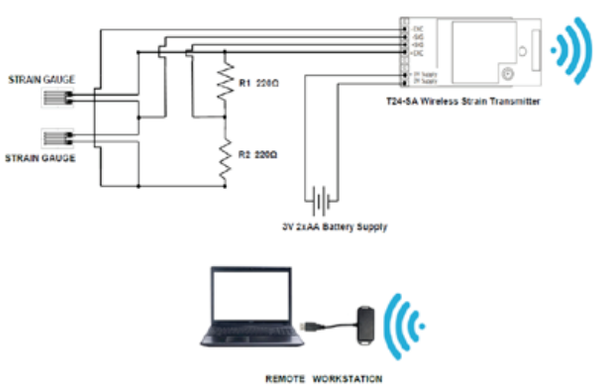

Figure 1: Schematic Diagram of the proposed Wireless Strain Network

Results and Achievements

The results from the Bland-Altman data-plotting technique for the comparison of measuring methods shows that only 5% of the readings fall out of the 95% limit-agreement criteria with a standard error of 0.05με; such that both the pre-disposed wired strain measuring solution and the developed wireless strain network can be freely interchanged and both provide reliable data.

The procedure for the implementation of the wireless solution in a dynamic scope proved successful in the obtaining of telemetry at a rate of 5ms and provided high-resolution results in an application that could not have a strain measuring system implemented without complications when using the wired solution.

References

[1] S. Hillenius, "The future of silicon microelectronics", *2004 IEEE Workshop on Microelectronics and Electron Devices*, p. 1.

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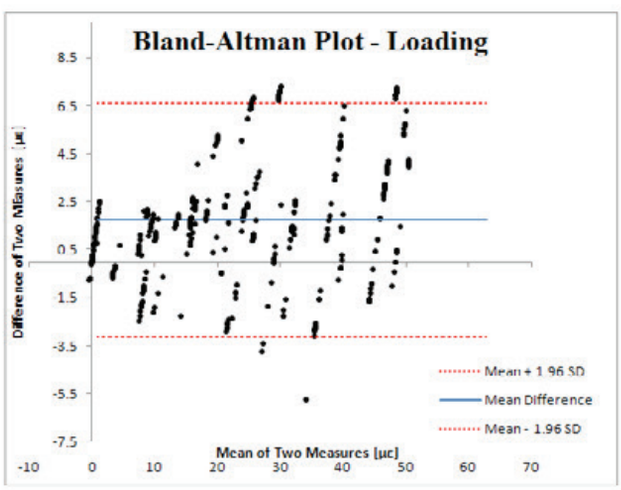

Figure 2: Results of the Bland-Altman comparison of the wired versus the wireless strain solutions

Residual Stress Measurements

Student: Gianluca Vassallo / Supervisor: Dr Ing. Pierluigi Mollicone

Introduction

An innovative welding technique named Friction Melt-Bonding has been developed by [1] in order to weld dissimilar metals. Since the technique is relatively new, investigations need to be carried out in order to prove the mechanical soundness of the weld and its structural integrity.

Project Objectives

To use the Vishay RS-200 Hole-Drilling apparatus based on the ASTM E837-13a Standard Test Method to determine Residual Stresses by the Hole-Drilling Strain-Gage Method [2]. To analyse the results obtained and investigate sources of uncertainty.

Project Methodologies

Friction melt bonded plates provided by the Universite catholiqué de Louvain are investigated for residual stresses. The procedure involves drilling a hole using the RS-200 equipment through the centre of a chosen strain gauge rosette attached to the surface of the material being tested. During the process, the material in the vicinity of the hole relaxes, resulting in strain relief which is read by the strain gauges and subsequently recorded via a data recorder. The measured strains will then be put through a series of computations defined by the ASTM E837-13a standard in order to obtain the residual stress values.

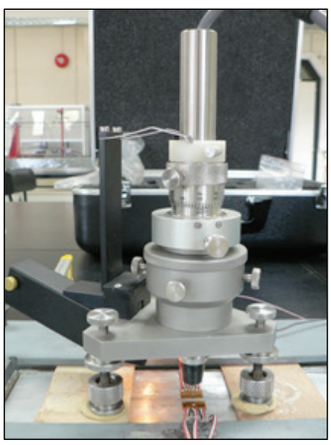

Figure 1: RS-200 Hole Drilling equipment

Results and Achievements

Residual Stress results were measured and computed through the H-Drill software for all sixteen strain gauges positioned systemically on the Aluminium alloy and Steel alloy surfaces. Longitudinal and transverse stresses were obtained at various transverse distances from the weld centreline. Results achieved were analysed and compared to theoretical data. It was observed that peak tensile stresses were recorded just beyond the tool's shoulder radius on the steel alloy side (refer to Figure 2) whilst compressive stresses were found to be more prominent in the transverse direction on the aluminium alloy side. The stress distributions achieved were deemed satisfactory since they are close to those expected from theory.

References

Journal:

[1] Camille van der Rest, Pascal J. Jacques and Aude Simar, On the joining of steel and aluminium by means of a new friction melt bonding process Scripta Materialia, 2014, Vol. 77, No. 8, pp.25-28

[2] ASTM E837-13a. International, "Standard Test Method for Determining Residual Stresses by the Hole-Drilling Strain-Gage Method," ASTM International, West Conshohocken, 2013.

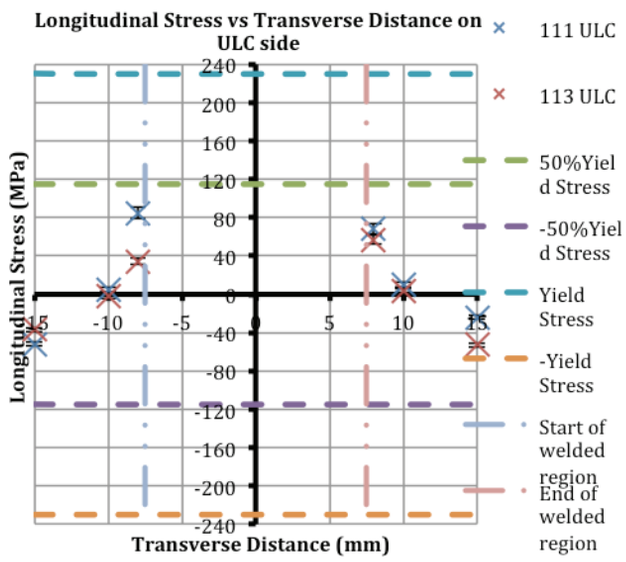

Figure 2: Longitudinal Stress (σ_y) (MPa) vs Transverse Distance (mm) on the E36 Ultra-Low Carbon Steel side

Characterisation of Racing Aerodynamic Package

Student: Roberta Michelle Vassallo / Supervisor: Dr Simon Mizzi

Introduction

Aerodynamic Packages have an essential role in race car performance to increase downforce, by creating a pressure gradient between the upper and lower surfaces of the car thus pushing the car downwards, enabling the car to go faster around bends. Such packages are studied and improved through use of Computational Fluid Dynamics (CFD).

Project Objectives

The aim of this project was to design an effective aerodynamic package to increase FSAE car downforce. The main objectives were to:

- Look into experimental and analytical methods to select the most appropriate method/s.
- Validate the CFD models used against published data before applying them to the car model.
- Design and optimise a diffuser for the FSAE car so as to reduce its lift as much as possible.

Project Methodologies

Different CFD models were validated against published data [1] [2], using a given flat plate model. A simplified faired surface for the provided University of Malta Racing car chassis was then created, around which the moving air flow was simulated in FLUENT for lift and drag results. Two diffusers were designed, added below the car, tested and optimised according to the obtained results.

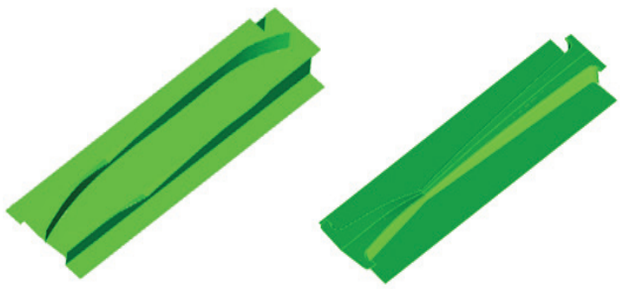

Figure 1: Design 1 (left), Design 2 (right)

Results and Achievements

Validation of a flat plate resulted in all tested turbulent models to be close to the published data. Thus, the standard $k-\varepsilon$ model with standard wall function was chosen for subsequent models as it requires less computation time than other models, whilst allowing varies velocities to be tested using a single mesh.

Design 1, shown in Figure 1, included side skirts and a central diffuser section to form two underbody tunnels. This resulted in an increase in lift which was later justified by a decrease in mass flow rate below the car; thus increasing the amount of air flowing above the car rather than below, leading to a positive upward force.

In Design 2, the central section was removed, leaving only one central converging, diverging tunnel. This achieved better mass flow rate than Design 1, and so a considerable amount of lift reduction could be observed. As can be seen in Figure 2, Design 1 increased lift even after improvement while Design 2 reduced lift and decreased it even more when the tunnel was constricted further, rendering the venturi effect more effective. Lift for the diffused car was reduced by as much as 86 percent than that for the undiffused car.

References

[1] J. Slater (2011, December) NASA Glenn Research Center [Online]. Available at: http://www.grc.nasa.gov/WWW/wind/valid/fpturb/fpturb.html

[2] J. Slater (2011, July) NASA Glenn Research Center [Online]. Available at: http://www.grc.nasa.gov/WWW/wind/valid/fplam/fplam.html

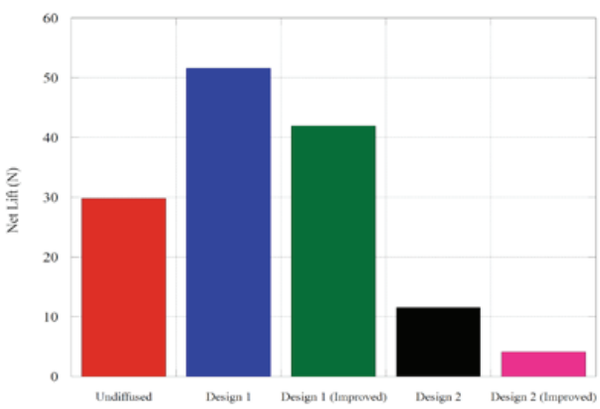

Figure 2: A bar graph showing net lift force (N) created at 80 km/hr for different designs

Experimental and Modelling the Response Framework of Liquid-Cargo Sloshing in Marine Vessel Hulls

Student: Kurt Vella / Supervisor: Dr Ing. Simon Mizzi

Introduction

As an external force acts on a free-surface liquid, whether being steady-state or transient, the liquid is disrupted from its equilibrium state, enabling its centre of mass and the free surface to shift from place to place within the container. This phenomenon is known as liquid sloshing and is typical in liquid-cargo marine vessels. Sloshing may induce large forces upon the ship leading to great damage to the ship's structural integrity.

Project Objectives

- To further explore the concept of liquid sloshing.
- To carry out experimental tests to determine the liquid-induced forces and moments on modified rectangular tanks.
- To simulate a two and three-dimensional models to verify the forces and moments induced by the slosh and the decelerating performance in a modified rectangular tank, to mirror the experiment.
- To create two further modified tanks with different baffle arrangements as slosh-suppressors.

Project Methodologies

A literature review was first completed outlining the fundamental properties of sloshing in marine vessel hulls. A rigid-body pendulum tank setup was created to model the rolling effect of small amplitude liquid sloshing within a partially filled modified rectangular cross sectional tank. The experimentation setup was employed with regards to five distinct tank setups, three of which were designed in the previous project that induce a certain degree of porosity within a partition situated in the line of symmetry of the tank cross section, and the other two consisted of different baffle placements rather than partitions. The tank setups consist of a hollow tank with no anti-slosh devices (100% porosity), a fully partitioned tank (0% porosity), and a perforated partitioned tank (50% porosity). Another tank has a baffle similar to the partitions with an orifice at the centre and the other comprises of horizontal and vertical baffles with orifices. These test subjects were examined at four distinct tank fill levels, 0%, 25%, 50% and 75%. Two and three dimensional simulation models were generated on computational fluid dynamics (CFD) software using ANSYS® Fluent to confirm experimental results.

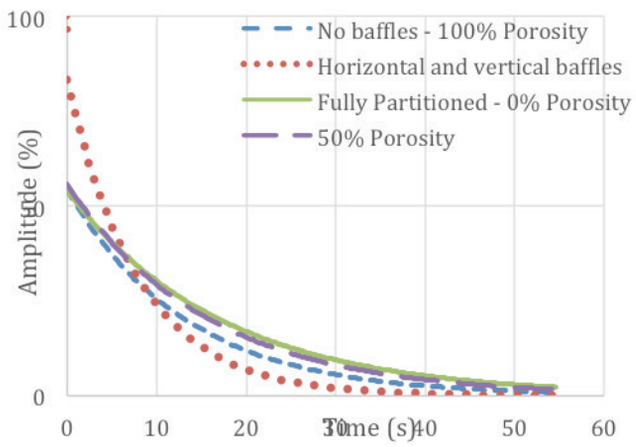

Figure 1: Amplitude (%) vs Time (s) for different baffle arrangements at a 50% fill-level

Results and Achievements

Two specific quantitative characteristics were derived with respect to time elapsed, to inspect the damping qualities of the internal structures applied; the angle of oscillation, and the maximum increase/decrease in torque within a single oscillation. Upon comparison, it was concluded that the horizontal-vertical-baffles arrangement tank achieved the most ideal results.
The two-dimensional and three-dimensional numerical models of the open-bore, the half porous-partitioned and the fully partitioned tank physical models were created and undergone simulation at all the three distinct fill levels, which achieved good agreement with the experimental data.

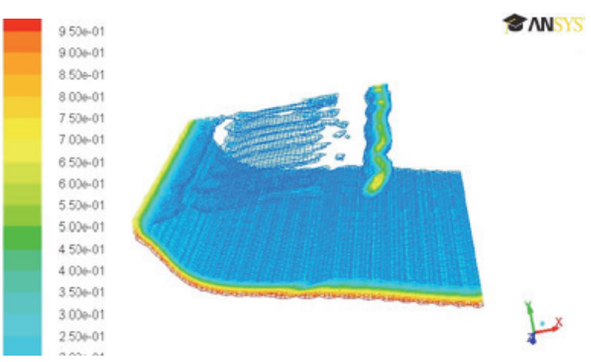

Figure 2: Three-dimensional simulation showing the sloshing free-surface

Rear Wheel Suspension

Student: Marvic Vella / Supervisor: Dr Zdenka Sant

Introduction

University of Malta Racing aims to better understand suspension systems to be able to design cars with better performance. Their request was to analyse the current suspension setup of the existing 2015 car (FC-15). A good understanding of suspension geometry and behaviour is fundamental to design any kind of vehicle, and even more important when it comes to competition cars. Through analysis of the present suspension system we can obtain the behaviour characteristics and effect of the suspension geometry on the car performance, which will support future design of a new car and its suspension.

Project Objectives

- To study and learn about the different types of suspension used and identify the most suitable system for an FSAE competition car;
- Study the effect of load transfer;
- To analyse the suspension system by performing: Static analysis, Kinematic analysis and Dynamic analysis
- To perform FEA analysis on the existing FC-15 suspension and identify possible improvements for future design.

Project Methodologies

Load transfer is studied for both linear and lateral acceleration together with the identified parameters that control the magnitude of load transfer. Roll performance for a double wishbone suspension system is studied. Static analysis is performed for a 3-D system. This analysis is applied using the geometry of FC-15 to find the static forces along the suspension members. Kinematic analysis is performed for a 2-D plane, rear wheel suspension system. This 4-DOF analysis considers roll, vertical displacement of sprung mass and vertical displacement of unsprung mass on both sides. This is used to find kinematic responses such as camber gain and wheel centre displacement for both roll and vertical displacement. Using the Lagrange analytical dynamics equations of motion the dynamic forces were evaluated [1]. Then these forces were used in a finite element analysis of the suspension geometry of FC-15 to find the magnitude and location of high stresses.

Results and Achievements

The magnitude of load transfer that occurs during turning, acceleration and braking was estimated and plotted for various levels of acceleration. By finding the roll gradient, it was possible to estimate the amount of roll occurring at various levels of lateral acceleration. This result was used in the kinematics analysis to obtain the values of kinematic parameters such as camber gain in the wheel, wheel centre displacement and deflection of the push-rod mechanism which operates the suspension springs. The kinematic equations were also used to calculate the response of the wheels when they encounter vertical displacements such as bumps in the road. The stresses that occur in the suspension members were found. This result provides insight to the required thicknesses of a certain load bearing members. FEA was also performed for the bearings used in the system thus allowing to have a design based on the analysis and provides the possibility to select the required size of the bearings.

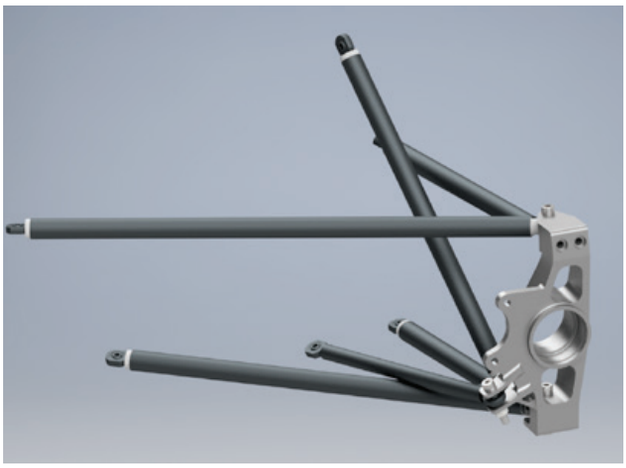

Figure 1: Rear wheel suspension assembly

References

[1]Jazar. 2014. Vehicle Dynamics - Theory and application. New York : Springer-Verlag, 2014.

Design of an Underwater Vessel using GFRP

Student: Timothy Vella / Supervisor: Prof. Ing. Martin Muscat

Introduction

A towfish is a relatively small vessel which is towed behind a ship or boat and is equipped with sensors to take measurements of underwater conditions. The department has already designed and fabricated a towfish using steel which, although successful, was considered to be relatively heavy. Therefore glass fibre reinforced polymers (GFRP) were proposed as an alternative material to reduce the mass of the towfish whilst maintaining the structural integrity necessary for operation.

Project Objectives

The main objective of this project was to review the previous towfish designed within the department and to redesign the structure using the design by rule (DBR) approach. Additionally design by analysis with finite element analysis (FEA) would be used to investigate non-standard components.

Project Methodologies

The maximum external pressure associated with the towfish's operating conditions was calculated to be 5.03 bar. Next, the code of standards BS EN 13121-3:2008+A1:2010 [1] was used to find the thickness of a single lamina, so as to determine the total laminate thickness.

The standards also provided equations relating the critical buckling pressure of certain shaped components to the dimensions as well as laminate thickness. Therefore the design by rule approach was carried out to find the minimum amount of laminae required to withstand buckling. An appropriate factor of safety of 1.5 was included in the buckling pressure load, to ensure stability in future operations.

For the flanges, FEA software ANSYS R15.0 [2] was used along with the DBR methods from standards which specified a maximum strain of 0.25% for these components. By modelling the components including the flanges, strain analyses were carried out to determine the ideal amount of layers necessary to meet the allowable strain limit.

Thus the design for the main body of the towfish was completed according to the DBR and DBA methods. Figure 1 shows a 3D image of the main towfish parts. The volumes and masses of the individual components were then calculated and compared to that of the previous steel structure.

Results and Achievements

The design obtained through the DBR approach managed to decrease the mass of the previous steel main body of the towfish by 29%. This is significant considering that the total mass of the previous towfish design was almost 90 kg.

According to the results of the linear buckling analyses, which were part of the DBA, further reductions in mass could be attained. This confirmed that the DBR was conservative in nature. However, these results could not be used for the final design since further analyses regarding other failure criteria would have to be carried out. These include loading due to hydroplane attachments, the rudder and ailerons.

Nonetheless this project succeeded in reducing the mass of the towfish, whilst also laying the groundwork for future work in carrying out a full design by analysis on the complete towfish vessel.

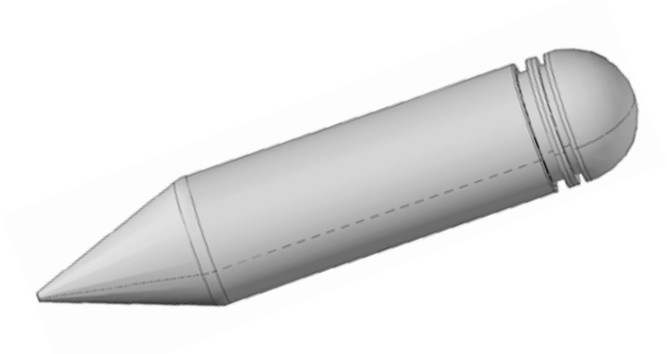

Figure 1: Main body of the Towfish Structure

References

[1] British Standards Institution (2012) BS EN 13121-3:2008+A1:2010 GRP tanks and vessels for use above ground – Part 3: Design and Workmanship.

[2] ANSYS 15.0 Mechanical. (2015). ANSYS Inc.

Free-Piston Engine

Student: Axel Zammit / Supervisor: Prof. Robert Ghirlando

Introduction

Though a relatively old technology with patents dating back to the 1920's, the free-piston engine has had very little going for it in terms of investment. A number of projects have been undertaken at the University of Malta for a number of years, with the purpose of creating a reliable and modifiable free-piston engine.

Project Objectives

The objective of this project was to understand why previous attempts to start the engine had all failed. It was intended to carry out a series of tests to diagnose potential faults, and to find and implement solutions to the faults to improve the engine.

Project Methodologies

After having become familiarized with the engine, a list of possible problems that were stopping the engine from starting was created. This led to the fishbone diagram in figure 1, which in turn allowed testing of the engine to be focused on the more important aspects of the engine.

The bulk of the testing involved the fuel supply, engine speed and in-cylinder pressure. Experiments carried out in the dissertation included flow tests to measure the discharge coefficient of the restrictions to the air supply going to the compressor, engine flow tests to measure the air flow going to the chambers during motoring, and pressure tests to gauge the health of the cylinders and piston rings.

The method of delivering fuel to the engine was changed from carburetion to fuel injection, which allowed better control of fuel quantities going into the engine. The engine motoring speed was also increased slightly by replacing the solenoid that supplies air to the compressor. Other changes were made to the circuitry involved with the engine, which were carried out to accommodate the changes made to the other engine systems. Trials were also carried out to try to start the engine. These were carried out to validate the changes made to the engine.

Results and Achievements

Utilizing the experiments conducted and the results gathered from those same experiments, the changes made to the engine improved motoring speed and controllability of the fuel quantity going to the engine. Unfortunately some problems with the circuitry did not allow the fuel injection setup to be exploited fully. The in-cylinder pressure testing together with some other tests proved that the engine blocks were not up to the standards expected. These problems related to the engine blocks were seen as the most likely cause of the failure to start the engine.

Though the engine could not be started after applying the changes to some parts, a good idea of the faults that troubled the engine was obtained. A list of possible improvements was created that, if followed, would most likely lead to the engine starting and running.

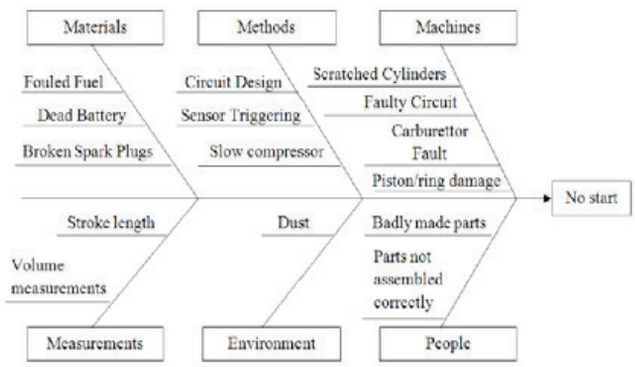

Figure 1: Fishbone diagram

Tribocorrosion of stainless steel in simulated body fluids

Student: Mark Anthony Bonello / Supervisor: Dr Ing. Bertram Mallia / Co-Supervisor: Dr Ing. Joseph Buhagiar

Introduction

The latest generation of metal-on-metal implants feature cobalt alloys as the bearing material. In this study, 316LVM stainless steel was investigated as a cheaper alternative to the current metals in use. A low temperature carburising (LTC) treatment performed by Bodycote Specialist Technologies GmbH (Germany) increases the hardness of austenitic stainless steels without detriment of corrosion by creating a diffused layer of carbon approximately 40 µm thick called the S-phase.

Project Objectives

The wear-corrosion response of an S-phase engineered counterface reciprocating against an S-phase engineered disc was investigated. Moreover, the significance of the biofilm formation on metallic surfaces brought about by the protein content found in diluted bovine serum was analysed to see how it affects the wear resistance of this alloy.

Project Methodologies

A carburised counterface in the form of a one sided hemispherical cylinder was made to slide over a carburised disc in Ringer's solution and also in bovine serum diluted in Ringer's solution. The latter is a protein containing solution which mimics the protein level of the synovial fluid found "*in vivo*".

The reciprocating counterface, supporting a load of 4.9 N, was placed inside a tailor made PTFE holder and made to slide over the disc at a frequency of 1 Hz. The test materials were immersed in the testing solution kept at 37°C and together with a reference and working electrode were connected to a potentiostat.

Each test consisted of three stages, during the first 10 minutes current values were recorded with the counterface static, sliding was then started and current values were recorded for 7200 seconds. During the third stage, current data was logged with the counterface immobile for 10 minutes. The coefficient of friction between the two metallic samples rubbing against each other was recorded by means of a strain gauge. The material lost after each test was quantified using the equation $T = W_0 + C_0 + C_w + W_c$ to identify how much material was lost by each element contributing to the volume loss. In this equation C_0 was assumed to be 0 and W_0 was found from testing at cathodic potentials. C_w and W_c are related to the synergistic effects of corrosion and wear [1].

Results and Achievements

"*In vitro*" studies showed that the treated stainless steel exhibited a remarkable improvement in volume loss when tested in both Ringer's solution and diluted bovine serum as can be seen in Figure 1. This hardening treatment was responsible to alter the wear mechanism by which material is lost from one that is governed by adhesion to an abrasive type of wear [2]. When testing in diluted bovine serum, the coefficient of friction was reduced thanks to a biofilm which induces a lubricating effect between the counterface and the

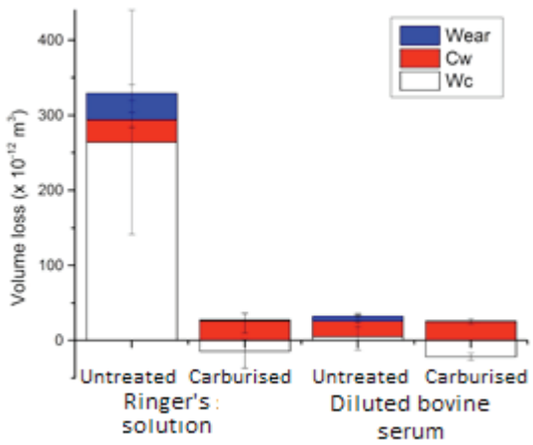

Figure 1: Material lost from untreated-on-untreated and carburised-on-carburised systems at anodic condition

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The Use of Calcium Tartrate as a Consolidant for Globigerina Limestone

Student: Christina Cardona / Supervisor: Dr Daniel Vella

Introduction

Malta's main building stone, Globigerina Limestone, is one of the island's few natural resources and its use dates back to ancient times. Deterioration of historical buildings, primarily due to environmental weathering promotes the need for stone conservation. A consolidant material is one that is applied to the stone to cement the weathered material with the underlying healthier stone core, thereby restoring the mechanical properties.

Project Objectives

In this study, di-ammonium tartrate (AMT) consolidant precursor was applied to as-quarried and artificially weathered Globigerina Limestone test specimens with the aim of evaluating the consolidation effects of calcium tartrate. The precursor AMT solution works in a similar manner to a conversion coating: on contact with limestone, calcium tartrate (CT) precipitates, serving as the consolidant material.

Project Methodologies

Franka-type Globigerina Limestone cubes c. $(45\times45\times45)$ mm^3 were cut out from a stone slab and processed to furnish: (1) as-quarried and desalinated (2) artificially aged and desalinated and (3) artificially aged, desalinated and salt-loaded stone blocks. To replicate the effects of naturally weathered limestone, artificial ageing was carried out by subjecting stone samples to several sodium sulphate salt crystallization cycles in accordance with BS EN 12379:1999 [1]. To further mimic the conditions of salt deterioration, some of the stone blocks were impregnated with a 1.0M solution of sodium chloride. Dried stone test blocks were then treated (by capillary action) to the precursor consolidant consisting of a 2.0M aqueous solution of AMT.

Treated and untreated control test blocks were characterized by different techniques including X-ray diffraction (XRD), scanning electron microscopy (SEM) coupled with energy dispersive spectrometry, infra-red spectroscopy, mercury intrusion porosimetry, contact angle and profilometry. A resistance to salt crystallization and resistance to drilling tests were carried out to evaluate improvements in respectively, the physical durability and mechanical properties of the stone. Water transport properties were assessed by a water absorption by capillarity test.

Results and Achievements

Electron micrographs showed that the consolidant material, CT, deposits within the stone pores. The deposited CT presents itself as a crystalline layer with distinct crystallographic orientations covering the underlying calcitic matrix, refer to Figure 1. The formation of CT was confirmed by XRD.

The mechanical properties of the treated limestone blocks were greatly enhanced after consolidation. The resistance of treated limestone to salt weathering was also markedly improved. Despite these improvements, water transport within the stone was reduced, even though CT, has hydroxyl (-OH) groups that should promote water flow over surfaces. A reduction in stone water transport properties is not desirable. SEM work appears to suggest that the slowing down of water uptake is due primarily to blocking of stone surface pores. Remedial action is being proposed to limit this effect.

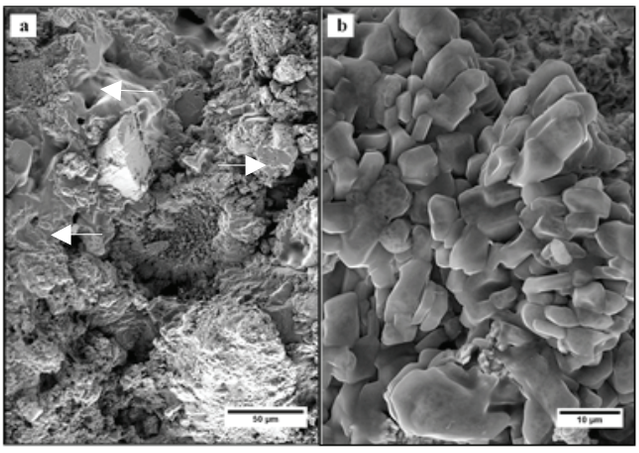

Figure 1: SEM micrographs of 4 hour treated sample showing (a) new material covering the underlying matrix at 1.0kX mag. and (b) newly formed crystals at 4.0kX mag.

References

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Towards temporary medical implants

Student: Carl Cassar / Supervisor: Dr Ing. Stephen Abela

Introduction

Temporary medical implants should ideally be made from biodegradable materials. In light of this, magnesium, a metal which degrades easily and is already present in the human body [1] was used. Magnesium's main problem however, is its excessively fast degradation rate. One way of mitigating this is by modifying its surface.

Project Objectives

- To modify the surface of several magnesium substrates at low temperature.
- To determine whether transferred arc corona discharge, a comparatively cheap surface engineering process, may help in this application.

Project Methodologies

Rectangular, industrially pure magnesium samples measuring about 30 by 20 mm, were treated in atmosphere. The surface treatment involved striking a high-frequency arc through a process gas using a plasma torch.

The process gas was used both as a medium to control the current flow, and as an oxygen source. Oxygen is required because this may lead to the formation of magnesium oxide on magnesium's surface, which is known be more passive than the metal.

One set of samples was treated using compressed air as process gas while the other set was treated with oxygen gas. Different time intervals were used for each set of samples.

The treated samples were potentiodynamically tested in a three-electrode electrochemical cell to test their corrosion resistance. Contact profilometry scans on the corrosion test areas were performed to measure the extent of damage on the sample's surface.

In addition, nanoindentation tests were carried out to test some mechanical properties of the modified layers.

Results and Achievements

Results from electrochemical tests seemed to show no trend in the correlation between surface treatment parameters and surface corrosion resistance. Similarly, no trends were observed in the values for hardness and Young's modulus obtained from nanoindentation tests.

However, Figure 1 shows that the corroded depth for 3 of the treated samples was significantly less than that of the untreated magnesium sample. Therefore, in spite of the lack of obvious observable trends, the surface treatment used may still be helpful in slowing down mangesium's fast degradation rate.

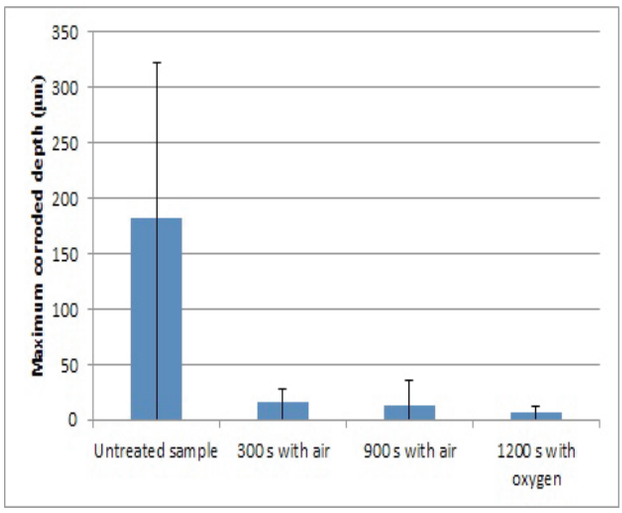

Figure 1: Maximum corroded depth from 3 repeats

Reference

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Tribocorrosion Response of Duplex S/Cr(N) and Cr(N)/S Coatings on Implant Grade 316LVM

Student: Raisa Chetcuti / Supervisor: Dr Ing. Bertram Mallia

Introduction

The need for orthopaedic implants to restore joint function of persons suffering from bone diseases are expected to increase sharply in people over 50 years of age by 2020 [1]. The increased use of implants in younger people coupled with longer life expectancy necessitates the increased longevity of implant materials. The study of the damage caused to the bearing surface of 316LVM implant material by the simultaneous action of mechanical wear and corrosion attack (tribocorrosion) helps in finding plausible solutions to mitigate such damage.

In this study, two dual-layered coatings deposited by magnetron sputtering Physical Vapour Deposition (PVD) at Boride Services Limited (UK) were investigated for the protection of 316LVM.

Project Objectives

The main objectives of this study were to investigate and compare the structure, properties and tribocorrosion response of Cr(N)/Co-Cr-Mo-(C) coated 316LVM [designated as: Cr(N)/S] and Co-Cr-Mo-(C)/Cr(N) coated 316LVM [designated as: S/Cr(N)]. The as-delivered biomedical grade stainless steel was used as the benchmark material.

Project Methodologies

The structure of the two coatings on 316LVM was investigated using X-Ray Diffraction (XRD). Their hardness and deformation behaviour were determined using Nano-indentation and Nano-scratch tests respectively.

The tribocorrosion response of medical grade 316 LVM, Cr(N)/S and S/Cr(N) was investigated with a reciprocating sliding test configuration under three distinct electrochemical conditions. All tests were conducted against an inert 7.94mm alumina ball, under a 1N normal load. Ringer's solution was the test solution used to simulate human body fluids.

The resultant scar morphologies were examined using Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDS), and contact profilometry.

Results and Achievements

The cross sectional fracture morphology of the Cr(N)/S and S/Cr(N) coatings are shown Figure 1(a) and 1(b) respectively. Both Cr(N)/S and S/Cr(N) exhibited higher nano-hardness with respect to untreated 316 LVM (~3.6 GPa), but that of the Cr(N)/S coating was the highest (~22 GPa). Cr(N)/S displayed the highest scratch resistance. Both coatings displayed very good adhesion both at the coating-substrate interface and Cr(N)-S coating interface.

The tribocorrosion response of both Cr(N)/S and S/Cr(N) coatings was superior to the untreated 316 LVM. CrN/S displayed the highest resistance to both material loss by corrosion and mechanical processes during tribocorrosion testing. The resultant scars had a smooth topography and the corrosion-wear resistance of CrN/S was 14.4 times better than that of the as-delivered 316LVM when tested under a potentostatic potential of +100mV versus SCE. In addition, the CrN/S coatings displayed an average dynamic coefficient of friction against the alumina ball of 0.16 which was much smaller than that displayed by 316LVM (0.38). Both Cr(N)/S and S/Cr(N) coatings displayed high resistance to localised corrosion/catastrophic damage during tribo-testing, making them candidates for deeper investigation for their application in the biomedical field.

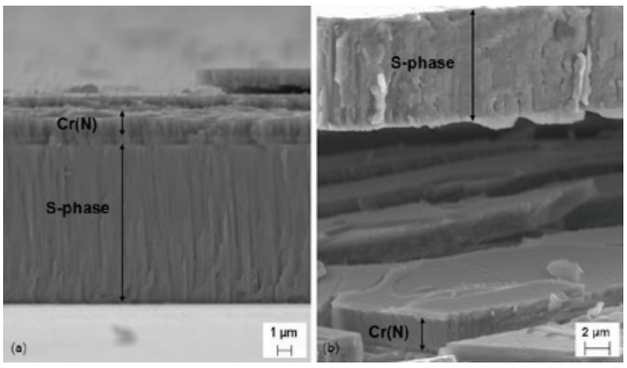

Figure 1: SEM images showing coating cross sectional fracture morphology of (a) Cr(N)/S, (b) S/Cr(N) coatings

References

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Design and Development of a Novel Biomaterial: Biodegradable Pure Iron

Student: Sean Farrugia / Supervisor: Dr Ing. Joseph Buhagiar / Co-Supervisor: Dr Ing. Glenn Cassar

Introduction

Biodegradable pure iron is a promising biomaterial for novel medical devices, particularly cardiovascular stents as it exhibits ideal mechanical properties for the application. Studies have shown that it has good biocompatibility within this application, however it degrades much slower compared to other proposed materials. This calls for further research into its degradation behaviour.

Project Objectives

Stents can be produced via electrical discharge machining (EDM) and laser cutting of thin sheets. In this study pure iron was characterised and its degradation behaviour after cutting was studied. The efficacy of electropolishing was also investigated as a potential final processing step.

Project Methodologies

Samples of pure iron in the annealed and tempered state were cut by laser cutting, wire EDM and abrasive water jet cutting. The latter was used as a control process as it has minimal impact on the microstructure of iron but is not practical for stent manufacture due to its poor cutting accuracy and efficiency. The cut edges of these samples were then analysed.

The effect of these conditions on the degradation behaviour was assessed by static immersion testing and potentiodynamic polarisation tests in Ringer's solution. The corrosion rates during both tests were determined using standard ASTM practices. Samples were then characterised using X-ray diffraction (XRD) before and after their corrosion. Topographical analysis was carried out via optical microscopy (OM) and scanning electron microscopy (SEM).

The microstructural changes as a result of the cutting processes were assessed by OM of chemically etched samples and electron backscatter diffraction (EBSD) analysis.

Finally, electropolishing was conducting using current and time as controlling factors. The results were analysed using OM.

Results and Achievements

The results of both the immersion and potentiodynamic corrosion tests indicated that laser cut samples degraded significantly faster than water jet cut samples. Finer grains towards the cut surface were detected via EBSD texture mapping, as shown in figure 1. This was linked to faster corrosion due to a higher density of grain boundaries [1].

Wire EDM cut samples degraded only slightly slower than laser cut samples. However, the microstructure did not contain fine grains. Unlike other sample types, phases of copper and zinc were detected by XRD. This was indicative of deposition of the wire material (brass) during the cutting process, thus the corrosion rate was accelerated due to galvanic coupling.

Analysis of electropolished surfaces showed that higher currents and lower polishing times resulted in the best quality surfaces. However, this was not consistent and localised corrosion was observed, thus this process requires further research.

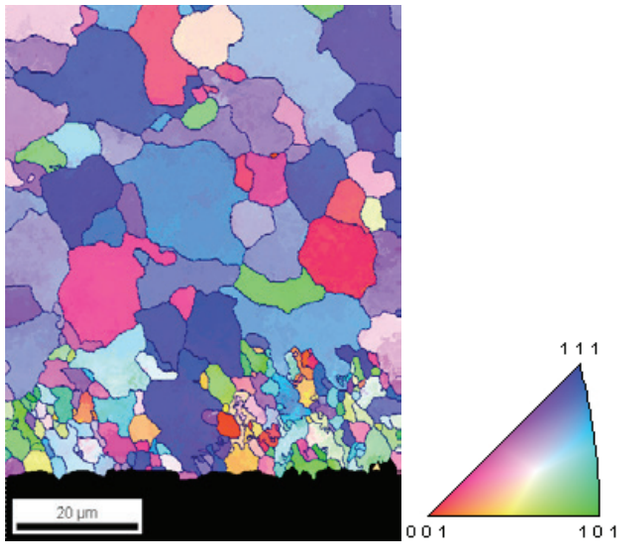

Figure 1: EBSD inverse pole orientation map for laser cut sample, located close to the surface

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Duplex CrN / CrC and CrC/CrN coatings for 316 LVM medical implants

Student: Karl Laspina / Supervisor: Dr Ing. Bertram Mallia

Introduction

Biomedical implants are used extensively in orthopedics. By 2030 it is estimated that the total number of hip replacement surgeries in the USA will increase by a staggering 174% [1]. It has become of paramount importance to improve implant materials to increase their longevity and cost effectiveness. Bearing surface of hip joint replacements made from biomedical grade stainless steel suffers from wear and corrosion damage that makes them inferior to other more expensive metallic alloys in use. The application of thin protective coatings deposited by Physical Vapour Deposition (PVD) is a plausible cost effective solution to address this challenge.

Project Objectives

The main objective of this project was to investigate the response of two dual-layer PVD coatings deposited on 316 LVM to the simultaneous action of corrosion and wear (tribocorrosion). Previous studies investigated the tribocorrosion response of single layer Cr(N) [2] and Cr(C) [3] coatings. This work investigates the tribocorrosion response of dual-layer coatings produced from Cr(N) and Cr(C) to provide better insight on the tribocorrosion damage mechanisms of PVD coated materials in particular at material interfaces.

Project Methodologies

In this project, the dual-layer coatings investigated were Cr(N)/Cr(C) and Cr(C)/Cr(N). Their surface chemistry, coating structure, adhesion, hardness, and deformation response were studied using material characterisation and testing techniques. The static corrosion response of the untreated and treated 316 LVM specimens was investigated by conducting potentiodynamic corrosion tests. The reciprocating sliding tribocorrosion testing was carried out under three different electrochemical potentials (Cathodic protection; Open circuit potential; Anodic potential of +100mV vs. SCE) at the DMME labs. Sliding was carried out at a frequency of 2 Hz against an inert 7.94 mm alumina ball under a load of 1N. All testing was carried out in Ringer's solution to simulate body fluid. Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDS) and contact profilometry were used to analyse the morphology of the wear scars generated during tribocorrosion testing.

Results and Achievements

The Cr(N)/Cr(C) coating displayed the highest hardness of 24 GPa followed by the Cr(C)/Cr(N) coating which had a hardness of 16 GPa. Both coatings were much harder than the substrate (3.6 GPa) and exhibited very good adhesion. Reciprocating sliding tribocorrosion testing resulted in the uncoated 316 LVM specimens to display much larger material losses ($10.4 \times 10^{-12} m^3$ under +100mV vs. SCE conditions) compared to the coated materials. The Cr(N)/Cr(C) coating exhibited the lowest material loss ($1.56 \times 10^{-12} m^3$ under +100mV vs. SCE conditions) but was susceptible to failure at the Cr(N)/Cr(C) interface (Figure 1). Although the damage observed for Cr(N)/Cr(C) in this study was much less severe in comparison to the Cr(N) coated 316LVM in [2], it is still a concern for their long term performance in service.

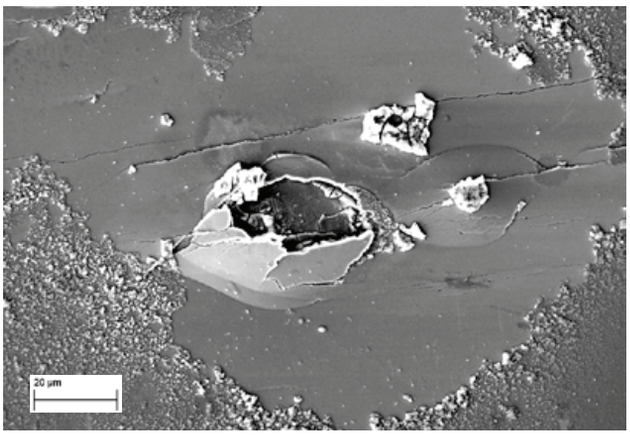

Figure 1: SEM image of Cr(N)/Cr(C) coating displaying blistering under anodic potentials

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Study of a Heat Treatment Process for Austenite Stability

Student: Roberto Migneco / Supervisor: Dr Ing. Ann Zammit / Co-Supervisor: Prof. Ing. Maurice Grech

Introduction

Today's technological demands require continuous improvement in existing materials and their processing techniques. A particular topic of interest is austempered ductile iron (ADI) which is a heat treated ductile cast iron (Figure 1). A wide range of properties can be attained by varying the treatment parameters, making ADI suitable for a wide range of applications, such as gears or crankshafts.

Project Objectives

The main aim is to determine the right combination of treatment parameters that will yield high ductility and toughness in ADI. These properties are obtained by producing a stable structure of high austenite volume fraction and austenite carbon content.

Project Methodologies

Nodular cast iron samples were machined and heat treated with a typical austempering cycle [1,2] to produce ADI. The cycle involved heating the samples to an austenitising temperature of 900°C or 950°C for a period of 2 hours, and then quenching in a salt bath to an austempering temperature between 260°C and 380°C for a period between 5 minutes and 6 hours. Finally, the samples were left to cool in air to room temperature.

The heat treated ADI samples were then analysed by X-ray diffractometry, optical microscopy and hardness measurements.

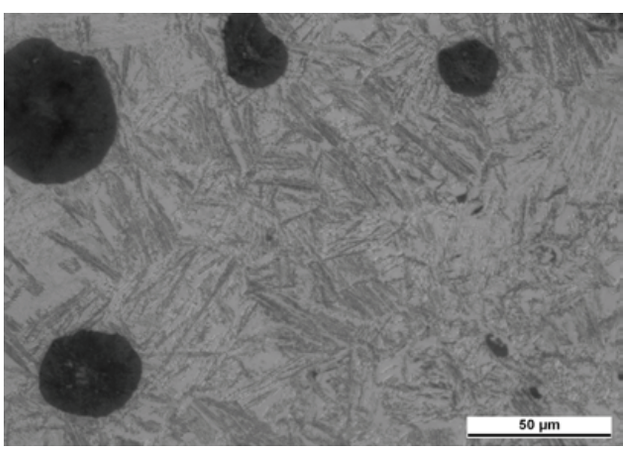

Figure 1: Micrograph of an ADI sample austenitised at 900°C and austempered at 380°C for 3 hours

Results and Achievements

Higher austenitising temperatures resulted in larger grains and thus, higher initial carbon content values of the austenite.
Low austempering temperatures and times produced the lowest values of austenite volume fractions and austenite carbon content as carbon diffusion rates are low and carbon is not given enough time to diffuse out of the ferrite and stabilise the austenite.

The highest value of the product of austenite volume fraction and austenite carbon content, i.e. the total austenite carbon content, ($V_\gamma C_\gamma$) was of 0.83 ± 0.07 wt% (as shown in Figure 2). This was achieved when austenitising at 950°C and austempering at 380°C for 6 hours. These treatment parameters also resulted in the lowest value of hardness of 27 ± 1 HRC, which is consistent with the high volume of austenite.

Consequently, these heat treatment parameters would need to be adopted for the highest possible values of ductility and toughness in Cu-Ni ADI.

References

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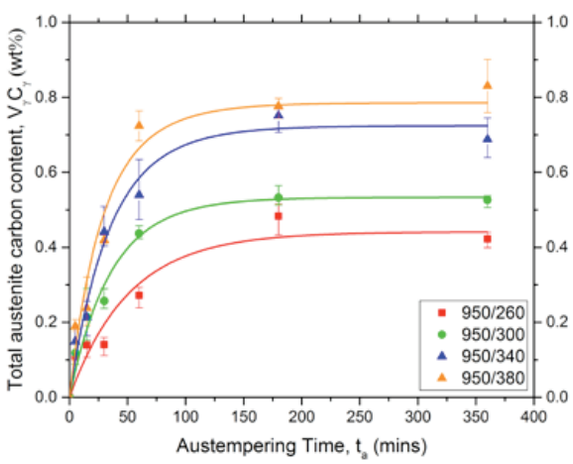

Figure 2: Product $V_\gamma C_\gamma$ vs Austempering Time, t_a (mins) for samples austenitised at 950°C

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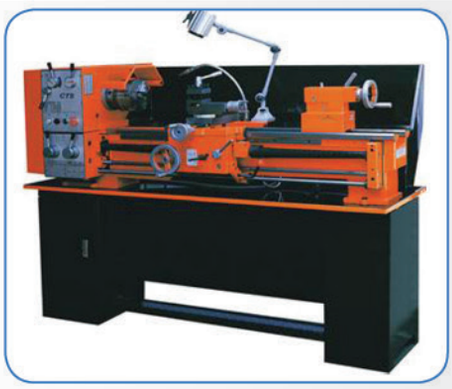




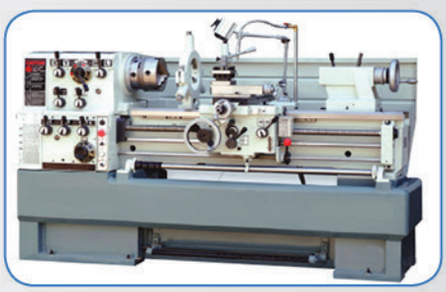








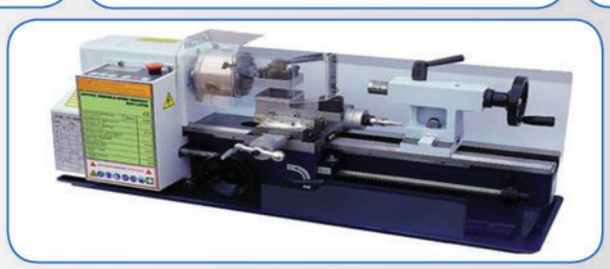
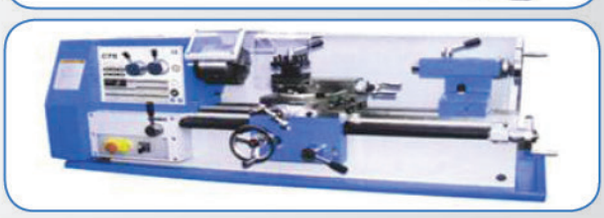

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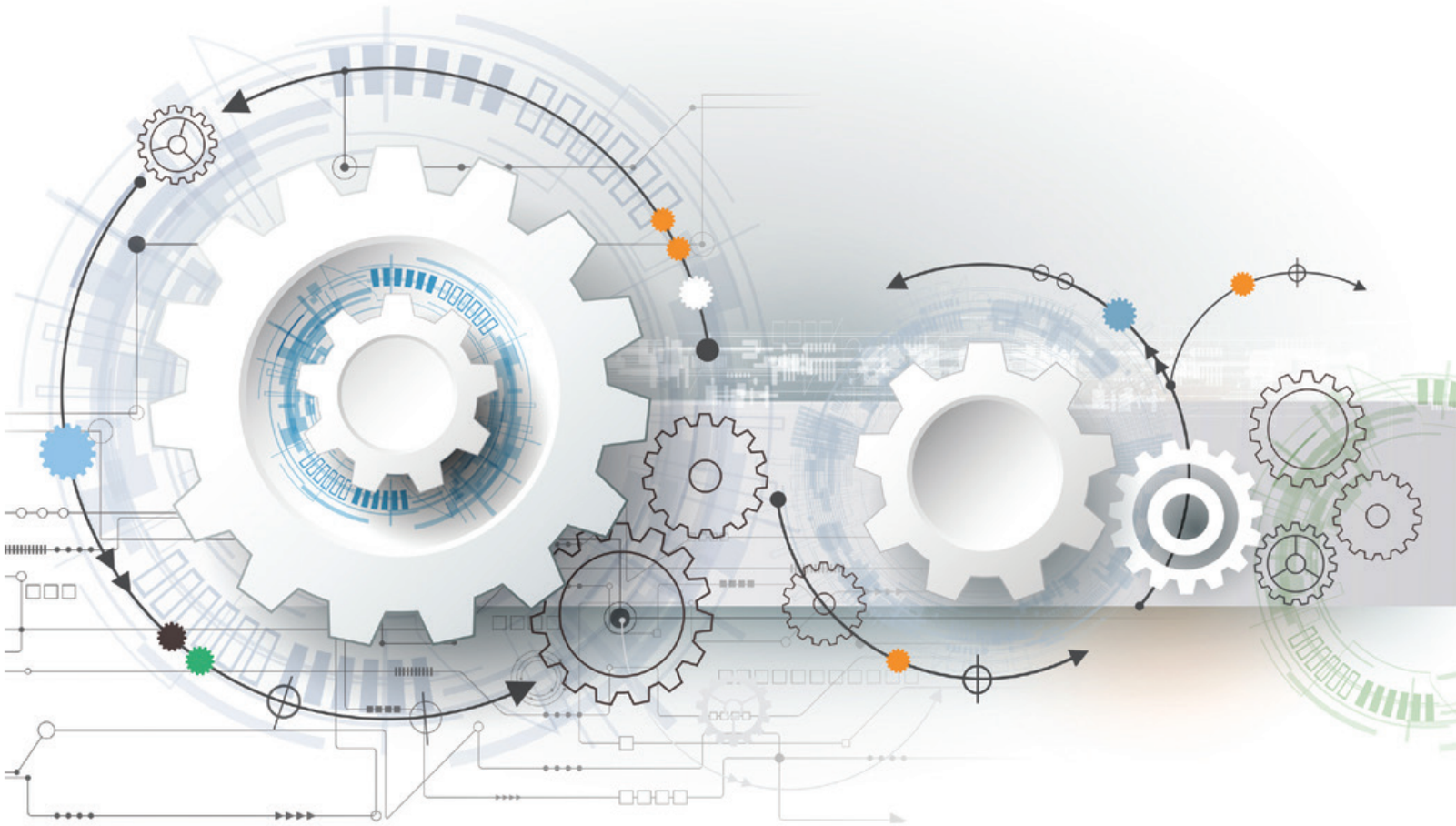

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