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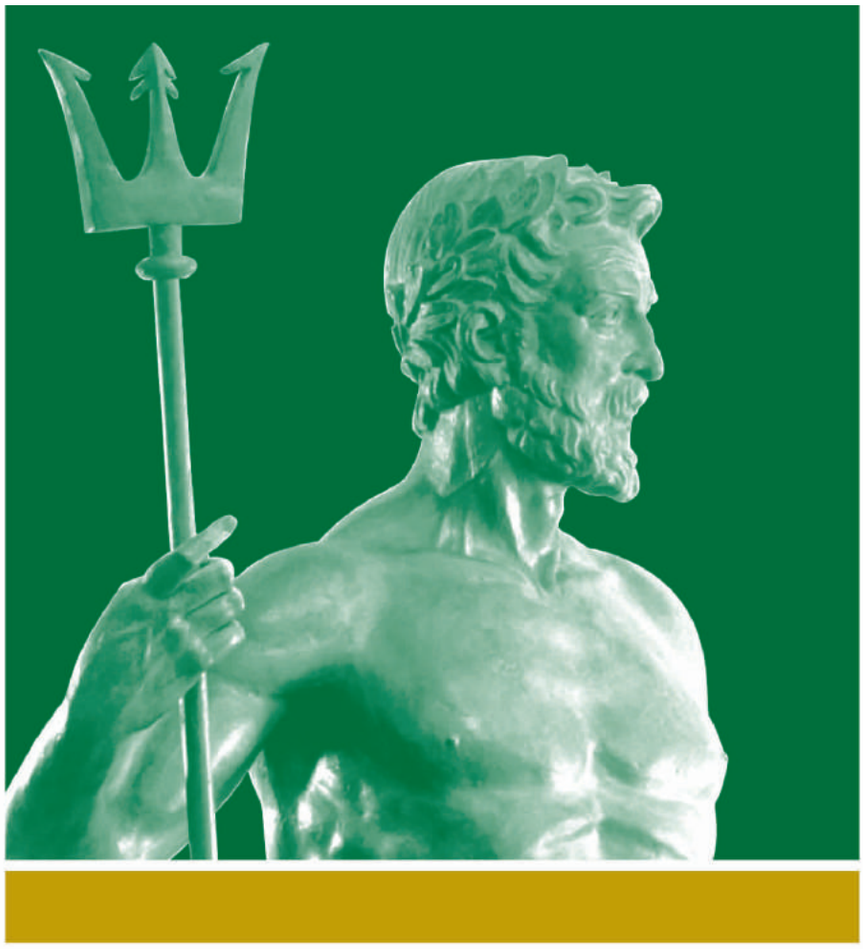

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FINAL YEAR ENGINEERING PROJECTS EXHIBITION 2013

Faculty of Engineering
University of Malta

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CONTENTS

MECHANICAL ENGINEERING STREAM

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

Projects supervised by members of the Department of Mechanical Engineering

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

FOREWORD

Dear Reader,

I have once again been given the privilege to write the foreword to this booklet, which presents the final-year projects created by students reading for the B.Eng. (Hons) degree at the Faculty of Engineering during the academic year 2013-2014. This is a particular occasion, as our Engineering degree is 50 years old this year, the first intake of students having started their studies in 1963.

Within this booklet each student describes her or his final year project, highlighting their achievements and showing how these were attained. Work on these spreads over both semesters of the fourth and final year of studies which culminates in the dissertation, a document of around 100 pages. Each dissertation is the product of individual work, guided by a supervisor, but produced by the student using the skills acquired over the course of the engineering degree: a capability for technical research, the design and implementation of experiments, the application of scientific methods and the analysis and interpretation of data to obtain valid conclusions. The outcome of this work is presented in the 24th annual exhibition, which seals the formation of our graduate engineers.

The changes which the course has undergone in these 50 years are great; this is unavoidable in a discipline which re-invents itself continually, and which consistently presents new concepts and technologies. The facilities available today reflect the vanguard of modern engineering practice; most of the projects presented here would have been unconceivable fifty years ago, using resources which have been acquired to retain the standard of excellence which has characterised our degree courses. Over the brief duration of the exhibition our students, who have maintained the tradition of hard work and dedication characteristic of the degree, become our alumni, and join the ranks of the hundreds who preceded them. We look forward to work as colleagues with these new graduates, as Prof.essional engineers in industry, or as successful postgraduate students in our own or in other universities.

In conclusion I once again thank all the staff of our Faculty, and in particular the PR team headed by Dr Bertram Mallia, and the Dean's Office Coordinator Mr Michael Spiteri. But a special thanks and congratulations go to our students, whose work and dedication make this booklet and the exhibition possible.

Dr Ing. John C. Betts

RESEARCH PROJECTS WITH EXTERNAL FUNDING

Improvement in the surface characteristics of titanium alloys using PIRAC nitriding treatments

Funding Body: Strategic Educational Pathways Scholarships (STEPS)
Project Fund: €8K
Student: Ms Bonnie Attard
Supervisor: Dr Ing. Glenn Cassar
Consortium/Partner: University of Technion Israel Institute of Technology, Israel

The aerospace industry; the main user of titanium and titanium alloys

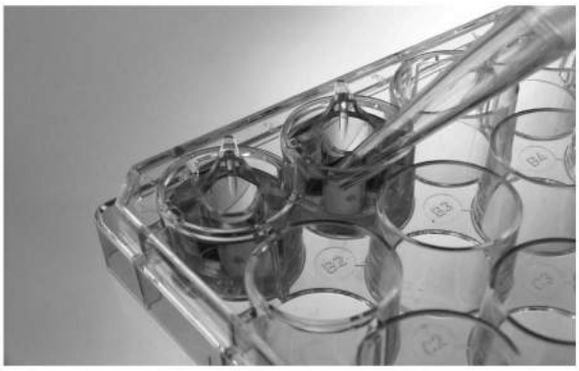
Towards Long Lasting Orthopaedic Biomaterials Implants

Funding Body: Strategic Educational Pathways Scholarships (STEPS)
Project Fund: €9K
Student: Ms Josianne Cassar
Supervisor: Dr Joseph Buhagiar
Co-Supervisor: Dr Bertram Mallia
Consortium/Partner: Bodycote Hardiff GmbH, Germany

X-Ray image of an implanted metal-on-metal Birmingham Hip Replacement (BHR)

In-vitro studies of surface hardened Cobalt-Chromium-Molybdenum alloys

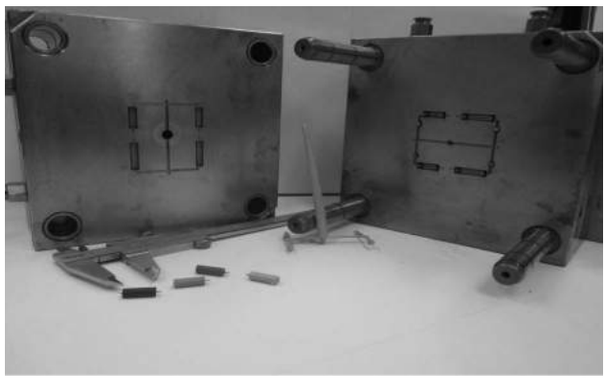
Funding Body: Bodycote Hardiff GmbH, Germany
Project Fund: €16K
Student: Malcolm Caligari Conti
Supervisor: Dr Joseph Buhagiar
Co-Supervisor: Dr Pierre Schembri Wismayer MD
Consortium/Partners: Bodycote Hardiff GmbH, Germany Dept. of Anatomy, Faculty of Medicine & Surgery, University of Malta



Biocompatibility testing using mouse and human osteoblast cell lines

Exploiting Multi-Material Micro Injection Moulding for Enhancing Manufacturing Competitiveness (EX-MMIM)

Funding Body: Malta Council for Science & Technology through the National Research & Innovation Programme 2012
Project fund: €141,871
Principal Investigator: Dr Ing. Philip Farrugia
Co Investigator/s: Dr Arif Rochman, Ing. Pierre Vella, Mr Luke Said
Consortium/Partners: Department of Industrial & Manufacturing Engineering, University of Malta (Project Coordinator), Tek-Moulds Precision Engineering Ltd, Techniplast Ltd and Playmobil Malta Ltd.
Project start date: 1st November 2012
Expected duration: 2 years



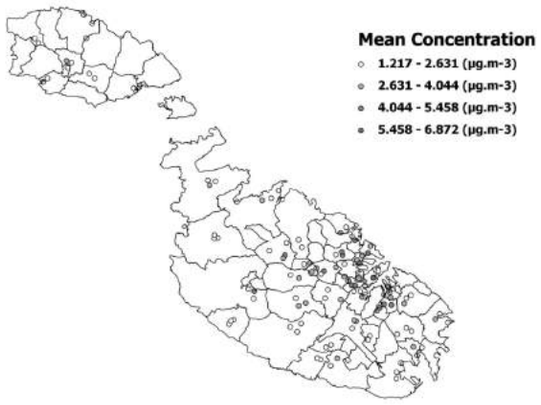
Eye-Communicate: Robust, Cost-Effective Eye-Gaze Technology for Assisted Communication

Funding Body: Malta Council for Science and Technology through the National Research and Innovation Programme 2012
Project Fund: € 167,683
Principal Investigator: Prof. Ing. Kenneth P. Camilleri
Co-Investigators: Ing. Stefania Cristina, Ms Marica Gatt
Consortium: Department of Systems and Control Engineering at the University of Malta, in collaboration with the School Resources Department at the Directorate for Educational Services, Ministry of Education and Employment
Project Start Date: 1st November 2012
Project Duration: 2 Years

Low-cost eye-gaze tracking platform comprising an inexpensive webcam

Spatio-Temporal Analysis of Air Pollution Data

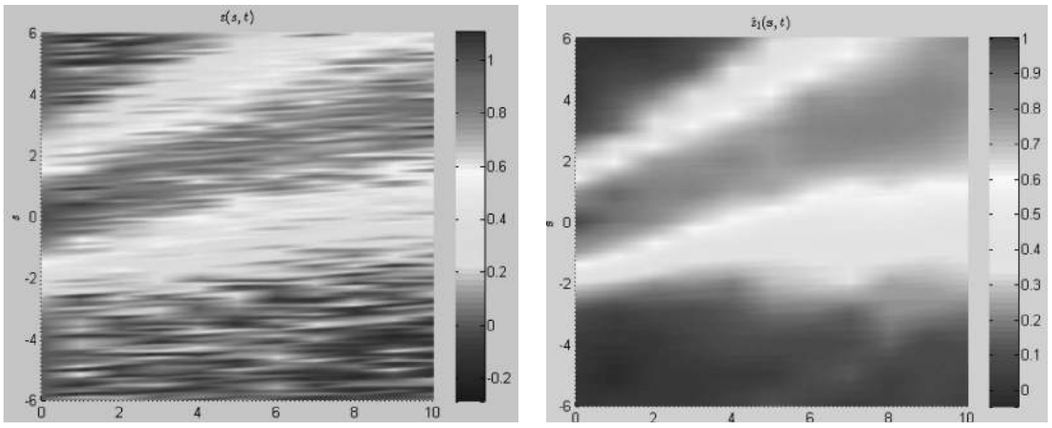
Funding Body: Malta Government Scholarship Scheme (MGSS)
Student: Ms Luana Chetcuti Zammit
Supervisor: Dr Kenneth Scerri
Co-Supervisor: Prof. Simon G.Fabri
Consortium/Partners: Maria Attard, Therese Bajada, Mark Scerri
Project start: October 2011
Project Duration: 3 Years



Mean Benzine Concentration at All Measurement Sites

Spatio-Temporal Modelling of Marine Pollution

Funding Body: Strategic Educational Pathways Scholarships (STEPS)
Student: Ms Nicolette Formosa
Supervisor: Dr Kenneth Scerri
Project start: October 2012
Project Duration: 1 Year



Measured and smoothed extra diffusive processes showing the diffusion of a gas affected by a prevailing displacement

SSVEP-based Brain-Computer Interface (BCI) System for a Real-time Application

Funding Body: Strategic Educational Pathways Scholarships (STEPS)
Student: Ms Rosanne Zerafa
Supervisor: Dr Tracey Camilleri
Co-Supervisor: Dr Owen Falzon
Project Start Date: 1st October 2012
Project Duration: 13 months

Setup of BCI system

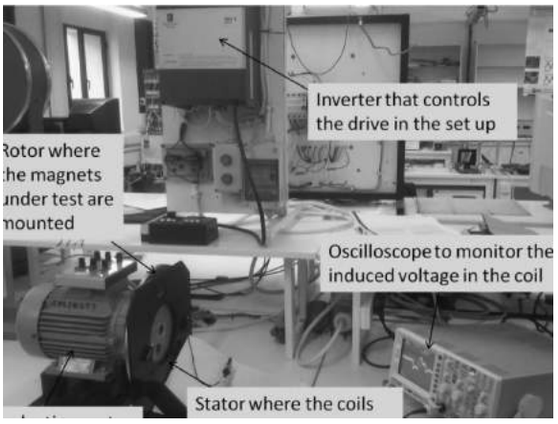
Nonlinear Control of a Ball and Plate System with Visual Feedback

Funding Body: Strategic Educational Pathways Scholarships (STEPS)
Student: Mr David Debono
Supervisor: Dr Ing. Marvin K. Bugeja
Project Start Date: 18th October 2012
Project Duration: 12 months

The newly-designed Ball and Plate test-bed

The Design of a Brushless Drive for a solar driven Stirling Engine

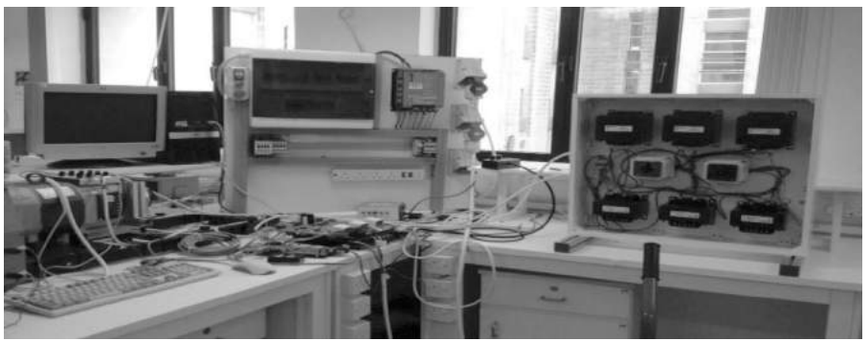
Student: Josef Mizzi
Supervisor: Prof. J. Cilia
Co-Supervisor: Dr M. Apap
Project Start Date: October 2011
Project Duration: 2 years
Consortium/Partner: Sirius Systems Ltd.



The experimental set up showing the drive and the inverter that controls the latter, together with the rotor & stator where the magnets & coils under test are mounted and also the oscilloscope used to monitor the energy pulse from the coil

Sensorless Control of a Matrix Controlled Doubly-Fed Induction Machine

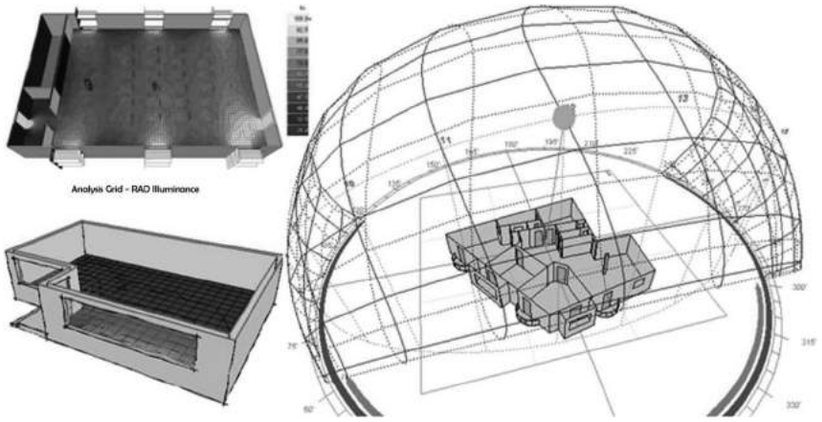
Funding Body: Strategic Educational Pathways Scholarships (STEPS)
Student: Kris Scicluna
Supervisor: Prof. Ing. Cyril Spiteri-Staines
Co-Supervisor: Dr Ing. Maurice Apap
Project Start Date: October 2011
Project Duration: 18 Months



Matrix Controlled DFIM Experimental Setup

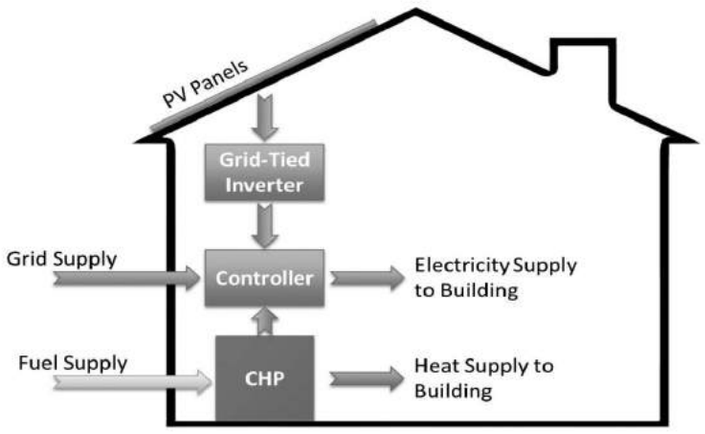
Analysis and Improvement of Energy Efficiency in Local Buildings

Funding Body: Strategic Educational Pathways Scholarships (STEPS)
Student: Matthew Bonello
Supervisors: Prof. Ing. Cyril Spiteri-Staines and Perit Ruben Paul Borg (Faculty of Built Environment)
Project Start: October 2012
Duration: 18 Months



Design and analysis of an electric drive for a domestic scale CHP Machine

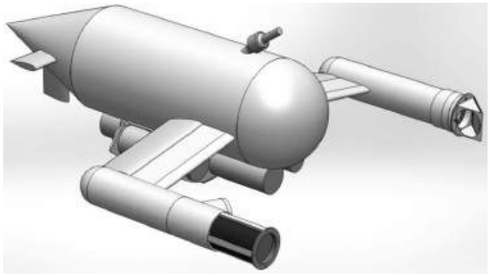
Funding Body: Strategic Educational Pathways Scholarships (STEPS)
Student: Matthew Schembri
Supervisor: Prof. Joseph Cilia
Started: October 2012
Duration: 18 Months

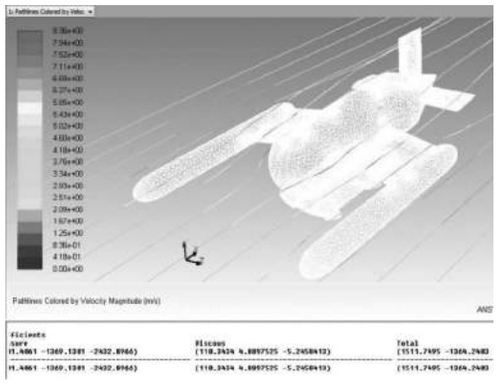


Block Diagram of the proposed system

BioDiValue - Biodiversity and Sustainable Development in the Strait of Sicily

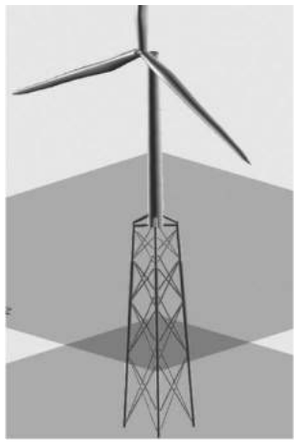
Funding Body: Italia-Malta 2007-2013 project
Project Fund/UOM fund: €2.2m/€218k
Principal Investigator: Dr Martin Muscat
Co-Investigators: Mr Mark Formosa, Mr Germ·n Alejandro Salgado MartÌn
Consortium/ Partners: ARPA - Lead partner(Siracusa), ConsorzioPlemmirio Area Marina Protetta (Siracusa), Department of Mechanical Engineering, Faculty of Engineering, University of Malta (link) International Ocean Institute - Malta Operational Centre, University of Malta
ISPRA (Roma),Area Marina Protetta ñ IsolePelagieSindaco del Comune di Lampedusa e Linosa(Lampedusa), Gal XLOKK, Malta, Universita` degliStudi di Catania (Sicilia), Green Life Soc. Coop. a r.l., Agrigento





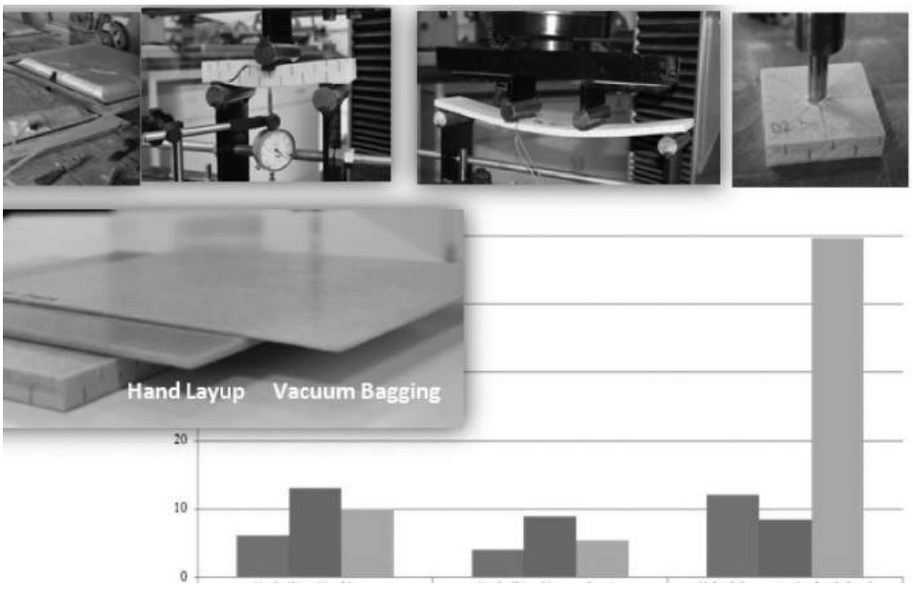
DOW - Deep Offshore Wind

Funding Body: Malta Council for Science & Technology through the National Research & Innovation Programme 2009
Project Fund: €98,000
Principal Investigator: Dr Tonio Sant
Co-Investigators: Dr Duncan Camilleri, Dr Pierluigi Mollicone, Dr Martin Muscat
Consortium/Partners: Institute for Sustainable Energy (University of Malta), Global Renewable Energy Ltd - GREEN Ltd., Honeycomb Services Ltd.



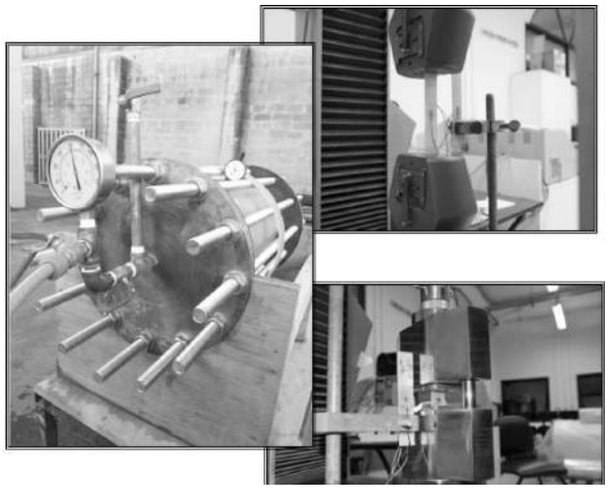
FACTS - Fabrication of Advanced Hybrid Composite Sandwich Panels – Testing and Simulation

Funding Body: Malta Council for Science & Technology through the National Research & Innovation Programme 2011
Project Fund: €95,660
Principal Investigator: Dr Claire De Marco
Co-Investigators: Dr Duncan Camilleri, Mr Jeremy Cortis, Dr Pierluigi Mollicone, Prof. Carmel Pule`
Consortium/ Partners: Buccaneer Boats Ltd



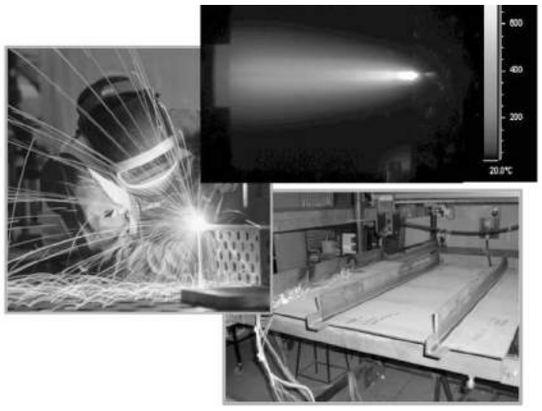
iReComp - Innovative Fibre Reinforced Composites Designed for Higher Structural Performance

Funding Body: Malta Council for Science & Technology through the National Research & Innovation Programme 2009
Project Fund/UoM Fund: €100k/€75k
Principal Investigator: Dr Duncan Camilleri
Co-Investigators: Dr Ing. John Betts, Mr Brian Ellul
Consortium/Partners: Department of Metallurgy and Materials Engineering (University of Malta), SilverCraft Products Ltd, Composite Solutions Ltd



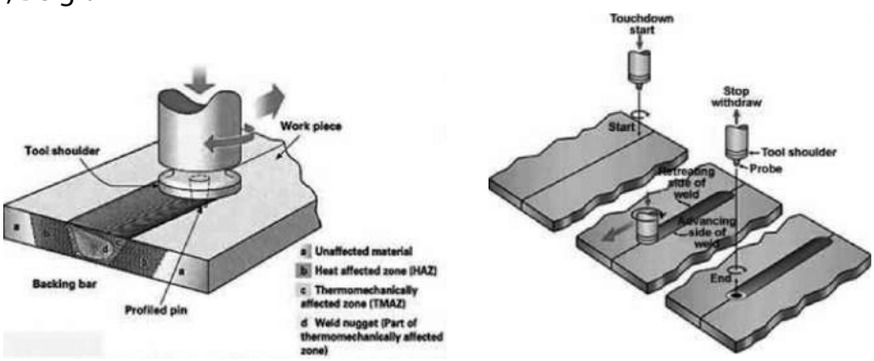
FLAMES - Fabrication of Lightweight Assemblies - Modelling, Experimentation and Simulation

Funding Body: University of Malta, Engineering and Physical Sciences Research Council, U.K.
Project Fund/UoM Fund: €400,000/€15,000
Principal Investigator: Dr Duncan Camilleri
Consortium/ Partners: Department of Mechanical Engineering, University of Strathclyde(U.K), School of Marine Science and Technology, University of Newcastle(U.K), BVT Surface Fleet Ltd(UK), Corus Ltd(UK), NST Welding(U.K)



HILDA – High Integrity Low Distortion Assembly

Funding Body: European Commission in Call FP7-SST-2012-RTD-1
Project Fund/UoM Fund: €2.2m/€210k
Principal Investigator: Dr Duncan Camilleri
Co-Investigators: Dr Pierluigi Mollicone, Dr Daniel Micallef
Consortium/ Partners: Department of Mechanical Engineering, University of Strathclyde, U.K. (Project Coordinator), Department of Mechanical Engineering, University of Malta, Centre de Recherche en Aeronautique ASBL (CENAERO) Belgium, The Welding Institute (TWI) Ltd., U.K, Lloyd's Register EMEA, U.K. , Center of Maritime Technologies e.V. (CMT) Germany, Naval Architecture Progress Greece,
GeonXsprl, Belgium



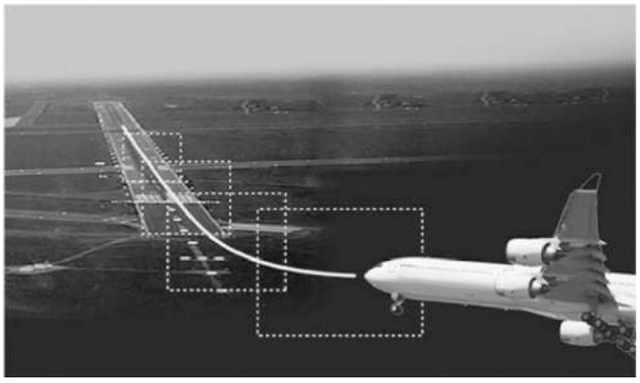
Generic principal of friction stir welding (courtesy of TWI Ltd)

SATVAWT - Self Adjusting Torque Vertical Axis Wind Turbine

Funding Body: Malta Council for Science & Technology through the National Research & Innovation Programme 2011
Project Fund/UoM Fund: €158,743/€38,327
Principal Investigator: Dr Pierluigi Mollicone
Co-Investigators: Dr Daniel Micallef, Dr Tonio Sant
Consortium/ Partners: Econetique, Alurwind, Architectural Projects - AP

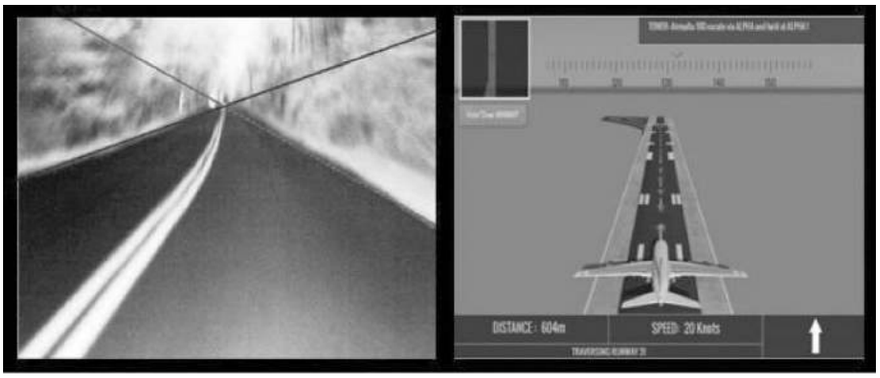
Clean Sky

Funding Body: European Commission/Industry Joint Technology Initiative (JTI)
Project Fund: €1,000,000
Principle Investigator: Prof. David Zammit Mangion
Co-Investigators: Ing. Kenneth Chircop, Mr Matthew Xuereb, Mr Matthew Sammut
Consortium/Partners: EADS, Airbus, Eurocopter, Fraunhofer, Alenia Aermacchi, Agusta Westland, Thales Avionics, Safran, SAAB, Liebherr, Rolls-Royce, Dassault amongst others, Department of Electronic Systems Engineering, University of Malta.
Project start date: 2008
Expected duration: 8 years



Alicia

Funding Body: European Commission FP7
Project Fund: €350,000
Principle Investigator: Prof. David Zammit Mangion
Co-Investigators: Ing. Evan Dimech, Mr Christian Zammit
Consortium/Partners: Agusta Westland (Lead Partner), Thales Avionics, Diehl, Latecoere, BAE systems, NLR, DLR, University of Braunschweig amongst others, Department of Electronic Systems Engineering, University of Malta.
Project start date: 2009
Expected duration: 4.5 years



Enhanced Vision Taxi Guidance System Outputs

ACROSS

Funding Body: European Commission FP7
Project Fund: €450,000
Principle Investigator: Prof. David Zammit Mangion
Co-Investigator: Dr Ing. Andrew Sammut
Project start date: 2013
Expected duration: 3.5 years

Clean Flight

Funding Body: Malta Council for Science & Technology through the National Research & Innovation Programme 2011
Project Fund: €102,000
Principle Investigator: Ing. Kenneth Chircop
Co-Investigators: Prof. David Zammit Mangion, Dr Ing. Andrew Sammut
Consortium/Partners: Department of Electronic Systems Engineering, University of Malta (Lead Partner), QuAero Ltd.
Project start date: 2011
Expected duration: 2 years

Touch Flight

Funding Body: Malta Council for Science & Technology through the National Research & Innovation Programme 2011
Project Fund: €160,000
Principle Investigator: Prof. David Zammit Mangion
Co-Investigator: Dr Ing. Andrew Sammut
Consortium/Partners: Department of Electronic Systems Engineering, University of Malta (Lead Partner), QuAero Ltd.
Project start date: 2013
Expected duration: 2 years

Product Industrialization of High-Speed Multi vision Instrumentation

Funding Body: Strategic Educational Pathways Scholarships (STEPS)
Project Fund: €12,500
Student: Mr Andre' Micallef
Supervisor: Ing. Marc Azzopardi
Project start date: Q4 2012
Expected duration: 13 months

Diacom

Funding Body: Malta Council for Science & Technology through the National Research & Innovation Programme
Project Leader: Ing. Michael Attard (IML ltd.)
Project Coordinator: Dr Ing. Stephen Abela
Researcher: Mr David Grech

Solar Desalination

Funding Body: Malta Council for Science & Technology through the National Research & Innovation Programme
Project Fund: €230K
Project Leader: Dr Ing. Stephen Abela
Project Coordinator: Prof. Robert Ghirlando
Researcher: Ing. Paul Refalo

Facilities

Department of Electronic Systems Engineering

Electronic Systems Laboratory

25 workstations individually equipped with circuit construction and test equipment
Standard grade equipment for calibration and verification
Digital storage oscilloscopes
Logic analyzers
PCB etching facility
IC programming facility

Embedded Systems Laboratory

ARM7 microprocessor development boards
OrCad circuit simulation and PCB design software licenses
National Instruments LabView licenses
National Instruments analogue/digital data acquisition boards
FPGA development boards

Avionic Application Laboratory

Presagis VAPS and VAPS XT - HMI rapid prototyping tools
MicroNav Best - ATM simulator
Aircraft simulation test bed
Model Aircraft simulation and training software
UAV flight control application board
UAV test bed

Department of Industrial Electrical Power Conversion

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Harmonic Voltage and Current Measurement Set-up
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Switching Frequency Current Sensing for Power Electronics and Control
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200V AC 28kVA 3-phase and 200V DC 20kW Supply for Testing Purposes
Electrical Drives and Control Simulation Software
High Performance Machine Control
Low to Medium Power Machine Loading Units
Vector controller Induction Motor, Permanent Magnet Synchronous Motor and Switched Reluctance Rigs
Electric Car with Lithium Ion Battery Technology
Electric Boat
Water Tank for Electric Outboard Testing
Solar Catamaran

Department of Industrial and Manufacturing Engineering

CAD/CAM Systems Lab

The CAD/CAM Systems Lab is equipped with a range of software which supports the following product development activities:

Design and optimization of products and tooling
CAD customization

CNC machining simulation
Factory plant layout design and simulation
Human ergonomics simulation

Concurrent Engineering Research Unit (CERU)
Concurrent Engineering Research Facilities
Thermoplastic Design Guidelines
Picza LPX-250 3D Laser scanner

Robotics and Industrial Automation Lab (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
PUMA 260 6-DOF robot, 40cm reach, 1kg 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, components and tools

Advanced Manufacturing Lab
Sodick AP3L CNC Electric Discharge Machining (EDM) with Micro EDM capabilities
Dimension 1200es Plastic Rapid prototyping equipment
Additive manufacturing equipment: Titanium - ARCAM EBM S12 (Electron Beam Machining)
Thermoforming machine
Injection moulding machine (Boy 22E) with a clamping force of 200kN equipped with a second perpendicular injection unit

CNC Lab
Bridgeport Interact Series 1 CNC Vertical Milling Machine
Cincinnati Arrow Series 2 CNC Vertical Machining Centre

Metrology Lab
Metrology Equipment Including CMM and Surface Roughness Measurement
Calibration of Metrology Equipment in Roundness, Linear and Angular Measurements

University (Engineering) Workshop
Conventional Machine Tools including centre lathes, milling, surface and cylindrical grinding, gear hobbing, drilling and welding

Department of Mechanical Engineering

Thermodynamics Laboratory
Laboratory experiments for thermodynamics and heat transfer
Testing 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

PhotoStress® Plus analysis kit from Vishay Precision Group – Micro-MeasurementsStrain Gauge Instrumentation
Machine diagnostics
Vibration monitoring
Run-up Run down vibration testing
Order analysis
Modal analysis
Dynamic balancing of machines
Sound level monitoring
Tensile and impact testing

CAE Lab - Computer Aided Engineering Laboratory

Computer facilities to run the following engineering software:
FEA – Finite Element Analysis – ANSYS
CFD – Computational Fluid Dynamics Fluent
MATLAB/Simulink
CAD – Computer Aided Design SOLIDWORKS
WindPRO (EMD)
WAVE/VALDYN (Ricardo)
FloTHERM
Maxsurf
ANSYS AQWA
BladeIt

Fluids Laboratory

Low wind speed wind tunnel 38 x 38 cm
Low wind speed wind tunnel 900 mm diameter
Wave making generator 8 m long and 750 mm wide and 1 m deep
Multi-channel hot wire anemometry
Fluid mechanics data acquisition systems

Department of Metallurgy and Materials Engineering

Process Equipment

Plasma Assisted Physical Vapour Deposition (PA-PVD)
Gas / Plasma Nitriding Furnace
Vacuum Furnace
Laser Added Manufacture Centre
Air Furnace
Aluminium anodising Facility
Low temperature foundry furnace
Martempering salt bath
50W CO2 laser

Mechanical Testing

Tension/ Charpy Impact tester
Compression Testing (5 Ton)
Bending Testing (10 Ton)
Multipurpose dynamic testing (25 Ton)
Macro hardness tester
Micro hardness tester
Shore hardness tester
Pin-on-disk wear tester
Reciprocating sliding tribo-corrosion tester

Rotary bending fatigue tester
Gear tribological tester

Characterisation Equipment
Optical Microscopy with real time image acquisition
Incident light metallographic Microscope
Side projected stereo Microscope
Support metallographic microscopes
Confocal microscope
Potentiodynamic wet cell corrosion tester
Laser Induced Breakdown Spectrocopy (LIBS) for elemental qualitative analysis
Dilatometer

Scanning Electron Microscope (SEM) with:
In-lens backscattering detector
In-lens secondary electron detector
External secondary electron detector

Electron Probe Micro-analysis (EPMA) within SEM including:
Energy dispersive spectroscope
Wavelength dispersive spectroscope
Electron Backscatter Diffraction (EBSD) within SEM

Ultra high vacuum Integrated Characterisation Facility including:
Surface analysis by electron analysis
Monochromated X-Ray source
High energy multi wavelength X-ray source
High intensity electron source
Low energy UV source
Electron energy analyser
Rastering ion source
Large area ion source
Quadrupole mass spectrometer
Low energy electron diffraction (LEED)
Secondary electron detector
Surface analysis by surface probe microscopy
Atomic force microscopy (AFM)
Scanning tunnelling microscopy (STM)

X-ray diffraction (Cu-tube) for thin film analysis with:
Parallel beam / Bragg Brentano optics
Variable temperature reaction chamber

X-ray powder diffraction (Mo-Tube) with:
Bragg Brentano optics
Variable temperature reaction chamber

Nano Indentation equipment with:
Wet cell attachment
Variable temperature reaction chamber
Dynamic testing attachment

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

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FINAL YEAR ENGINEERING PROJECTS ELECTRICAL STREAM

An FPGA-Based Object Tracking System

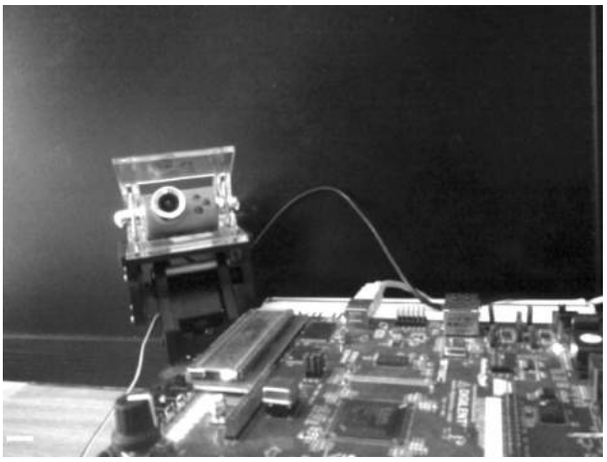
Student: Mark Calleja
Supervisor: Ing. Kenneth Chircop

Introduction
The use of FPGAs in image processing algorithms is becoming more popular especially where repetitive tasks are performed. Working at much lower frequencies than microprocessors, processing time is still highly reduced due to easily parallelizable processes.

Project Objectives
The aim of this project was to implement a simple object tracking system. This should be able to track objects against a relatively simple background. A typical application would be to track the moon at night. Implemented on a larger scale, such systems could be useful for astronomical studies.

Project Methodologies
An object tracking system needs to be able to get data about the scene, find the object within the scene and move the input sensor in the direction of the object to try and keep it centred. Thus the system was divided into three stages: Input, Image Processing and Output. In the Input stage, an image of the scene is captured using a camera. Therefore an interface was built to set the desired image parameters and to capture the data that is sent by the camera. From this stage, a gray scale image is obtained. This is then used in the Image Processing stage, where the first step is to convert the image from gray scale to binary by comparing all pixels to a threshold value. A binary image is one where the object pixels are represented as 1s while the rest of the pixels are 0s. However, an image typically contains noise which is not desired, as false results might be produced. Therefore the image goes through four stages of filtering in which the object is kept whilst removing the rest of the scene. The last step in this stage is to find the coordinates of the centre of gravity of the object. The output stage consists of a pan-tilt system which moves using two servo motors. The motors are controlled using two PWM signals. Therefore, depending on the coordinates of the object found in the previous stage, the pulse width of the servo signals is de/increased to turn the servos accordingly. Effectively, by mounting the camera on the pan-tilt system, the object is kept at the centre of field of view of the camera.

Results and Achievements
Some modification to the original plan had to be made. Unfortunately, the camera interface did not entirely work and so the image could not be captured. Therefore this was replaced by a webcam and a laptop. Using Matlab, the images are captured, converted to gray scale and sent to the FPGA through a UART interface. UART is a serial interface and hence much slower than the original parallel interface. This slowed down the whole system and so some modifications had to be made to compensate. However the rest of the system worked well and with the new input stage, the system is capable of tracking slow moving objects with relatively simple backgrounds.



Remote Monitoring and Control from a Smartphone or Tablet using a Raspberry Pi

Student: Matthias Fenech
Supervisor: Dr Ing. Andrew Sammut

Introduction
A network control system (NCS) was used to monitor and control a system from a remote location. A Raspberry Pi is considered ideal for the server-side of the system due to its low-cost, small design while also offering a great deal of flexibility with regards to its communication links. The client-side is made up of three separate applications, where each application controls a mobile robot in a unique way.

Project Objectives
The primary objective is to control and monitor the system from a remote site while utilizing a Raspberry Pi in the most efficient way possible. These milestones were planned:

- Research on server design, video transmission and serial transfer respectively with regards to the Raspberry Pi.
- The selection of a webcam and server packages and their implementations.
- The setup of the front end and back end of the server.
- Experimental implementation and testing of the separate applications.

Project Methodologies
Each application developed implemented a different control method while also presenting a different interface. The client-side provides the user with the information needed to control the system while the server-side script allows the browser to communicate with the Raspberry Pi by using the WebSocket protocol, which in turn communicates serially with a microcontroller located on the mobile robot. All applications developed are optimized for both mobile and desktop browsers, thus able to handle both touch and mouse events.

The three applications developed are: a manual control application that utilizes velocity control based on a Proportional-Integral-Derivative (PID) controller, a virtual line tracking application that operates position control also based on a PID controller and an object following application that uses data received from the camera to follow certain pre-defined objects.

Results and Achievements
The Manual Control application was tested by setting the target velocity of the robot, while comparing this value to the actual speed of the robot. The results obtained as depicted in Figure 1, are then utilized in the tuning of the controller.

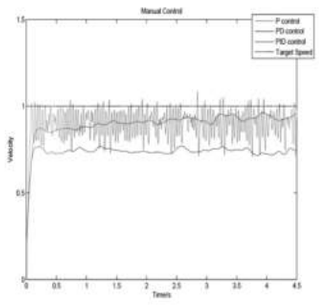


Figure 1: Velocity Control Output

The Virtual Line Tracking application was tested by comparing the actual path the mobile robot takes with the one requested. Several different paths were drawn on the browser, comparing the drawn path to the actual path and the odometric reading path.

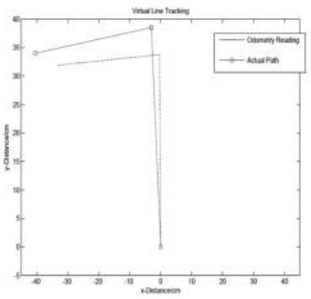


Figure 2: Actual Mobile Robot Path compared to Odometry Reading Path

Figure 2 shows a subset of the mentioned test were the mobile robot was requested to move in an L-shaped fashion.

The Object Following application was tested by fixing the object to be followed onto a uniform background while altering the mobile robot's pose. The robot then moves to centre the object in the image, resulting in the final horizontal pixel distance from the centre of the object to the centre of the image.

Low Level Signal Acquisition for the Life Sciences

Student: Savio Galea
Supervisor: Ing. Marc A. Azzopardi

Introduction
Analytical chemistry is a discipline which involves several analytical methods in order to analyse the chemical composition, identification and measurement of a substance. The use of its knowledge helps in solving science related problems, including assisting physicists in diagnosing diseases, ensuring good quality and safe water and pharmaceutical supplies. Most methods make use of the electrochemical cell made up of electrodes which are immersed in an electrolyte. Different electrochemical techniques are applied to a potentiostat connected to the electrochemical cell. The main objectives of the potentiostat are to control the potential difference and provide the required current to these electrodes.

The advances in these electrochemical techniques led to the introduction of small electrodes such as ultra-microelectrodes. These electrodes imply small currents. The size of these currents means that externally coupled noise has a significant effect on the results attained and hence noise must be mitigated.

Project Objectives
The scope of this project is to analyse all the possible sources of noise found in the potentiostat. A list of all the feasible noise mitigation techniques must be applied to the potentiostat circuit. Another important objective is to implement a computerized, signal generation and data acquisition system using optical transmission. The whole system design as shown in Figure 1, comprising all the noise suppression techniques should be implemented on a multilayer PCB.

Project Methodologies
The first phase involves listing all the possible noise sources found in a potentiostat circuit.
In the second phase the potentiostat circuit must be built and tested. A review on the noise coupled in the potentiostat circuit should be carried out.
The next phase involves an assessment on the noise mitigation techniques which can be applied to the potentiostat. A computerized, signal generation and data acquisition system using optical transmission should also be designed and tested. The analysis on the choice of components should be carried out right afterwards.
The fourth phase should include a careful design of a multilayer printed circuit board layout including all the viable noise suppression techniques

The last phase includes the soldering of components onto the manufactured PCB including the testing and calibration of the system.

Results and Achievements
The potentiostat was first built on a PCB and tested by using an electro-analytical method. The results obtained conformed to theory. After listing all the feasible noise suppression techniques, a signal generation and data acquisition system was implemented by the use of an audio codec, capable of receiving and transmitting digital data in the S/PDIF standard to a computer via TOSlink fibre optic cables. After this arrangement was tested, it showed good results. The last objective of this project was to implement all the system on a multilayer PCB. The PCB layout was designed carefully also including the valid noise suppression techniques. After the PCB was manufactured, all the components were assembled onto the board, including the final testing and calibration of the whole system.

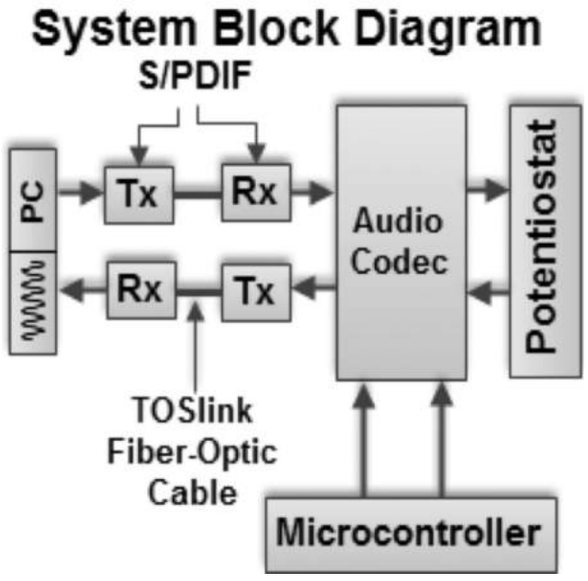


Figure 1 – System Block-Diagram

Smart Street Lighting Management System

Student: Warren Gauci
Supervisor: Mr Paul Zammit
Co-supervisor: Ing. Evan Dimech

Introduction

In an age where the importance of a clean environment has been recognised while fossil fuel is becoming even scarcer, reducing the consumption of fossil fuel and consequently the emission of green-house gases has become a major goal for most countries around the world. Research has focused primarily on the generation of power from renewable energy sources. A complimentary approach to this problem is to reduce the demand by increasing the efficiency of the current infrastructure. This approach entitles the employment of more established and relatively simpler technologies; therefore, the desired effect can possibly be achieved faster and at a lower expense. In this work, the local street lighting system has been taken as a case study in order to investigate these claiMs

Project Objectives

The aim of this project was to design an embedded system that controls the operation of street lighting, in order to obtain a smart system, which reduces the consumption of power and thus operational costs. The objectives were as follows:

- Investigation of street lighting requirements as per local and European lighting standards.
- Establishment of a management strategy for street lighting that meets the previously mentioned standards as efficiently as possible.
- Design of the hardware and software needed to develop an embedded system to manage street lighting according to the established management strategy.
- Evaluation of the energy saving potential of the designed and implemented embedded system.

Project Methodologies

The first project phase involved conducting a literature review in order to analyse lighting design considerations, applicable standard regulations, smart street lighting categories and implemented pilot project systeMs It could then be concluded that a fully adaptive type of system would best suit a local implementation. A system layout and a lighting strategy that the latter system should perform in order to achieve the best energy saving results were suggested.

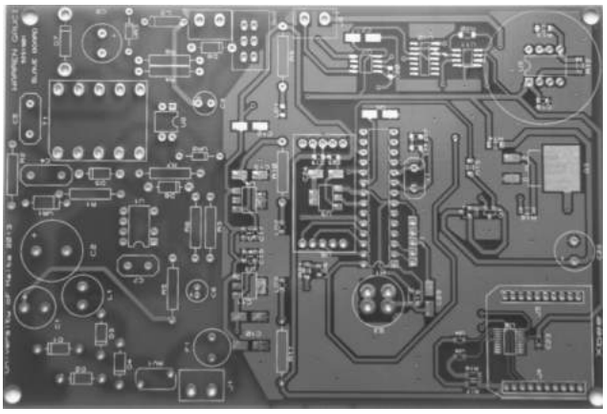


Figure 1: Lamp controller prototype board.

The next phase of the project was the embedded system design phase. Subsequent to a detailed requirement analysis the hardware and software needed to realise the mentioned lighting strategy was designed and rigorously tested. This led to the manufacturing of a final prototype board, shown in Figure 1. An algorithm that interfaces this board with a PC was programmed and the designed strategy was simulated on the PC. Limitations of the designed street lighting strategy were addressed and future recommendations were made.

Results and Achievements

The achieved results include the operational hardware and software that make up an embedded system which performs the function of a lamp controller in a proposed local smart street lighting system. The manufactured embedded system is capable of: measuring ambient light, monitoring the energy consumed by the lamp, detecting a tilted luminaire pole and performing dimming of the lamp. By the use of a ZigBee module it is also capable of wirelessly connecting with a PC and adopting an algorithm that imposes a lighting strategy which was designed to control the amount of light emitted by the lamp, thus reducing power consumption and maximising efficiency.

References

[1] [P.Van Tichelen, B.Jansen, A.Vercalsteren], '[Public Street Lighting]' [Final Report], 20[07], Vol. [40], No. [56457], pp.[17-20]

A Distance Measuring Technique for Indoor Localisation

Student: Daryl Martinelli
Supervisor: Ing. Brian Zammit
Co-supervisor: Dr Ing. Andrew Sammut

Introduction

The use of robotics in everyday life is constantly on the increase. In many instances, an increasing demand for autonomy was experienced, with robots required to operate for long periods of time without any or little human intervention. In order to achieve this high level of autonomy, a navigation function is required. The accuracy and success of the intended operation is only warranted if high localisation accuracy is possible. For outdoor applications a commonly used technology is the Global Positioning System but this is useless for indoor localisation, hence an alternative solution needs to be adopted. Some authors claim that, mobile robot localisation is the "most fundamental problem to providing robots truly autonomous capabilities" [1].

Project Objectives

This work is intended to provide a good insight on a chosen hardware to achieve accurate distance measurements. One technique is then selected and an in-depth analysis of its performance is carried out. The parameters of interest are the execution speed, measurement accuracy, development cost and ease of implementation. The work then focuses on improving the accuracy of the selected technique using signal processing methods.

Project Methodologies

A survey of various measuring techniques that can be adopted for indoor localisation was carried out. The use of ultrasonic technology was pursued for implementation of the distance measurement hardware. The ultrasonic hardware was tested for different characteristics especially, power radiation and detection angles. Figure 1 shows a polar plot for a single transducer power loss against detection angle.

A complete system was set up for ultrasonic distance measuring. This setup uses a time of flight measurement for the ultrasonic signal to propagate in air from point A to point B, to obtain a distance measurement using the speed of sound as a conversion factor. Distance measuring was obtained using three different methods. A common ultrasonic distance measuring technique was used as a base test, compromising of triggering the reception of an ultrasonic signal based on an accumulated voltage received. Two other methods involving line fitting techniques were implemented to improve accuracy over the basic distance measuring technique. This was done by using the line fitting to back-track the accumulated voltage received to the exact instant when the first ultrasonic signal was received.

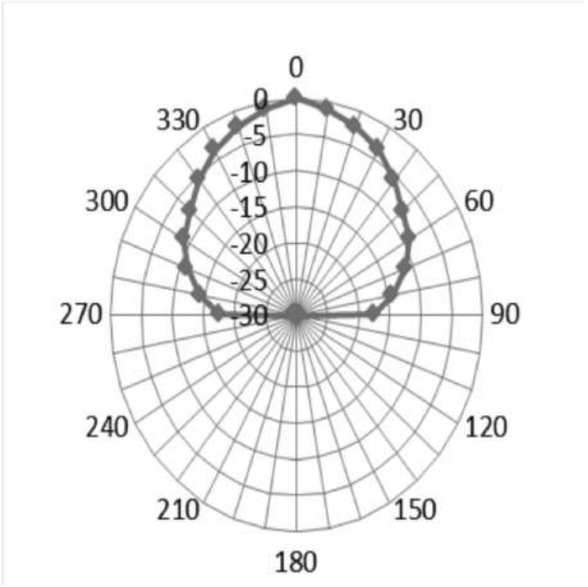


Figure 1 - Polar Plot

Results and Achievements

The results obtained when using the common method for ultrasonic distance measurement revealed an expected error that increases with respect to distance. The two line fitting methods offer an improved distance measurement, where the errors obtained are less than those obtained with base method, and the most beneficial factor being that the errors do not increase with distance. This is an important result, as indoor localisation can now be accurately obtained and robot autonomy capabilities are increased.

References

[1] I. J. Cox Blanche, 'Position estimation for an autonomous robot vehicle' Autonomous Mobile Robots: Control, Planning, and Architecture, 1991, Vol. 2, pp.285-292.

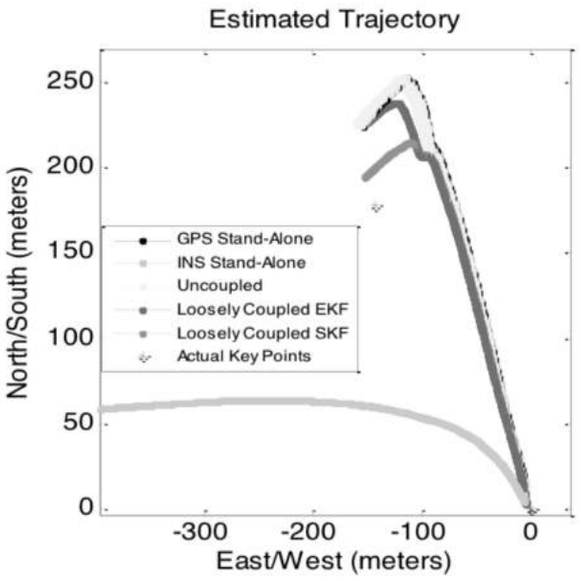
Data Fusion of Multi Sensory Information for Reliable State Estimation

Student: Merlin Mifsud
Supervisor: Dr Ing. Andrew Sammut

Introduction
Nowadays most of regular vehicles are equipped with a Global Position System (GPS) that constantly updates the vehicle's position in order to provide the driver information about his position, with accuracy up to several metres [1]. However, GPS suffers significant limitations such as the slow update rate, particularly at high speeds, and the sensitivity in low signal areas. On the other hand, Inertial Navigation System (INS) provides an alternative, self-contained solution that can provide high update rates, typically up to 100Hz. However, as INS make use of dead-reckoning, low frequency noise and sensor biases are amplified when integrated. Such opposing errors make it possible for both systems to be integrated and provide corrections to each other, which is the topic of this thesis.

Project Objectives
This project aims to obtain a satisfactory level of navigation performance in three-dimensions suitable for autonomous navigation of ground, aquatic or airborne vehicles. Such accuracy can be attained by fusing two independent navigation systems, typically having independent error characteristics.

Project Methodologies
In this project an approach of integrating a GPS and a strap-down INS is performed. The continuous time INS navigation and error equations are achieved. The navigation equation continuously integrates accelerometer and gyro measurements to output heading, velocity and position. These are corrected to the Earth's rotation, while the vertical channel being furthermore integrated with a Barometer. Inertial Measurement Unit (IMU) error dynamics are observed and plots are attained to justify the unbounded error obtained due to integration. Position fix and velocities are derived from the GPS which are then aided with the INS. An Extended Kalman Filter (EKF) with closed loop integration between the GPS and INS is applied to acquire velocity and position correction, providing closed loop feedback to both navigation systeMs Real-time navigation data is gained and stored, which is then applied off-line using MATLAB to test the integration algorithm.



Results and Achievements
A GPS aided INS was integrated using three methods, uncoupled, loosely coupled using EKF and Standard Kalman Filter (SKF). From Figure 1 it can be appreciated that the EKF attempts a correction at the exact point of turn. As corrections are applied on the error between the current corrected INS state and the current GPS state, corrections are performed to limit the error in relation to the GPS state. This is because the GPS is the long term navigation technique. Therefore, as expected, as the navigation continued the EKF coupling method converged to the GPS position. Conversely, the standard Kalman filter provides corrections in relation to current position and velocities according to covariance values for both INS and GPS independently. By tuning the Kalman gain through covariance values, more prominence was given to the GPS speed, INS orientation and corrected INS position. This combination was chosen in order to counteract for the hardware limitation, which better results were attained as can be seen in Figure 1.

References
[1] A. Schumacher, "Integration of a GPS aided strapdown inertial navigation system for land vehicles", M.S. thesis, Royal Institute of Technology, Stockholm, Sweden, Mar. 2006, XR-EE-SB 2006:006.

Detection of Critical Driving Situations in Motorcycles

Student: Stefan Sant
Supervisor: Prof. Carmel Pule'

Introduction

Motorcycles are one of the most affordable and popular means of transport across the world. However, over the last fifteen years, the portion of motorcycle crash fatalities has risen. Motorcycle and moped fatalities, often referred to as Powered Two Wheelers (PTW), accounted for 16% of the total number of road accident fatalities in 2009 in the EU 24 countries [1].

An analysis of an accident database and a motorcycle rider survey [2] revealed the following as causes for accidents that could be potentially avoided:

- Roadway damages, e.g. unevenness, ruts, and pot holes
- Obstacles on the road, such as broken down vehicles
- Excessive speed in curves, especially in irregular road conditions
- Friction steps caused by oil, gravel, sand and bitumen.

Motorcycles are statically unstable and only become stabilised in motion. The stabilisation of these two wheeled vehicles is mainly achieved through steering, which is designed to turn into the lean of the vehicle. The resultant centripetal acceleration tends to correct the lean in much the same way as a controlled inverted pendulum. These mechanisms rely on the availability of sufficient friction between the tires and the road. If a lower frictional force is available, as for example in slippery conditions, motorcycles can become irreversibly unstable, unlike four wheeled vehicles.

Considerable progress has been achieved with the introduction of vehicle control systems, such as the Bosch Motorcycle Stability Control (MSC) and Antilock Brake Systems (ABS). However these systems control braking and accelerating, mainly by monitoring wheel speed. Therefore, there is scope for research in situations where loss of traction is not due to thrust or braking, but due to lateral slip.

Project Objectives

The main objectives of this project were to:

a. Provide a background about the behaviour of motorcycles and identify parameters from which lack of stability during turning could be identified.
b. Design and construct an electronic data capturing system for a test rig intended to collect the identified parameters.
c. Install and test the electronic data capturing system under different operating conditions.

Project Methodologies

Theoretical analysis identified that the following measurements could be used to identify slip:

- Vehicle Roll Angle, Angular Velocity and Lateral Acceleration
- Steering Position
- Steering Torque Measurement

The practical setup was to include a twelve inch wheel bicycle. This would be inclined at a progressively increasing angle until slipping occurs, while the frame's motion is being observed.

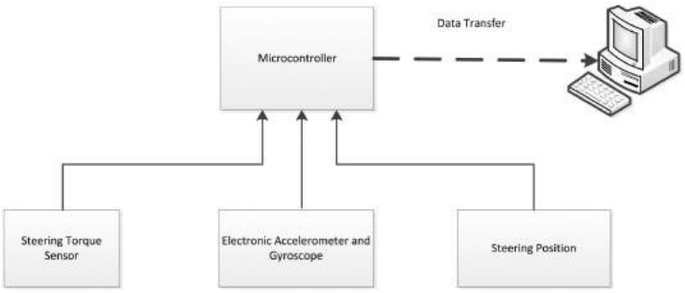
Results and Achievements

The system is being assembled and tested. Throughout the development work, it was shown that the system was successful in measuring the required parameters reliably.

References

[1] European Commission, Traffic Safety Basic Facts 2011 - Motorcycles & Mopeds, http://ec.europa.eu/transport/road_safety, Accessed February 2013.

[2] Lattke, B., Müller, T., Winner, H., MOLIFE - Hazard Detection in a Cooperative Assistance Systems for Motocycles , Paper No. 11-0070, http://www-nrd.nhtsa.dot.gov/pdf/esv/esv22/22ESV-000070.pdf, Accessed November 2012.



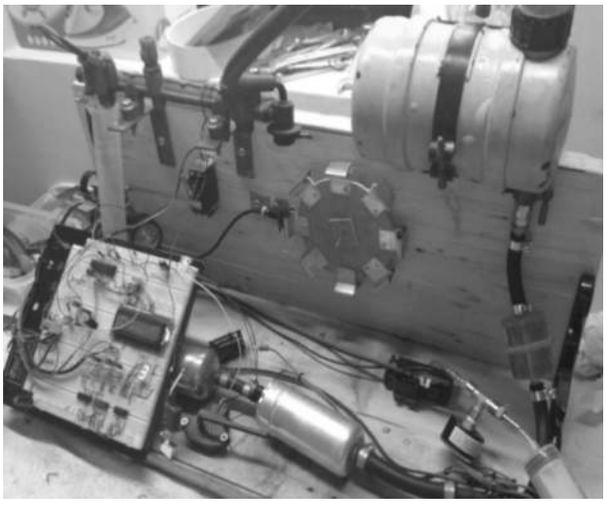
Data Monitoring for Motorcycle Parameters

Design and development of an Electronic Fuel Injection system

Student: Anton Tabone
Supervisor: Prof. Carmel Pulé
Co-supervisor: Ing. Paul P. Debono

Introduction
The principal technological innovation of these last 30 years which has had great success in the car industry was the electronic fuel injection system (EFI). Automobiles have improved in several aspects, such as improved reliability, better driveability, reduced CO2 emissions and improved fuel economy [1], [2].

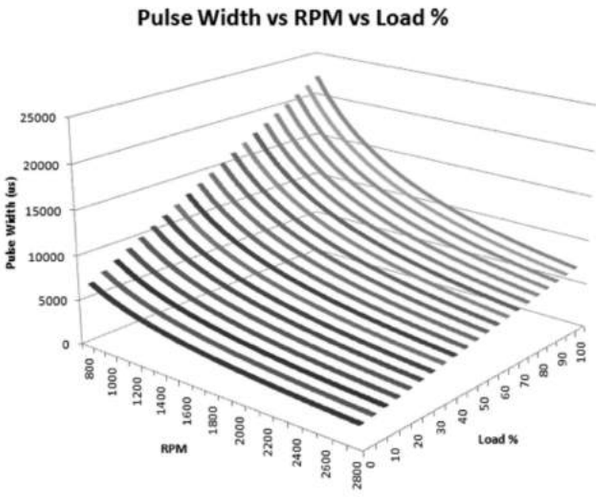
Project Objectives
The aim of this project was to study the operation of a four-stroke internal combustion engine and analyze the fuel and air mixture of the engine which works on a carburettor system. Then, the study moves on how the EFI system works and how to implement the system on an internal combustion engine instead of using its standard carburettor system.



Project Methodologies
To implement the EFI system on a 1300cc manual engine a system had to be designed. The system consists of three sections: the fuel delivery system, the electronic control system and the air induction system.

The fuel delivery system consists of equipment required to supply the fuel to the injector at the required fuel pressure. The air induction system is the section which controls the amount of air which flows inside the intake manifold through the throttle body. The electronic control system consists of a circuitry which controls both, the timing of the injector and the fuel metering [3].

Results and Achievements
To convert an internal combustion engine to operate on fuel injection, the maximum fuel flow rate was calculated to select the appropriate fuel injector/s to be able to achieve the peak power attained with its standard carburettor system before conversion.



Several fuel demand values where calculated for different load levels of the engine to achieve a knowhow regarding the variance of the duty cycle of the fuel injector. Then, the pulse width values were obtained depending on the speed of the engine. All the pulse width values were store in a two-dimensional array according to the Load% and the RPM of the engine. The array which stores the pre-calculated data was uploaded into a microcontroller unit which runs the EFI system. The microcontroller observes continuously the Load% and the RPM of the engine with the use of several sensors around the engine and selects the pulse width value from the array to achieve the best power output performance with the least fuel consumption and the lowest CO2 emissions.

References
[1] J. Hartman, How to Tune and Modify Engine Management Systems, Minneapolis, MBI Publishing Company, 2003.
[2] J.B. Heywood, Internal Combustion Engines Fundamentals, Singapore, McGraw-Hill Book Company 1988.
[3] Toyota Motor Sales. (2013). Electronic Fuel Injection Overview. [on-line]. Available: http://www.autoshop101.com/forms/h20.pdf

Governor for Speed Control and Synchronization of Various Systems

Student: Mauro Xuereb
Supervisor: Prof. Carmel Pule'
Co-supervisor: Ing. Paul Debono

Introduction
As automation in industry is taking over several manual processes, synchronisation between various stages of a process is increasingly becoming important. This can eliminate the need for manual synchronisation which can be tedious and inaccurate. Inaccuracy can result in damage to the components and machines.

Project Objectives
In this dissertation, a research about the speed control characteristics of various machines and motors that are commonly used worldwide was carried out to determine the best way of controlling each system. Also an extensive simulation of a PID control was carried to determine the best way to implement this system for phase synchronisation control.

Project Methodologies
First the principle of a speed governor and how it controls the speed of a machine through a closed loop system was explained in some detail. A mechanical way to control speed is by a centrifugal governor while electronically the most used system nowadays is a PID controller. A PID was implemented to phase synchronise two permanent magnet DC motors as shown in figure 1. The speed of one motor was used a reference while the PID controls the speed of the other motor. A set of simulations was done with different settings for the PID and different loads on the DC motor to analyse the system response.

Results and Achievements
When the final PID control system was tested it was found out that the only way that two motors will be synchronised is when they are initially synchronised. The PID is only capable of correcting the phase change only when the two motor are phase synchronised before a load is connected. It was decided that a differential synchro connected to two other synchros will be used. The differential synchro will only give the phase difference between the two rotating motors and when integrated, the output is summed up with the PID controller output to correct the phase error between the motors.

From this dissertation one can understand the true meaning of the velocity, acceleration and position states when using differential equations. It is easier to understand their meaning when a position control system is taken into account. When these states are translated into a velocity control system one tend take some time to get used to meaning of the new states. While this project was meant to produce a practical understanding of the engineering requirements it was also treated as a study how to transfer knowledge when one is dealing with states in controlling speed rather than position.

It was also concluded that it is easier to control and synchronise heavy systems with high inertias since their long time constants make it easier for the controller to follow the reference input. Systems with small inertias tend to become unstable when the output oscillates about the reference input.

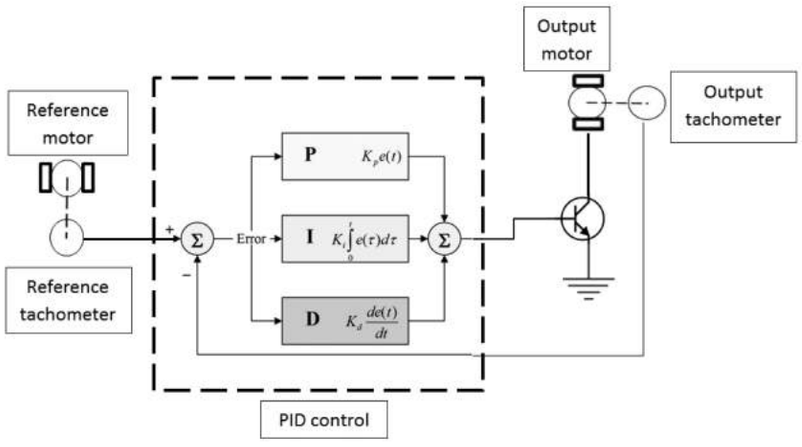


Figure 1 PID controller for velocity synchronisation

Small Scale Wind Energy Conversion

Student: Nicholas Abela
Supervisor: Dr Cedric Caruana

Introduction

The ever increasing demand for energy is questioning our reliance on fossil fuels. Recently there has been a large drive to use renewable energy. Having a renewable energy setup that has a low start–up cost, high system efficiency and a good output yield will further motivate investment in this area. This project aims to increase the efficiency of a small scale wind turbine.

Project Objectives

The main aim of this thesis is to understand better the electrical side of a small scale wind energy conversion system. This knowledge would be used to improve the efficiency of the system by matching the inverter power curve to the wind turbine. The project aims to develop a procedure that can be applied to obtain the power curves of different wind turbines.

Project Methodology

The project was organised as follows:

- Familiarisation with the components in a small scale wind energy conversion system.
- Literature review on small scale wind turbines and Maximum Power Point Tracking methods.
- Mathematical Modelling of the system.
- Development of a procedure to obtain the power curve based on obtaining the maximum power extraction from the wind. This power curve would then be used to program the inverter.
- Verifying the developed procedure via simulations.
- Revised procedure in order to obtain the maximum output power for each wind speed. This was achieved by considering the generator losses in the power output.
- Update the present wind turbine rig.
- Design, prototype, test and calibrate a number of PCB s. These are signal opto-isolator, encoder splitter board, motor current monitoring and a DC link current and voltage monitoring board.
- Use the wind turbine rig to test the procedure developed experimentally (Figure 1).

Results and Achievements

The developed procedure was evaluated both in simulation and experimentally. In the simulation tests, the operating points obtained were verified to give the maximum output power for set static wind speeds. The power curves were then implemented on the grid–connect inverter. Experiments using two permanent magnet synchronous generators from different manufacturers showed improvements in the energy yield through consideration of the generator losses and through the use of a parabolic power curve as compared to a linear curve. This project limited the comparison to the range of wind speeds covered by the procedure and considered static wind speeds. Figure 2 plots both theoretical output power obtained via simulation (dashed lines) and the hardware output power (continuous lines).

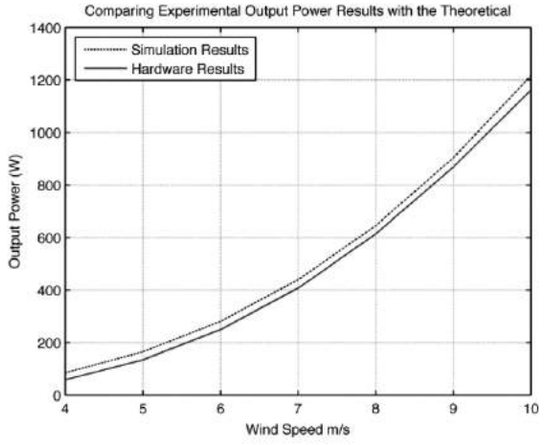


Figure 1: Hardware block diagram

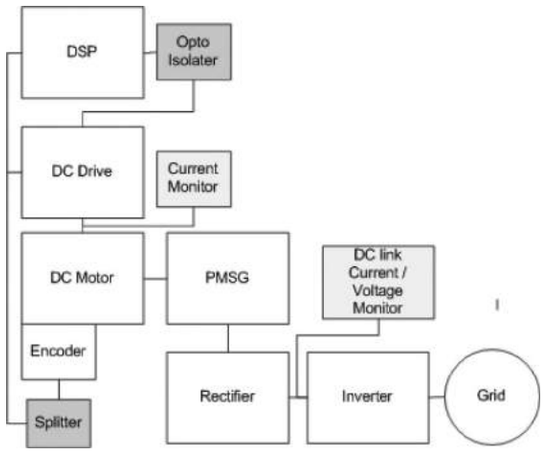


Figure 2: Ginlong Generator.
Comparing Theoretical and Actual Output Power

Wave Energy Conversion

Student: Shawn Azzopardi
Supervisor: Dr Cedric Caruana

Introduction

Nowadays, it is an alarming fact that unfortunately natural resources such as oil energy are being depleted, thus leading to a drastic rise in price. This is a troubling problem even when it comes to energy conversion as prices of energy also increase. Price is not the only setback; other problems that are brought about when using oil as energy, are climate change and pollution. Malta is currently facing a challenge in that by year 2020, 10% of the total energy must be renewable. A potential energy source for Malta, due to its small size and vast territorial waters, is wave energy. Wave energy has the potential to compete with solar and wind energy for alternative electrical energy generation. It is then important for each country which is surrounded by sea (like Malta) to analyze the available wave resource.

Project Objectives

The main aim of this project is to construct a wave energy conversion emulator rig. This is intended to test the electrical part of wave energy converters where the captured energy is converted into electrical energy. The project objectives were: to review different wave energy converter solutions published in the literature; to develop software models to analyse the operation of a wave energy converter; to construct an emulator rig and to test it.

Project Methodologies

The project was carried out in the following manner. First, research on wave characteristics and wave energy converters was done. Relevant data for Maltese waters was obtained from the International Ocean Institute (IoI). Due to the focus on the electrical side, it was decided to consider a simple heaving buoy of cylindrical shape coupled to a rotational permanent magnet synchronous generator. The heaving buoy concept is shown in Fig. 1. Software models were set up to examine the generator coupling and the energy conversion. Different torque Prof.iles were applied to the generator to examine different ways of coupling. The loading of the generator was also examined to verify the conditions for maximum power point operation. An experimental rig was then constructed to emulate the considered wave energy converter. The buoy movement was obtained by an electric motor driving a linear gear. This was coupled to a permanent magnet generator through a designed mechanical converter, as shown in Fig. 2. Typical amplitude and frequency of waves in Maltese waters were used to drive the rig.

Results and Achievements

The wave energy conversion emulator rig was successfully constructed. It was tested in open loop reaching powers of circa 300W. This was limited due to operating the drive feeding the driving motor at a very low frequency. Different experiments were done testing the energy conversion using both strokes of the buoy and only the upwards stroke. A sample of the output current of the generator when loaded with a resistive load of 32Ω/phase is shown in Fig. 3.

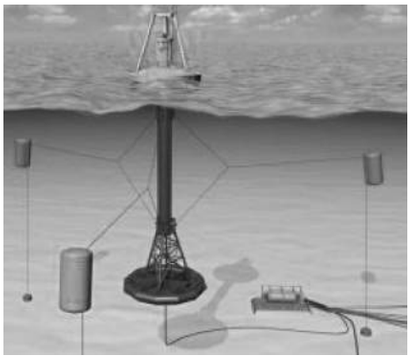


Fig1: Wave Energy Converter

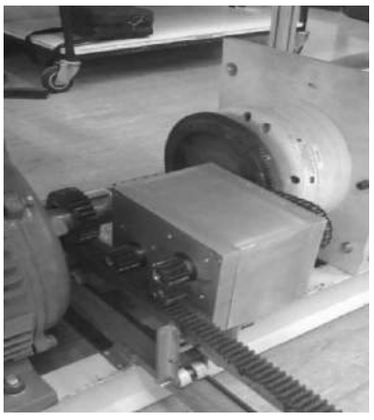


Fig2: Wave energy converter emulator rig

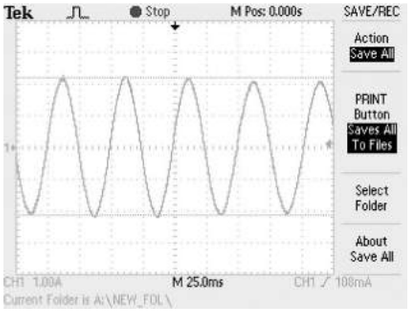


Fig3: Generator output current for resistive loading

Design and Implementation of a Solar Powered Catamaran

Student: Sara Baldwin
Supervisor: Prof. Joseph Cilia

Introduction

In the last few years, depletion of fossil fuels, pollution caused by the burning of the said fuel to create energy, together with the on-going rise in oil prices have become great concerns to mankind. In order to reduce the exploitation of natural resources and pollution, mankind decided to opt for Renewable Alternative Energy which is more sustainable.

The concept of using renewable energy sources on the land has been progressing rapidly however at sea this adoption is taking place at a slower pace. This thesis focuses on the use of solar power as a cost effective replacement of fuel on a small leisure catamaran. The design and implementation of the onboard energy sourced from renewable energy has been developed for a boat trip around Malta on a sunny summer day.

Project Objectives

- Design and Implementation of an electrical control circuitry
- Setting up of a management system for the two on board battery banks
- System Integration of all electrical components
- Testing and verification of performance

Project Methodology

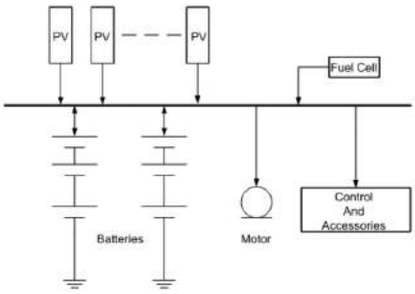


Figure 1 - Overview System Block Diagram

Figure 1 gives an overview of the whole system. All the wiring circuit designs of the system were designed in order to be able to order the components prior to implementation. The system consists of a six 230W solar panels that charge a 24V battery bank by means of a solar charger which transfer the energy gathered from the solar panels to chemical energy into the batteries, when it is sunny.

When the weather is cloudy and there is insufficient solar energy to charge batteries, the backup setup is used. This charges the batteries by means of a fuel cell which transfers the chemical energy from methanol to stored energy into the batteries.

The stored energy in the battery banks is used to power to a 2kW motor for propulsion and to supply the auxiliary circuits. A control system was designed where on the console, gauges will monitor all system's voltages, currents and state of charge and led lights will give indication of which parts of the system are active.

The system is also modelled in Simulink and parameters are obtained through practical experiment of a model.

Results and Achievements

Battery charging follows an IU characteristic as shown in figure 2, where the charging initiates with a constant current were the voltage increase up to a point where it reaches a maximum voltage of 2.4V/cell. On reaching the maximum voltage, the charger will supply decrease in current to maintain this maximum voltage. When the battery reaches its maximum capacity the charger will switch off automatically.

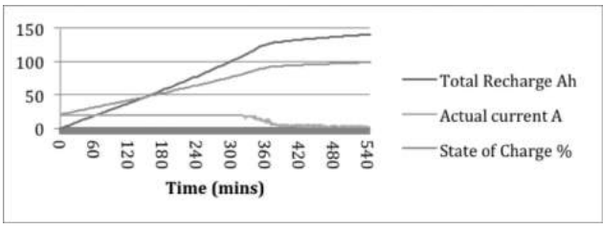


Figure 2 - Charging Prof.ile Solar Charger

Fuel cell charging is only possible when battery voltage is below 2.4V/cell. The fuel cell will be used as a backup charge since it has a very slow charging process. Apart from this, the device goes through a cold start phase which takes about 20 minutes before reaching the full rated current.

References

[1] Testa C. (2009) Design and Implementation of an Electric Boat University of Malta
[2] John Payne; The Marine Electrical & Electronics Bible (3rd Edition), 2007, Ad lard Coles Nautical

Set-up of 'intelligent load scheduling' for a stand-alone RES system

Student: Romina Ciantar
Supervisor: Prof. Ing. Cyril Spiteri Staines

Introduction

This project is based on a standalone RES system, implemented at the University of Malta laboratory using a Sunny Backup System [1]. The project consists of the design and implementation of a load scheduling system that monitors connected loads, the PV arrays and the battery bank's state of charge in order to shed these connected loads based on particular set criterion. The Sunny Backup S2200[2] is restricted to performing load shedding of two loads, when the battery state of charge reaches 50% and 30% consecutively. This was a restrictive feature within the system, that this project was aimed to overcome, by implementing load shedding on four connected loads.

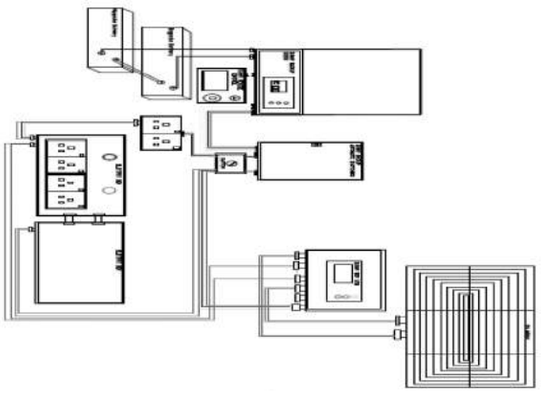
Project Objectives

The project makes use of a modular Programmable Logic Controller (herein after "PLC"), which averages the readings from; the load current and voltage transducers, the current and voltage transducers of the PV panels; so as to estimate the flow of power within the system. A battery management unit (herein after "BMU") is used to monitor the battery bank's state of charge. The PLC communicates with the BMU in order to use the value of the state of charge of the battery bank, for comparison purposes. The instantaneous power generated by the PV array is compared to the power consumed by the loads. Upon reaching a particular criterion, load shedding is done. Another main feature is to ensure that the highest priority load, is always energized.

Project Methodologies

Load shedding utilises the principle of balancing of energies; between the PV arrays, the loads connected to the system, and the stored energy within the battery bank. The power being generated by the PV panels is compared to the power being drawn by the loads. Provided the PV power exceeds the load power, no load shedding was done. The surplus of power is utilised to charge further the batteries. However, if the PV power that was being generated is less than the amount of power being drawn by the loads, different conditions have been set up in order to start load shedding of the least priority loads. The order of priority loads was essential; in the sense that the highest priority load was designed to run for the longest of time.

Different modes of operation were established for the load shedding system. There are two operating main modes: during the first mode, the highest priority load is always energized, provided the state of charge of the battery exceeds 20%. Such a value was selected in order to avoid the battery from deep discharge. Furthermore, a high level of state of charge is important in this mode, in order to preserve battery operating time. Loads are switched on or off, in order of preference and depending on the amount of energy being generated by the PV panels. During the second mode of operation, load shedding is done in order to maintain the highest priority load running for the longest time possible, whilst the battery's high state of charge is not of great importance. Hence, load shedding was performed according to the battery's state of charge. The values selected for load shedding according to the state of charge were varied, as the appliances connected in order of preference were varied. Whenever the PV panels generate power more than the power that is being drawn by the loads, the surplus energy flow goes to charging further the battery bank.



Results and Achievements

One load scheduling condition included the following values of state of charge, from the highest to lowest priority load: 20%, 50%, 75% and 85%. Household appliances that were considered were: refrigerators, freezers, air-conditioning units, ceiling fans, lighting systems and computers. This system provides the user with flexibility, as it allows a vast range of loads to be connected thereto. The parameters dictating the load shedding conditions are easily alterable (as the programming interface is very user-friendly) in order to shed loads of different power consumption.

References

[1]SDC-TEN081450 | Version 5.0
[2] SBU2200_Eigv-TB-en-12, DBEN-SBU22_EIGV, Version 1.2

Control of an Active Filter for Non-linear load Harmonics Filtering

Student: Melchior Grech
Supervisor: Prof. Ing.Cyril Spiteri Staines

Introduction
Technological development in the industrial and domestic fields of engineering has lead to the increase of use of electronic equipment whose operation can result in distorted voltage and current waveforMs In a non linear load, a non sinusoidal current, made up of harmonics is absorbed from the supply. These consequently cause a voltage drop of non sinusoidal type to be se-t up which in turn supplies even linear loads with a distorted voltage. This could lead to unnecessary heating and premature ageing of equipment. Harmonics also increase transmission losses.

Project Objectives
The objectives are to interface and control an Active Filter, measure the current harmonics before and after filtering and analyse the results.

Project Methodologies
Research on power factor correction, harmonic compensation and active filtering was carried out. The setup consisted of an active filter, an inverter drive, a soft starter, an active front end and two mechanically coupled motors as shown in Figure 1. The drive motor was driven either by an inverter or by a soft starter. An active front end drive was used to load the motor. The harmonics generated by the inverter were simulated and actual readings were recorded at different loads. An active filter was used to correct the generated harmonics, the affect of which was analysed.

Results and Achievements
The setup was operated both as a motor drive and also in the regenerative mode were an approximate 67% of the drive's input was fed back to the grid. The active filter was set to compensate for harmonics which resulted in a THDi reduction of 77%. The 5th, 7th, 11th and 13th current harmonics were reduced by the active filter by 93%, 83%, 86%, and 70% respectively, when used with the inverter as a drive in motoring mode. This resulted in the supply current waveform to be more sinusoidal as shown in Figure 2.

References
Case Study; Jean Noël Fiorina 'Inverters and harmonics' E/CT 159 first issued September 1993

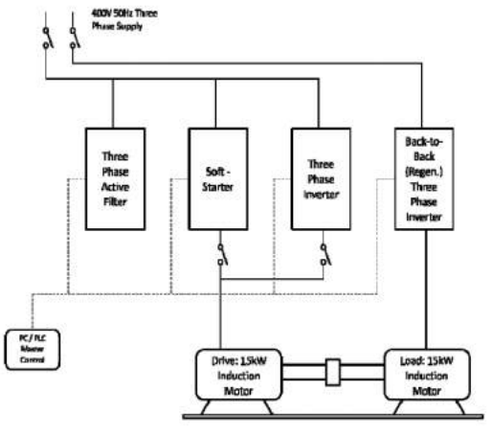


Figure 1: Test Rig

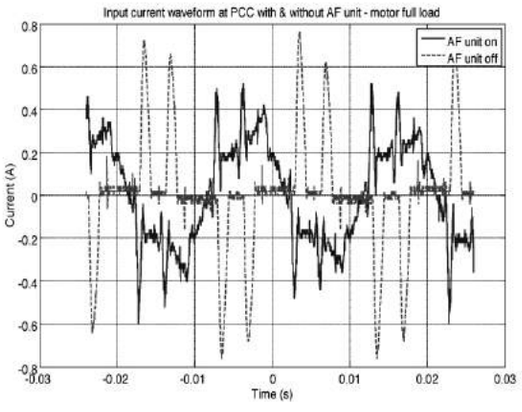


Figure 2: Waveforms w/o AF unit

Simulation of methods for Increasing Energy Efficiency in Electric Drives

Student: Keith Schembri
Supervisor: Prof. Ing. Cyril Spiteri Staines
Co-supervisor: Peter Spiteri B.Eng(Hons)

Introduction

More than 50% of the total electric energy in industry is consumed by motors, and the largest portion of this percentage falls under the induction type motors. Nowadays they are the most common type of motor found in industry since they are cheap, robust and easy to maintain since they don't contain any brushes. In the simulations carried out in this project the motor supply voltage is reduced to analyse its effect on the motor's efficiency. This method is tested with different atypes load Prof.iles commonly found in industry. Commercially available methods to control the efficiency of the motor are the MEC (motor energy controller) or the VVVF (variable voltage variable frequency) inverter.

Project Objectives

The main objective is to model and simulate the induction motor including losses. This model shall be used to analyse several different load Prof.iles and operating points whilst the supply voltage is reduced accordingly to determine the increase in efficiency and the energy savings.

Project Methodologies

The methodology used could be summarised by the following steps:

- Literature research on motor dynamic models [1] was carried out.
- Different methods on how to represent motor losses in the model were researched.
- Simulated model was constructed using Matlab/ Simulink.
- Constant loads were applied and results measured.
- Various load Prof.iles (Injection Mould machines, mixer, conveyor belt) [2] were modelled and applied to the simulation, the resulting powers, current, speed and torque were measured
- Two tests were performed, both for constant and variable loads. The first test consisted of reducing the supply voltage in steps for the whole duration of the load. The second test consisted of reducing the voltage only at low loads or during idle times.
- Finally, several observations were made, such as the minimum voltage at which the motor can still operate at low/high loads or the difference in efficiency and energy savings between the two tests.

Results and Achievements

There were two kinds of results analysed, those obtained with steady loads, and those obtained with the simulated load Prof.iles. In general it was observed that as the load decreases the efficiency decreases and the power factor decreases. But as the supply voltage is reduced for each load, the efficiency is improved by reducing the input power and losses for the same output power. The efficiency is improved most when the voltage is reduced at the low loads, it was also observed that during this operating point the motor's power factor would be very low. The result also showed that low loads allow further reduction of voltage compared to high loads.

References

[1] D.W. Novotny & T. A. Lipo, 'Vector Control and Dynamics of AC Drives' Oxford Science Publications, United States, 1996.
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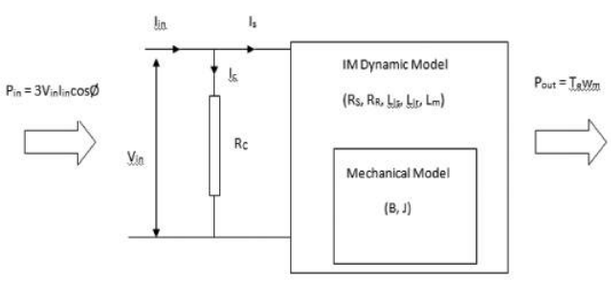
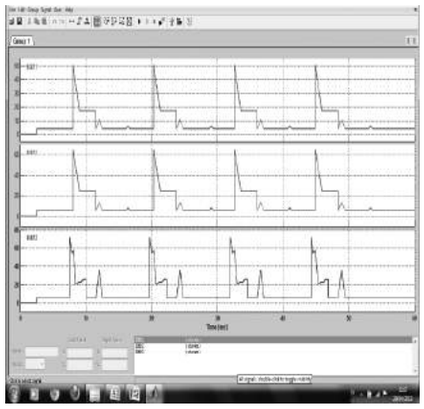


General model of induction motor including core-loss



Simulated Injection Mould Machine Load Prof.iles

Experimental test of a linear motor drive

Student: Eman Vassallo
Supervisor: Dr Cedric Caruana

Introduction
The majority of electric machines are designed to produce rotary motion. For applications requiring linear motion, like product handlers in industry, the rotary motion is then converted into linear motion using appropriate mechanical linkages. Linear motors are capable of producing the linear motion directly. This ability presents various advantages over the conventional rotary-to-linear solutions due to the absence of the conversion stage that typically involves a combination of gears. Apart from the higher efficiency, the advatnages include the possibility of high speed axis travel with high acceleration and deceleration, no contact and thus no friction between the drive elements, simplified mechanical structure design and higher precision.

Project Objectives
This thesis aims to understand better the performance of linear permanent magnet synchronous motors and their associated drive packs. The objective for this thesis is to set-up a linear motor drive, program it and analyse its behaviour experimentally under different conditions. It will examine the suitability for different applications and compare the performance to that of traditional solutions.

Project Methodologies
The project started with a review of permanent magnet linear motors with their corresponding equations of motion and the functionality of commercial drive packs. The project then proceeded with the construction of a test rig. Firstly, a mechanical structure was designed to accommodate the linear motor complete with a linear encoder for position feedback. Aluminum was used so as not to influence the magnetic field set up by the permanent magnets. The linear motor was interfaced to the drive pack that was programmed with the relevant parameters. A number of safety features were included in the rig such as limit switches at the end of the driveway. The linear drive is fed from a specially designed control box that safely switches on the drive pack and the linear motor. A microcontroller is used to generate reference signals for the drive packs. A number of sensors were installed such that the operating data of the linear motor can be captured and compared to the reference.

Results and Achievements
The project is currently ongoing and is expected to generate experimental data showing the performance of the linear drive under different operating conditions. Its suitablity and attractiveness as a replacement for traditional rotary to linear drive trains will be examined.

References
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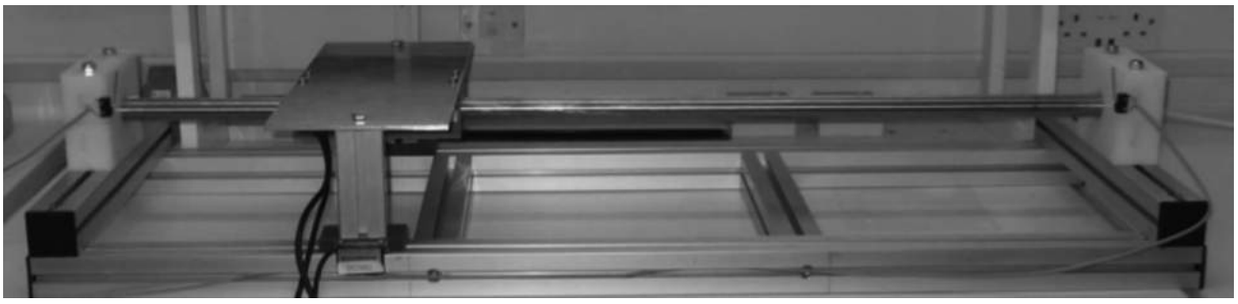

Figure 1: Linear Motor test rig

Electromagnetic Design of Electrical Rotating A.C. Machines

Student: Nolan Vella
Supervisor: Prof. Ing. Cyril Spiteri Staines

Introduction

In today's world, electrical energy has become so essential in our lives that it would be very hard for us human beings to maintain a good quality of life without it. The major use of electrical energy is for electric motors whose usage ranges from running wheels in industries to small appliances in our households. Among the various types of electric motors, the two mostly used are the A.C. Induction Motors (IM) and the Permanent Magnet Synchronous Motors (PMSM). They operate differently from each other and have different rotor configurations. For example in an IM the magnetic flux induced by the rotor is created by means of induction whereas in the case of the PMSMs the magnetic field is induced independently of the stator through permanent magnets.

Project Objectives

The main aim of this project was to setup a basis for modelling the two mostly used types of A.C. machines mentioned above (IM and PMSM) using Finite Element package. This thesis has simulated both IMs and PMSMs in ANSYS 2D & 3D with the aim of deducing the most efficient design. As regards IMs, a standard type and a high efficient type were designed and modelled respectively, so as to outline the main differences between them. In the case of PMSMs, the effect of their magnet topologies on the motors' performance was studied.

Project Methodologies

In order to analyse their construction two types of IMs (one standard and the other High Efficiency) were taken apart. These were then modelled on ANSYS where the differences between the two types were outlined. The design of each type of IM was further analysed with the aim of obtaining the most efficient design possible for each particular change in parameter.

The 2004 Toyota Prius PMSM was also designed on Maxwell. This was followed by the analysis of different PMSMs' rotor configurations. Consequently, an analysis on the effect of cogging torque on torque ripple was carried out. Thereupon, the stator stack was skewed to observe the effect on the torque ripple.

Results and Achievements

Through observation, design and modelling, this project has reached a number of conclusions and results. The most relevant are the following: magnetic flux distribution and patterns was observed in both types of IMs and PMSMs, the high efficient IM proved to be more efficient when compared to the standard type IM, the 2004 Toyota Prius PMSM turned out to be the most efficient design with respect to the other rotor configurations analysed, and skewing the stator stack resulted in less torque ripple.

Figure 1: Surface Mount Permanent Magnet Synchronous Motor

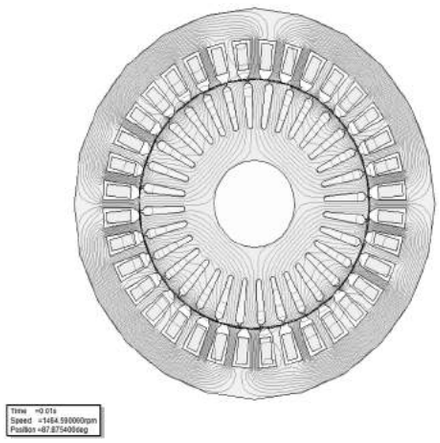

Figure 2: Magnetic flux induced inside an Induction Machine

Construction of a Combined Heat and Power System

Student: David Zammit
Supervisor: Prof. Joseph Cilia

Introduction

Efficient and clean renewable energy is undoubtedly one of the top issues in today's energy sector and has led to the rethinking of energy generation from a once centralized to a decentralized system. The latter consists of small-scale generation systems such as solar photovoltaic, micro wind-turbine and combined heat and power (CHP) connected to the electric grid. Studies show that water and space heating/cooling applications in a Maltese household account for a total of 46% from the total electricity consumption. This scenario presents the requirement for an alternative and efficient energy source other than electricity to address heating and cooling needs in a household which can account for the reduction in electricity bills whilst providing the same or even better comfort.

Project Objectives

The aim of the project is to construct an ON grid connected CHP system to be utilized in Maltese households. The physical construction must be compact in order to occupy the minimum possible footprint. The system's specifications consist of 1-2kWel power to be fed back to the electric grid and 3kWth power to be utilized for space heating at 25°C and water heating at 65°C.

Project Methodologies

It was suggested that in order to obtain 1-2kW of electrical power and 3kW of thermal power, a 125cc engine will be required. A research was conducted locally evaluating various internal combustion engines available. The engine power output required was a maximum of 5kW. A motorcycle scooter engine was chosen which was then mounted on a specifically designed structure. After testing of the engine was completed, an asynchronous electrical generator with a rated output of 2.2kW was chosen and tested in order to obtain the system's parameters. The engine throttle was converted from wire to servo control and was controlled by a microcontroller. The engine and the electrical generator where then directly coupled in the structure as shown in Figure1. Heat exchanger design calculations were carried out and three heat exchangers were required for the project. A complete circuit containing the heat exchangers was constructed. The system containing the heat exchanger circuit and the engine coupled to the electrical generator was completed as shown in Figure 2.

Results and Achievements

Testing of the system connected to the electric grid was carried out and resulted in the maximum electrical power generated to be 1.4kW whilst a thermal output power of 3.2kW was recorded, and therefore yielded a system efficiency of 90%. The results obtained exceeded the set values and the system has created a number of ideas for future development on the subject.

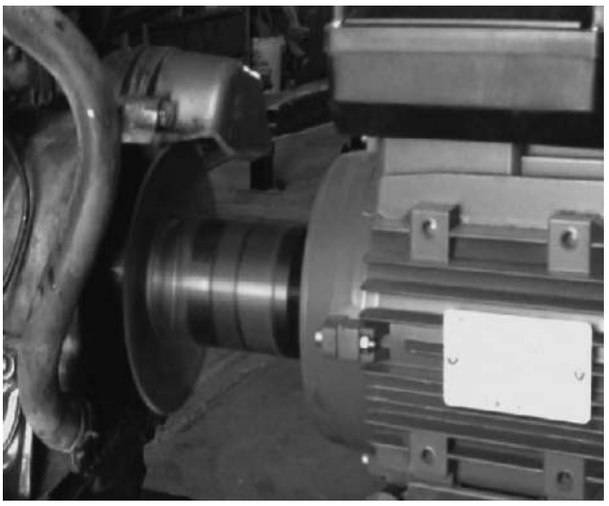

Figure 1: Engine coupled with Generator

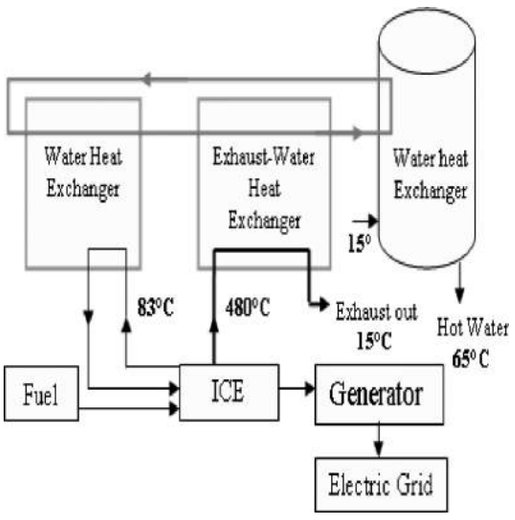

Figure 2: CHP system block diagram

Electromyographic Signal Analysis during Gait

Student: Maria Aquilina
Supervisor: Dr Owen Falzon
Co-supervisor: Prof. Ing. Kenneth P. Camilleri

Introduction
Electromyography (EMG) provides a means for measuring the end effect of signals which are produced by the brain and passed on to skeletal muscles via nerves. The electrical activity captured from muscles contains useful information for gait analysis (i.e. study of the human walk). One particular advantage of EMG recordings is that it can highlight abnormalities in cases of neurological disorders. In gait analysis, the accurate detection of muscle activation intervals is essential to determine any discrepancy in muscle contracting timing between healthy and problematic situations.

Project Objectives
The aim of this study was to simulate EMG signals in order to evaluate the performance of different muscle activity detectors. These detectors were then applied to real EMG signals obtained from healthy and scoliotic patients during gait. A number of detection methods were applied to real data in order to determine any distinguishing muscle activation timing characteristics between healthy and scoliotic patients. At this stage, it is assumed that scoliosis might have an effect on assymetries in the contraction timing between the left and right limbs.

Project Methodologies
Three different muscle activity detectors were tested. The first method consisted of a double-threshold algorithm using envelope detection [1]. This method is the most commonly used algorithm in gait analysis. The second method considered consisted of a statistical method [2] that provides the advantage of selecting values for detection probability and false-alarm probability. The final method of detection was based on the continuous wavelet transform [3]. This method tries to detect muscle activity by recognising motor unit action potentials (MUAPs), which are the individual signals that when summed together form the EMG signal.

Results and Achievements
Results from the artificial signals show that the commonly used method of detection has a poor performance especially at low signal-to-noise ratios. The other two methods have a much better performance and onset and offset timing errors are significantly lower. Figure 1 shows the detection of muscle activity using the statistical method from a real EMG signal. The detectors were then applied to the real data obtained during gait to determine whether the better performing algorithms can detect any asymmetries between right and left limb for scoliotic patients.

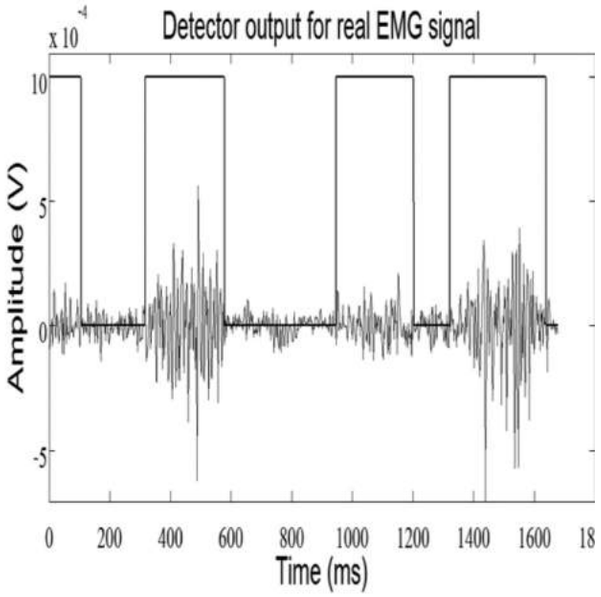

Figure 1: Detector output for real EMG signal using statistical method

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The Use of CSP for a Motor Imagery Based BCI

Student: Joseph Axisa
Supervisor: Dr Tracey Camilleri

Introduction

A Brain Computer Interface (BCI) system interprets brain activity, typically recorded through an electroencephalogram (EEG), and translates it into control signals that can be used to interact with a computer.

The use of BCIs has grown dramatically in recent years and they play an important role in communication, environmental control, locomotion, rehabilitation and motor restoration. Due to their immense potential, multinational companies such as Microsoft have been investing in research to develop low-cost BCIs and companies such as Emotiv are now even developing commercial BCI applications for the general public.

Project Objectives

The aim of this project is to design, implement and test a motor imagery based BCI that allows users to communicate with a software application, specifically by imagining left and right hand movements. The use of Common Spatial Patterns (CSP) as a feature extraction technique to improve the classification of the two hand movements is investigated.

Project Methodologies

Data was recorded using the gTec EEG equipment in the Biomedical Engineering Laboratory at the University of Malta. The equipment was interfaced with a SIMULINK model that processed the data in real-time and provided visual feedback to the users based on their brain activity as shown in Figure 1.

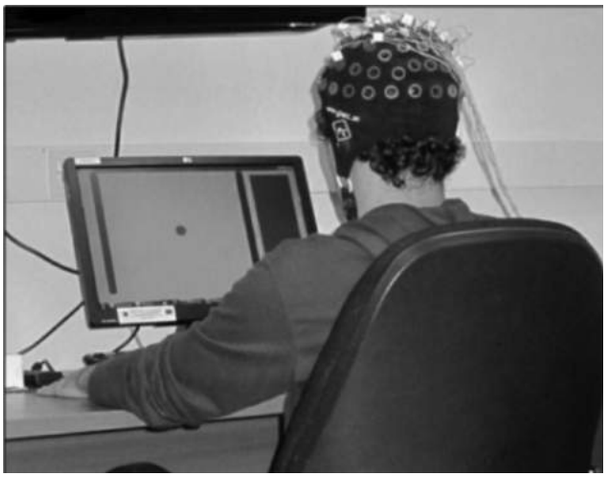

Figure 1: Recording of EEG data

A preliminary analysis of the recorded data revealed significant inter- and intra- subject variability. To tackle this issue and simultaneously develop a system that allows users to make use of the features they are best able to control, a BCI system based on pattern recognition was built using MATLAB. The system makes use of the CSP algorithm that extracts subject-specific features from the recorded EEG data. These features are then fed to a pre-trained linear classifier that identifies the motor imagery task being performed by means of decision boundaries. The output of the classifier is translated into appropriate commands to give continuous feedback to the user in the form of a moving ball on the screen.

Results and Achievements

The designed system yielded successful results when tested on the recorded EEG data of four subjects, with the maximum accuracy reaching slightly above 95%. For the best subject spatial patterns as shown in Figure 2 depicted a clear correspondence to the expected event related desynchronization occurring on the contralateral side to the hand movement.

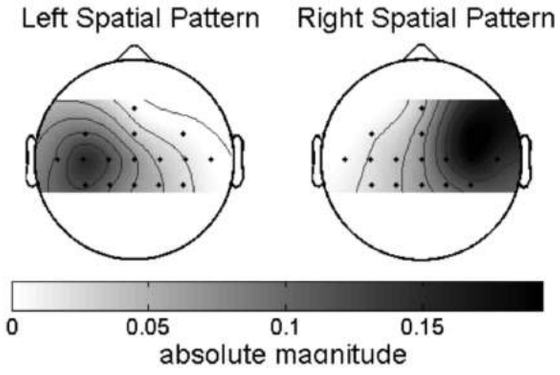

Figure 2: Left and right spatial patterns obtained through the CSP algorithm for the best performing subject.

Such a system can be used to give the user the possibility of answering questions through a 'yes' or 'no' selection or incorporated within a spelling device that allows the user to recursively select from two sets of letters to spell words.

Traffic Assignment Modelling of the Maltese Arterial Network

Student: Stephanie Baldacchino
Supervisor: Dr Kenneth Scerri

Introduction

Millions of people worldwide deal with traffic congestion on a daily basis. Roadways can become congested due to accidents, ongoing road construction or a high number of cars on the road. Traffic congestion can have a number of effects on drivers, the environment, health and the economy due to longer travelling times, increase in pollution as well as in fuel consumption respectively. Since the possibility of providing more streets is limited by economical and ecological factors, the transportation system cannot keep up with traffic growth, and therefore it is necessary to optimize traffic movements on the existing street network.

Project Objectives

The aim of this project is to implement traffic assignment modelling of the Maltese arterial network in order to estimate the actual number of trips carried out daily on the roadways of the transportation system. The replica of the actual trip counts on the network can be obtained given the traffic network to be optimised, the origin to destination trip counts and the roadway characteristics.

Figure 1

Project Methodologies

The engineering approach to the analysis of roadway traffic flow problems is primarily based on empirical analysis, where most of the modelling is achieved through observation and mathematical curve fitting. For traffic assignment modelling of a network, a number of resources are needed, these primarily being:

- Graphs are a powerful problem solving tool due to their ability to represent a complex network in a way which can be analysed both visually and with the aid of a computer. A Graphical Representation of the Maltese Arterial Network is represented in Figure1.
- The typical travel demand between all possible locations in the network, where traffic is broken down into origin to destination pair components based on start and end location of each trip.
- Traffic Flow Data, which data was not available but was approximated based on theoretical traffic flow analysis.
- An Optimisation Algorithm.

Results and Achievements

Travel flow data is important for transportation design, which subject tends to vary significantly with time of day, day of week, month of year and from year to year. This introduces an inevitable factor which results in error due to the lack of traffic related data available. Consequently, the daily trip counts obtained through simulation for the roadways of the Maltese Network can be considered to be satisfactory.

The major drawback was that the graphical representation of the network was restricted in size by the numerical solver; whereby increasing detail to the network, the error in the resultant trip counts has decreased considerably. The high errors obtained in the simulated trip counts were due to:

- No data related to the traffic flow characteristics of roadways being available and therefore speed density curves were approximated based on theoretical studies.
- The effect of junctions not being modelled due to the lack of available data.
- Inaccuracies in Origin to Destination data and actual recorded Trip Counts.

EMG Based Control of a Robotic Arm

Student: Paul Bezzina
Supervisor: Dr Tracey Camilleri
Co-supervisor: Dr Ing. Marvin Bugeja

Introduction
Electromyography (EMG) is the recording of muscle activity that can be recorded non-invasively through surface electrodes which are placed on specific muscles of a human subject. The recorded EMG signals can then be used to control a robotic arm in such a way that the arm mimics the spatial movements done by the subject. This can be used for restoring several everyday upper limb functions to amputee patients.

Project Objectives
The main objective of this project is to create a system that allows non-invasive surface electromyographic signals recorded directly from the human's upper limb muscles to control a robotic manipulator. The feasibility of using EMG signals as a source of control for a rehabilitation robot is also analyzed.

Project Methodologies
The methodology adopted in this project is based on that of Artemiadis et al. [1] where a linear state-space model is assumed to give a good mapping between EMG signals and the corresponding joint angles. The process of controlling a robotic arm using EMG can be divided into two phases:

TRAINING PHASE: The goal of this phase is to estimate a model that can map the EMG signals recorded from a subject into corresponding joint angles. The EMG signals are recorded while a subject moves his or her arm in the two-dimensional frontal plane. Simultaneously, the spatial positions of the subject's joints are recorded through a motion capture system and translated into the corresponding joint angles. Finally the processed EMG data and the corresponding joint angles are used to estimate the parameters of a linear state space model which is assumed to give a good representation of the mapping between muscle activations and corresponding joint angles.

TESTING PHASE: This stage uses the estimated model to translate the processed EMG recordings into corresponding joint angles, this time without the use of the motion capture system. This process is shown in Figure 1. Forward kinematic equations are then used to translate the estimated joint angles into the estimated end effector position of the subject. The robot is then controlled by supplying it with the necessary joint angles which allows its end effector to reach the same position of the subject. These are found through the robot's inverse kinematic equations.

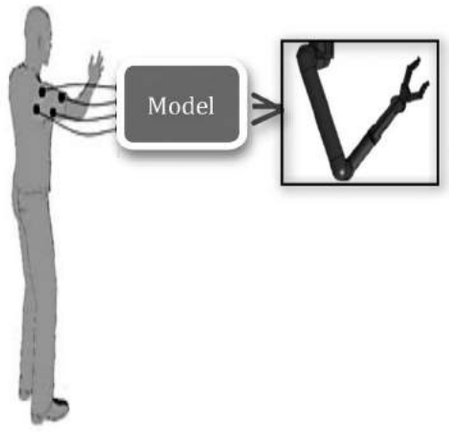

Figure 6- The testing phase where EMG signals are translated to robot kinematic parameters via the estimated model.

Results and Achievements
The performance of the system was measured by comparing the root mean square error and correlation coefficient between the actual and estimated spatial trajectories. The results showed that correlation coefficients exceeding 0.83 were obtained in both dimensions indicating that the model did capture the dominant trends in the actual trajectories. Performance started to decay with cross-validated data due to the non-stationarity of the EMG signals.

References
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Statistical Spatio-Temporal Fusion of Pollution Measurements

Student: Dora Lee Borg
Supervisor: Dr Kenneth Scerri

Introduction

Pollution is a threat to the environment; acid rain is caused by air pollution which is accountable for the destruction of crops and trees resulting in significant economic impacts. On the other hand water pollution reduces the level of oxygen required for the organisms and the water plants to survive. Recent studies have also provided evidence regarding the negative aspects caused by pollution on human health particularly respiratory probleMs Engineers and Statisticians have been using statistical methods for hundreds of years to try and answer questions regarding such geographical phenomena. At the centre of these studies is data. However data alone sometimes is not enough and statistical methodologies have been developed to obtain models to represent phenomena. The blending of data and models is achieved through Data-Driven Modelling.

Project Objectives

The aim of this project is to develop spatial models and temporal models to analyse the result of combining the two together through statistical fusion to obtain a spatio-temporal estimate. The models are tested and analysed on two datasets related to pollution to obtain a comparison between the three different methods based on the level of accuracy of the predictions obtained from each. One of the datasets is the air pollution dataset gathered by MEPA where values of Nitrogen Dioxide were collected through 123 diffusion tubes spread around the Maltese Islands. The marine pollution dataset on which the models are tested was collected by a AUV deployed in a fjord in Norway were oxygen levels were recorded. This data was provided by the Computer Science Department at the California Polytechnic State University.

Project Methodologies

The following steps were carried out to implement this project:

- Familiarise with the two datasets and perform some pre-analysis of the data
- Select the right model that best fits the data temporally and estimate its parameters for all sites
- Select the right model that best fits the data spatially and estimate its parameters for all sites
- Validate all the models by various validation techniques
- Fuse the spatial model and the temporal model through statistical fusion
- Validate the spatio-temporal estimates obtained from fusion
- Evaluate the results obtained from each model by statistical analysis

Results and Achievements

The predictions from the three methods were reasonably accurate. All of the estimates fall within a 95% confidence interval. The standard deviation of the model proved to be a determining factor to define the accuracy of the predictions. The accuracy of the prediction in general improved after statistical fusion was performed. For some sites the weak predictive accuracy of one of the models significantly affected the fused estimate.

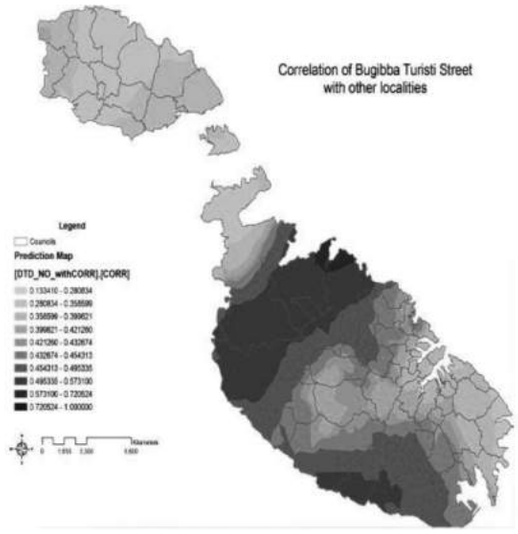

Figure 1 Correlation of 'Bugibba Turisti St.' with other localities

Figure 2 AUV used to gather the marine data

Autonomous Exploration and Mapping Using a Mobile Robot

Student: Ciantar Patrick
Supervisor: Dr Ing. Marvin K. Bugeja

Introduction
To create an accurate map of the environment by means of a mobile robot, the precise path of the robot must be known, along with accurate sensor readings. This is generally not possible as every sensor has its own uncertainties. Simultaneous Localisation and Mapping (SLAM) deals with the problem of combining two imperfect readings to produce a better estimate of the robot's location and the map of its environment.

Project Objectives
The main aim of this project is to program a mobile robot to autonomously explore an unknown area whilst simultaneously creating a map of its surroundings in real -time. This is a very active research area, referred to as the online SLAM problem in literature.

Project Methodologies
This project is a continuation on one of last year's final year project where data was first collected by the robot (driven by a human operator) and then processed separately on an off-board computer [1]. This year, new algorithms (based on [1]), were written in C++ to allow for real-time implementation on the PowerBot's on-board computer. These include a feature extraction algorithm, where lines (features) are extracted from the on-board laser range-finder's data, a feature association algorithm, where features extracted at the current time step are associated to previously observed features (used by SLAM to correct the robot pose), and an algorithm to allow for the robot to travel in the environment autonomously whilst avoiding obstacles. The algorithms were first tested on a simulator (provided by the robot's manufacturers [2]) to determine their effectiveness and to simplify the tuning process. Later they were implemented to the real robot. Finally an Occupancy Grid Mapping algorithm was written on MATLAB which allowed for the creation of a human-readable map perceived by the robot.

Results and Achievements
Figure 1 shows the robot that is being used for this project, the PowerBot, a differentially driven robot with a full on-board computer and a laser range-finder capable of scanning an area of 180° up to a range of 40m.

Figure 2 presents an occupancy grid map of the Engineering faculty corridor and foyer, developed using the calculated robot pose and raw laser data. An expected error in the odometer, due to drift and noise buildup because of dead-reckoning, can be clearly observed. This error is what the SLAM system aims to correct.

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Figure 1 – The Powerbot

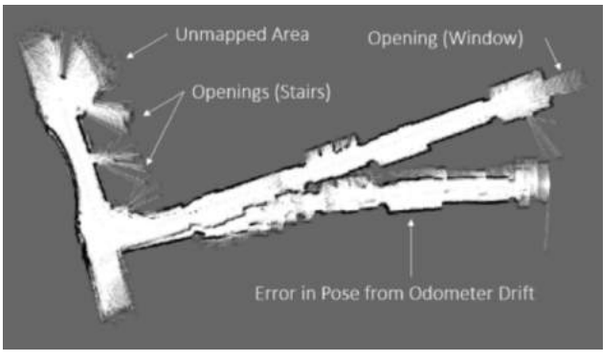

Figure 2 – Occupancy Grid Map

Neural Network Implementations using FPGAs

Student: Glenn Galea
Supervisor: Dr Marvin Bugeja

Introduction
Field Programmable Gate Arrays (FPGAs) are fast, cheap and small replacements for supercomputers and application specific integrated circuits. Their fine-grained parallelism offers great performance boosts in many fields, one of which is computational intelligence. The original inspiration for this project came from the implementation of an Artificial Neural Network (ANN) used to control an adaptive non-linear controller of a mobile robot. This involves a function approximation neural network which can learn different functions in real-time and adjust according to a desired output.

Project Objectives
Due to the FPGA resource limitations and time limitations, a simpler function approximation ANN had to be designed instead of the one used to control the mobile robot. This ANN had to be designed on a sequential platform using MATLAB and on an FPGA using VHDL (Hardware Description Language). Differences in performance and error, difficulties in programming and ease of simulation offered by the two platforms are compared to see whether and when is it useful to use an FPGA for ANN implementation.

Project Methodologies
To start off, different ANN structures and training algorithms had to be reviewed to find an ideal one to implement. Keeping the original idea in mind, the training algorithm had to be on-line, that is, the weight updates occur as the program is executing and not pre-adjusted for a specific application. Investigation of several methods of training for the ANN was carried out to change the weights of the ANN in real-time. VHDL implementation then started. Originally the network was a five neuron network with an input dummy neuron, three sigmoid neurons making up the hidden layer and a sigmoid neuron at the output. Due to VHDL impairments when compared to other programming languages and FPGA resource limitations, the architecture was altered during implementation to make it less computationally expensive. During the implementation, problems with VHDL were documented and a possible solution is offered. After finishing up the VHDL implementation, the same ANN was then programmed on MATLAB and the differences in the ease of programming and testing results were noted.

Results and Achievements
Results regarding performance are currently being extracted from behavioural models created on MATLAB and on Xilinx ISim. That said, this simple ANN is capable of learning variations of simple trigonometric functions with a discrepancy between actual and desired values of 0.0001 per point as shown in Figure 1. Also with regards to FPGA implementation the ANN was programmed in three different ways; a fully parallel method which offered the fastest performance but it required 384% of the FPGA resources, a fully sequential method using 31% of the resources but not exploiting the FPGAs potential and an ideal scenario exploiting almost 100% of the resource in such a way that the ANN is executing in a semi-parallel fashion at the fastest possible speed without using more resources than available.

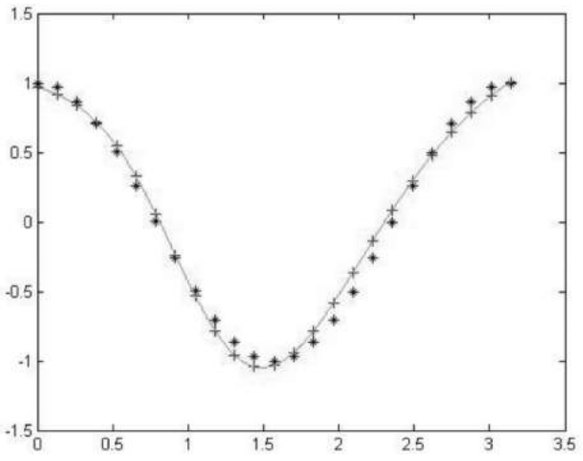

Figure 11 - (+) Desired Network Response (*)
Training Validation (-) Actual Output

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Vision-Based Tracking and Remote Control of a Mobile Robot

Student: Norbert Gauci
Supervisor: Dr Ing. Marvin K. Bugeja

Figure 1 – NeuroBot: The experimental wheeled mobile robot (Front view)

Introduction
Wheeled Mobile Robots (WMRs) are autonomous vehicles capable to move and perform specific tasks. Such robots contrast significantly with the robotic manipulators that are fixed to a surface. WMRs incorporate a combination of hardware and software components. They are also widely employed as transport vehicles as they can follow a particular trajectory either manually or autonomously.

Project Objectives
This project has two main objectives, the installation of a remote manual control system and the implementation of an embedded vision system including a control algorithm for autonomous target following. The first task enables a mobile vehicle to be manually controlled by human beings. The second task involves an autonomous motion of a mobile robot through feedback sent from a single camera mounted on the robot itself. Both tasks were physically implemented and tested on NeuroBot, a differentially driven WMR developed by Bugeja for research purposes in [1].

Project Methodologies
The methodology followed during this project can be summarized as follows:

Part One – Remote Control System for NeuroBot
- Review of existing wireless technologies and wireless remote controllers.
- Identification of the hardware components to assemble this technology on NeuroBot.
- Identification of the necessary modifications of the existing hardware on NeuroBot.
- Design, testing and implementation of the required electronic system boards.
- Determination of a feedforward current controller to ensure safe operation.
- Derivation of suitable mathematical relationships to generate the desired control signals.
- The use of simulation studies to determine the best controller parameter for the task at hand.

Part Two – Vision-Based Tracking Control for NeuroBot
- Review of different WMR visual tracking approaches and interception of a moving object through vision.
- Derivations of mathematical models for this problem and review of the control algorithm selected for this task [2].
- Implementation of these models in MATLAB/ SIMULINK for simulation purposes.
- Familiarization with the camera module (CMUcam4) to determine its functionality and operation, as well as the non-trivial task of interfacing this camera with NeuroBot's embedded computer – MicroAutoBox from dSPACE - using SIMULINK.
- Installation of all the designed hardware components on NeuroBot.
- Interconnection of the existing dynamic controller with the implemented controller to enable NeuroBot to perform visual tracking.

Results and Achievements
The remote control system was successfully implemented on NeuroBot along with the hardware and software components making up the system.
Simulation of the vision-based tracking control system was made, where the nonlinear kinematic controller was tested. The camera was also successfully interfaced with MicroAutoBox using SIMULINK. Currently, the camera module is being physically implemented on NeuroBot where the performance of the visual tracking task is going to be analysed.

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Development of a system to acquire and visualise foot posture and plantar pressure

Student: Josef Grech
Supervisor: Dr Owen Falzon
Co-supervisors: Prof. Ing. Kenneth P. Camilleri, Dr Alfred Gatt

Introduction

In podiatry, plantar pressure data is usually recorded in order to determine problematic foot conditions, but this is sometimes not sufficient for an appropriate analysis. The consideration of foot posture information can make the diagnosis more reliable but is generally not taken into account [1]. The aim of this thesis is to develop a system that measures both plantar pressure and foot posture, and that provides a straightforward visualisation software tool for the clinician.

Project Objectives

The main objectives were to design a wireless mobile system that could measure plantar pressure and foot posture, and display these measurements both in real-time or offline on a graphical user interface.

Project Methodologies

The first stage of developing this system consisted of choosing the appropriate sensors and testing their performance to verify that they were fit for this application. With regards to foot pressure measurement, force sensing resistors (FSRs) were chosen due to their thin structure and satisfactory accuracy. The circuitry required to interface these sensors to a microcontroller was designed. For the analysis of foot posture, a combination of gyroscopes and accelerometers were used, and the data from these two types of sensors were fused using a Kalman filter in order to obtain the angles of inclination. Figure 1 shows the placement of the inclination sensors at the forefoot and rear-foot areas used to obtain foot posture angles.

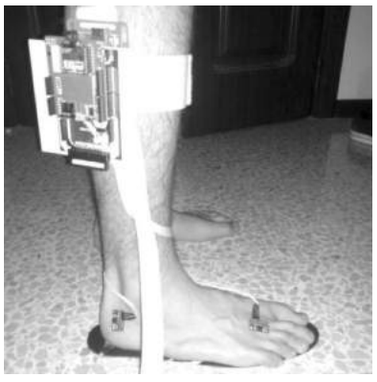

Fig 1 – The system to acquire and visualise foot posture and plantar pressure

The software that was developed as part of this system plots and displays the plantar pressure and foot posture measurements, as shown in Figure 2. The software can be used both to display both real-time data as well as pre-recorded data in offline mode. Moreover, a 3-dimensional visualisation program was designed in order to illustrate the foot's posture and the plantar pressure.

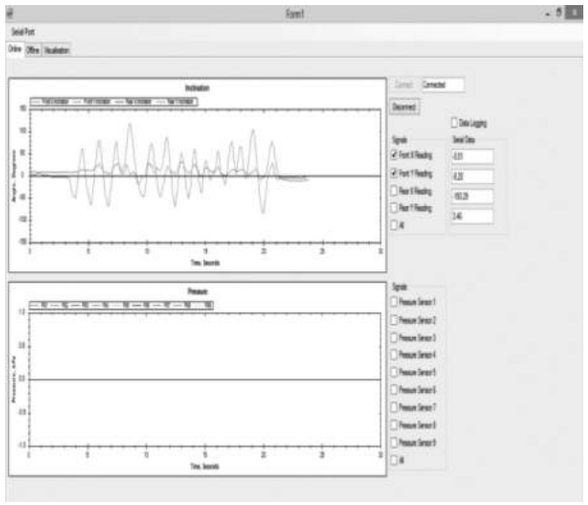

Fig 2 – The developed system software

Results and Achievements

The results obtained from the designed system were compared with those obtained from the Tekscan and Vicon systems, which constitute the state-of-the-art pressure and angular measurement systems, respectively. From the readings of plantar pressure recorded from the developed system, a measurement error of mean $2.97 \times 10^{\wedge(-4)}$ V and standard deviation $9.34 \times 10^{(-5)}$ V was determined. The deviations in the measurements of the foot posture sensors were as negligible as 1.62° for slow movements, but somewhat significant for very fast movement, evaluating up to an error of 18.31°.

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Driving a mobile robot using Steady-State Visually Evoked Potentials

Student: George Sapiano
Supervisor: Prof. Ing. Kenneth P. Camilleri

Introduction
The brain contains billions of cells called neurons that relay information trough-out the brain and communicate with all the parts of the body. A Brain-Computer Interface (BCI) is a communication system where the user communicates with an external object, hardware (robot) [1] or software (cursor, spellers) [2] without using the normal communication pathways of the brain.

Project Objectives
The main aim of this project is to review the relevant literature related to the real-time analysis of EEG signals and particularly to the application of thought control of a physical object. Identify the feasibility of and a suitable method to build a real-time BCI to drive a mobile robot and finally implement a real-time BCI system to drive a physical object and perform a systematic study of the technical issues involved and possible ways to address them.

Project Methodologies
An extensive literature review was done about different types of BCI phenomena in order to identify the best BCI for the purpose of this project. A BCI using Steady-State Visually Evoked Potentials (SSVEP) was chosen and the theory behind the chosen BCI was studied extensively.
The proposed approach was to build flashing LED targets that when the user looks at them a particular brain signal is produced that can be encoded and used to drive a robot. Different targets correspond to different commands to the robot.
A setup consisting of 8 flashing LED clusters shown in Figure 1 was built to induce SSVEP's so that EEG data could be recorded and later used to control the robot.

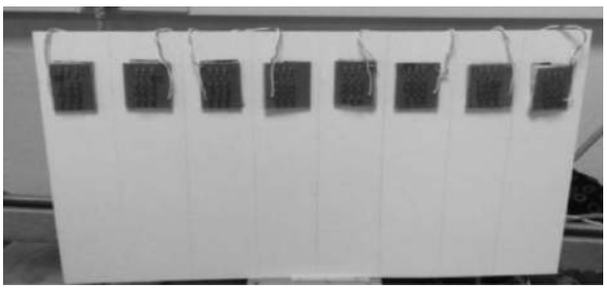

Figure 1: Setup used to obtain SSVEPs

Signal processing was done on the Raw EEG data to extract the useful characteristics for this project. An Interface using Simulink was built to connect the EEG and the robot. The robot being controlled is a LEGO NXT Mindstorm shown in Figure 2

Figure 2: The robot used for the project

Results and Achievements
Data was analysed offline and inputted in the Simulink model and results confirmed that the method used was feasible and different frequencies translated into different commands correctly. When the model was implemented online classification issues arose due to the spontaneous nature of the EEG signal further improvements on the model must be done in order to improve its online performance.

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Mobile Robot Trajectory Control for Measurement Uncertainty Reduction

Student: Disney Schembri
Supervisor: Dr Kenneth Scerri

Introduction

A huge demand for monitoring of areas using autonomous robots is increasing every day. This is ideal to monitor areas which may be hazardous to people or when large areas are considered where it would take an autonomous vehicle much less time to scan such an area when compared to the average person. The objective of this project is to develop a control algorithm to reduce the uncertainty of temperature measurements taken on a finite surface, by an autonomous wheeled mobile robot.

Project Objectives

To obtain the above mentioned aim, research regarding interpolation techniques was performed. A design circuit for the temperature sensor was built as well as an I2C interface between the temperature sensor and the Khepera III robot, shown in figure 1. A Bluetooth interface which communicates between the main computer and the robot is used. The problems encountered in this project can be split into two: Generating a Temperature Map based on Precision and Mobile Robot Modeling.

Project Methodologies

Sampling and reconstruction techniques [1] are used to interpolate the data sampled from the temperature sensor at precision locations where the uncertainty is zero. The method of splines is used to achieve a smooth interpolation [2]. A discontinuous controller is implemented, indicating the robot different locations to travel to at certain speeds. A common problem when operating with autonomous robots is to estimate its location. Unless its current location is determined, the control signals cannot be estimated. Odometry uses feedback from the encoders to estimate the current pose [3].

Results and Achievements

For simulation purposes, four different scenarios were taken into consideration to find a scheme which allows the robot, to cover the desired area in minimum time and have a detailed map of the temperature and its precision. In all the cases, an inverse function is plotted, centred at the current location of the robot, its minimum is found and a temperature value is recorded. The minimum point marks the highest uncertainty in the surface, thus providing the next location. The robot travels to this new location, takes another temperature reading and interpolates the current and previous temperature readings at their respective precision locations. The previous location is scaled down by a forgetting factor to keep track of previously visited locations. The surface maps are all plotted in real time, so the surface changes with every location and reading obtained.

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Figure 1: Autonomous Mobile Robot

An Investigation of Dynamic Control Strategies for Robotic Manipulators

Student: Nicholas Vassallo
Supervisor: Dr Kenneth Scerri

Introduction

Tasks assigned to robotic manipulators originally included object pick and place, assembly and spot welding [1]. Nowadays the possible application of robotic manipulators have varied to include tasks such as teleoperation, prosthesis and arc welding [2]. Such tasks require a degree of accuracy in trajectory tracking which was not a requirement in the earlier tasks performed by robotic manipulators. Kinematic controllers use the geometric properties of the robotic manipulator in order to determine the end-effector coordinates in space [3]. However when accurate trajectory tracking is required kinematic controllers can no longer guarantee an accurate control of the end-effector pose. Nonlinear controllers can however be designed to handle the arising dynamic elements, hence improving the performance of robotic manipulators [3]. These benefits encourage the investigation of nonlinear dynamic control strategies and their application to robotic manipulators.

Project Objectives

- Implementation of different dynamic control strategies as applied to Thermo CRS Catalyst-5 robotic manipulator.
- Investigation of the dynamic control strategies under varying trajectory control velocities
- Investigation of the dynamic control strategies under load variation

Project Methodologies

The robotic manipulator used in this project, the CRS Catalyst-5, has a data acquisition board with a Simulink interface. Hence all the control strategies developed are implemented in Simulink [4]. This software package gives the user the possibility of simulating all control strategies before implementation. Simulating the selected control strategies requires the design of a manipulator model in Simulink, which simulates the actual behaviour of the robotic manipulator under given conditions. The procedure for implementing any of the selected control strategies first requires the derivation of mathematical laws governing the control strategy. Then simulation of the control strategy on the designed model with analysis and modifications is performed. Finally the controller is interfaced with the data acquisition board in order to physically control the robotic manipulator and obtain results.

Results and Achievements

When compared to the other two inverse dynamics controllers implemented, Slotine and Li's adaptive controller generally proved to be the most accurate trajectory tracking controller. As a general classification, the operational space inverse dynamics controller was shown to be inaccurate, even under normal operating conditions. However both a well-tuned joint space inverse dynamics controller and the adaptive controller were shown to be able to perform accurate trajectory tracking under normal and increased velocity conditions. When end-effector load changes occur during operation, the adaptive controller's performance surpasses the other controllers'. This is due to the fact that such a controller can cater in real-time for the changes in load.

Figure 1 - Thermo CRS Catalyst-5

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FINAL YEAR
ENGINEERING PROJECTS
MECHANICAL STREAM

Development of Online Inspection Systems for Valve Assembly

Student: Jean Paul Attard Baldacchino
Supervisor: Prof. Ing. Michael A. Saliba,
Co-supervisor: Prof. Joseph Cilia
Industrial Partner: Abertax Technologies Ltd.

Introduction

Manual sampling and inspection is a basic means to maintain product quality. However for large production volumes or in cases where it is advantageous to segregate parts, alternatives should be considered. In cases were product failure is a critical issue, 100% inspection or operational testing is necessary.[1]

Project Objectives

The aim of this project is to develop automated inspection systeMs The systems developed will act as an intermediate between manual and fully automated inspection.[2] The dissertation focuses on the following components of the gas release system shown in figure 1.

- Lid depth measurement
- Valve body seating surface inspection
- Valve body outer seal inspection

Project Methodologies

The problems presented were abstract in nature hence a structured design approach was adopted so that the best solution could be developed. The following tools were used in the design and prototyping stages: Quality Function Deployment (QFD) was used to translate the customer requirements into technical requirements. This method is an organizational approach aimed towards product innovation.[3] Product design specification (PDS) is a formal declaration of what is to be expected of the product. [4] Brainstorming synthesises innovative concepts and Evaluation reviews the concepts generated. Decision matrices were then used to decide which of the wide ranges of solutions or processes would be used. The respective properties were compared using relevant weightings. The "SCAMPER" approach, which stands for Substitute, Combine, Adapt, Modify, Put to other uses, Eliminate and Rearrange was used for the improvement of the provisional design.[3]

Results and Achievements

For the outer seal inspection a machine prototype was manufactured as shown in Figure 2. This was tested under various scenarios to determine possible issues that would be encountered in a production setting. A Process Failure Mode Effects Analysis (PFMEA) was carried out to determine what possible issues could be encountered.

Prototypes systems were also developed for the Lid measurement and valve seating inspection. They were tested under operating conditions and from the prototype an automated inspection system can be developed.

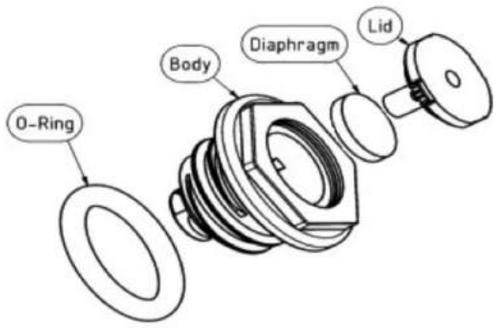

Figure 1. Exploded view of valve assembly. [5]

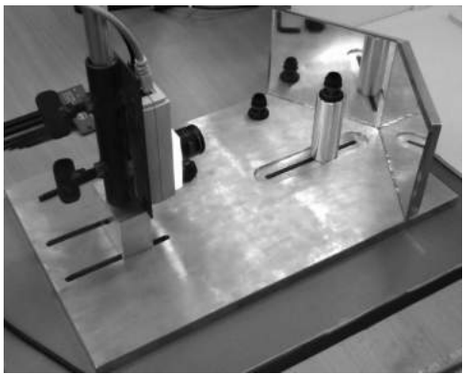

Figure 2. Prototype inspection jig

References

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Design, Manufacture and Testing of Titanium EBM Insert for Injection Moulding

Student: Althea Kate Borg
Supervisor: Dr Arif Rochman
Co-supervisor: Mr Günther Kurz, Playmobil Malta Ltd.

Introduction

The concept of rapid tooling allows for quick fabrication of injection moulding tools directly from computer-aided design (CAD) data [1]. Using the electron beam melting (EBM) technology, the capability of producing tools with the required finish and accuracy was investigated. This approach has been pursued through a case study, provided by the industrial partner to develop cooling inserts with freeform channels in order to improve part quality.

Project Objectives

- To investigate techniques used for rapid tooling
- To assess the applicability of the EBM process
- To modify the cooling system of the cavity inserts
- To manufacture the two inserts using Arcam EBM S12 machine
- To carry out the necessary post-processing requirements
- To perform an injection moulding trial

Project Methodologies

In this study, the manufacturing stages involved in the production of cooling inserts starting from the design and EBM process to the post-processing operations were analysed. In particular, powder removal testing using a wire brushing technique, ultrasonic cleaning and borescope inspection were first performed on potential cooling layouts. The design solution was based on various criteria, but mainly on the presence of existing mould systeMs Pre-processing operations were made to prepare the CAD model for the EBM process. Apart from powder removal, post-processing methods such as drilling and high speed milling were applied to meet the specifications for the injection moulding trial. These are illustrated in Figure 1.

Results and Achievements

The choice of electron beam parameters and preheating sequence strongly influence the sintering levels of adjacent powder next to solidified areas. From the powder removal test it was concluded that with a lower number of turnings and reduced levels of sintering, the trapped powder can be easier to remove from internal cavities such as complex cooling channels. Using the EBM process, the restriction of drilling straight routes was eliminated and freeform channels with sufficient powder removal were achieved. Owing to the high material volume processed, a greater shrinkage was experienced in the building direction. From a comparative simulation study between the conventional and the new designs, a slight reduction in the surface temperature of the parts and cooling time were observed. For the injection moulding trial the cooling performance was the same as for the conventional cavity inserts, despite the low heat conductivity of the new inserts made from titanium alloy Ti6Al4V. The cooling results would have been enhanced if the choice of material was not restricted to Ti6Al4V. Further developments are expected to improve the EBM process in order to eliminate post-processing requirements and to open up new areas of application.

References

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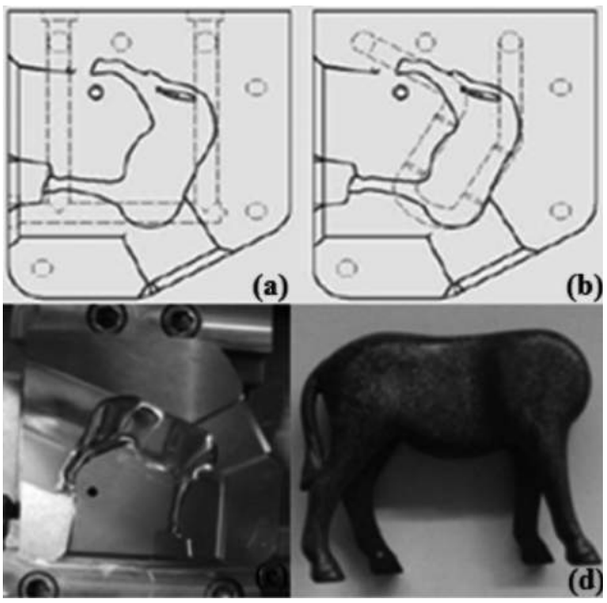

Figure 1: Injection side cavity insert: (a) conventional cooling channel; (b) modified cooling channel design; (b) finished cavity surface and (c) injection moulded part

Development of the RIAL Representative Case Studies

Student: Norbert Brincat
Supervisor: Prof. Ing. Michael A. Saliba

Introduction
The Robotics and Industrial Automation Laboratory (RIAL), has over the years developed and acquired a number of high technology devices. These include a Mitsubishi 6-DOF revolute industrial robot, an Epson SCARA robot, two machine vision systems, a number of programmable logic controllers (PLCs) and two conveyor systems, one of which has variable speed.

In this project a strategy was to be developed to tackle how to communicate the capabilities of the RIAL to the local industry and to the general public. This would involve the development of a number of demonstration projects incorporating the above mentioned assets with the intent of serving as showpieces for the RIAL and a website.

Project Objectives
The primary objectives of this project were:

- Familiarization of the student with the RIAL equipment so as to increase competence in the use and application of automation devices.
- Development of various concepts for small projects for the effective demonstration of these assets to students and other visitors to the lab.
- Development of a coherent demonstration strategy for the RIAL.
- Development of a selection of projects along with appropriate presentation methods.
- Communication of lab assets to the local manufacturing industry and to the general public.

Project Methodologies
Initially a literature review was carried out. Specific topics covered included technological aspects related to the equipment within RIAL, as well as public relationships of foreign universities. Following that, a strategy for the RIAL was formulated. This analysed the current situation of the RIAL and suggested things to be done in order to achieve objectives. A design process was then utilised in order to develop a number of demonstration concepts, from which four demonstrations were selected by means of decision matrices. These demonstrations were interactive, informative and reliable while exploiting the capabilities of the equipment within RIAL.

Parts required for these demonstrations were machined and the setup for each demonstration was assembled as required. Programs for the robots were written and tested for each selected demonstration.

Results and Achievements
Four demonstrations were finalised. The first one includes a tower building demonstration performed by the Epson SCARA robot as seen in Figure 1. The remaining demonstrations, all performed using the Mitsubishi revolute industrial robot, consist of a drink serving demonstration, as seen in Figure 2, a colour mixing demonstration and a tracking function demonstration. All demonstrations make use of signals from sensors and data communication with the operating system.

Furthermore a pilot version of the RIAL website was developed and preliminary work on hosting is being done.

Figure 1, Setup of demonstration by SCARA robot

Figure 2, Mitsubishi robot serving drinks

Manufacturing System Modelling and Simulation

Student: Giulio Calleja
Supervisor: Ing. Emmanuel Francalanza

Introduction

Manufacturing is an operation that companies perform to sell products to their customers. Due to the dynamics of a competitive market, excellent manufacturing operations are essential for any manufacturing firm. For this to occur, an accurate and elaborate planning of the upcoming manufacturing system has to be carried out. Yet this is very difficult to perform since manufacturing systems are generally very complex.

To support this process, modelling and simulation of manufacturing systems is performed. This can help the manufacturing engineer to prototype various scenarios before actually implementing them in real life. This process supports the manufacturing system designer to identify the most appropriate scenario to be selected.
This is not an easy task, since the modelling and simulation process can be rather challenging. This problem is always being highlighted throughout literature especially the aspect that these techniques are very time consuming, and as a result trying out different scenarios takes up a lot of time.

Project Objectives

The main objectives of this project are the following:

- To develop a method by which manufacturing engineers can be supported during conceptual manufacturing system design.
- To identify the technical requirements for a tool which enables the modelling and simulation of this method
- To develop a proof-of-concept tool.

Project Methodologies

- A literature review was carried out to identify the different possibilities of modelling and simulation. The different strengths and weaknesses were identified.
- A framework architecture that could satisfy the final object was created, such as what criteria are needed in the modelling phase that would satisfy the simulation phase, and how the results would be analysed.
- Development of a proof-of-concept tool that could provide the targeted results of the manufacturing system immediately hence reducing simulation and modelling time
- Validate and evaluate the concept tool by checking out the error margin of the concept tool with a state of the art program.

Results and Achievements

Various scenarios have been modelled and simulated in the developed concept tool and compared with state of the art technology software. One of the scenarios included processes having a small process rate to processes having a larger process rate. The parameters and their average errors that have been examined are the following:

- Machine utilization: 0.11%
- Throughput: 0.23%
- Buffer Size: 1.39%
- Time in queue: 1.33%

As a conclusion the results were found to be very similar to the results achieved from the state of the art simulation tools available on the market, but with an improved simulation time. Hence manufacturing system designers can use this tool to simulate various scenarios and get an idea of what the results will be. Once satisfied with the layout a more intense study can be carried out.

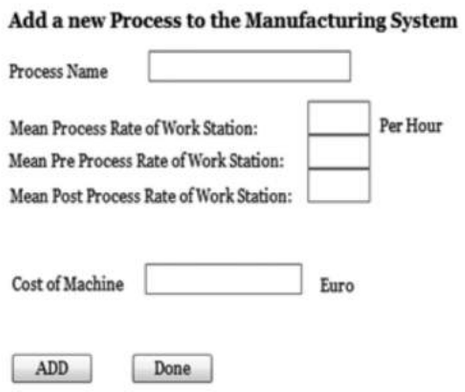

Figure 1: Modelling Phase in concept tool

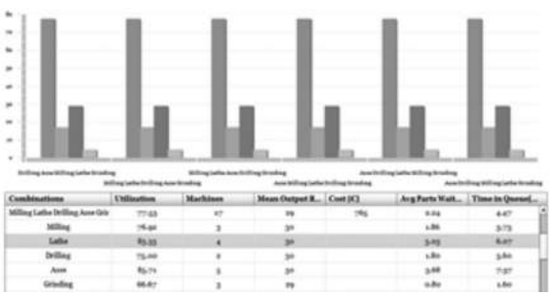

Figure 2: Results analysis using graph

Developing and Testing a Prototype Maintenance System Assessment Tool

Student: Axel Chan
Supervisor: Ing. Pierre Vella

Introduction

In the past, management considered maintenance as a necessary evil, where equipment had to be fixed after failure. As time passed, this mentality had to be changed as many firms realized that proper maintenance management would contribute to world class performance [1].

One of the essential things that provide better control of any system is the ability to assess its performance. Within this context, an assessment tool is required to establish the status of the maintenance system.

Project Objectives

The project objectives are to propose a methodology in maintenance management and develop a prototype tool which is capable of assessing the health of the maintenance system. In addition, a pilot implementation must be conducted to test the tool by assessing three different manufacturing companies.

Project Methodologies

Multi Criteria Decision Analysis is a technique which is used to structure and organise the information, thus facilitating the decision process [2]. This approach was adapted for this project and developed a plan consisting of five main stages shown in the diagram below.

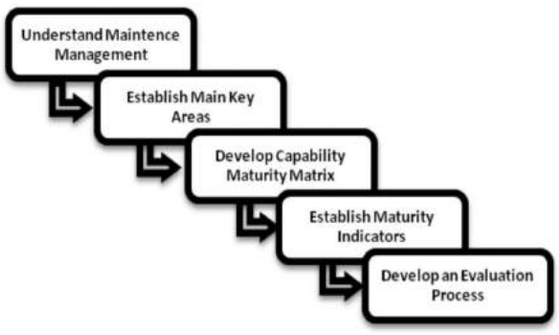

Figure 1 :- Developed plan adapted from MCDA [2]

In the first stage sufficient knowledge had to be acquired to be able to select the appropriate maintenance strategies and identify the major key areas that should be assessed. Twelve Key Areas were selected and a Capability Maturity Matrix was developed. Each key area was categorize into different levels from adhoc up to an optimize level [3]. This is used as benchmark and as an evolutionary improving process supporting the maintenance management. The next stage was to determine the main indicators and compile a questionnaire to be able to assess the maintenance system within the organisation. Finally the evaluation process was developed.

Results and Achievements

Three different companies from distinct sectors of manufacturing namely Pharmaceutical, Semiconductor Technology and Sealing Technology industries, were assessed. An interesting conclusion from this assessment was that, although all of the three companies are all ISO certified, several key areas still did not manage to achieve world class maintenance status. As it could be shown from the evaluation, there were cases where although good procedures were adopted, a relatively low maturity rating was achieved. This indicates that, individual factors might not be sufficient to achieve a "state of the art" maintenance system. To the contrary these should be all comprehensive as most of the factors are interrelated to each other.

Through these innovative key areas, this assessment tool is generic enough to assess any maintenance in a manufacturing company. The whole tool methodology is capable to expose both maintenance problems and areas for maintenance improvement. Thus, these factors can form a basis for maintenance auditing or maintenance annual reports.

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Machining Miniature components on the Sodick AP3L EDM

Student: Christian Grima
Supervisor: Ing. Pierre Vella

Introduction
Micromachining technologies are used to produce micro parts to enhance product functionality in limited space whilst saving material and energy. [1]

Micro-EDM provides several advantages when compared to the other methods, thus making it a potential candidate in manufacturing micro-holes and micro-components. Micro-EDM is mostly preferred where the high aspect ratio, high surface integrity and low cost are required on any conductive material regardless of its hardness [2].

Project Objectives
The main objective of the project was to design and perform a number of experiments on the Sodick AP3L in order to evaluate its effectiveness in manufacturing miniature components. The second objective was to identify preliminary guidelines in order to aid the operator in the rapid setup, programming and machining of miniature components.

Project Methodologies
A total of 5 sets of experiments were conducted in order to assess tool wear ratio, Machine positioning accuracy, hole quality, surface roughness and how the machining performance varies with rotational speed during micro hole machining using the Sodick AP3L.

Stainless steel 316, aluminium and bright mild steel sheets were used as workpiece material. Copper (Cu) electrodes where used as tool electrodes, both in solid and tubular form. Furthermore, the solid electrodes were prepared on the machine as can be seen in figure 1 using a modified electrogrinding stationary block based technique.

Once the machining process was finished, data was obtained via the use of specific apparatus such as Mitutoyo Surftest, Nikon optical microscope and engineering microscope to evaluate the outcome of the respective experiments and to generate further results.

Results and Achievements
The following are some of the main results that were obtained from this project:

1. Micro holes in SS 316, Aluminium and bright mild steel where successfully fabricated by the Sodick AP3L(figure 2) and fully characterized in terms of micro hole expansion, DVEE, TWR, SR and MRR.
2. Electrodes where fabricated on the machine via the use of a CuW stationary block. In addition this technique was improved.
3. It was possible to fabricate micro-holes with an aspect ratio of 20.
4. More empirical research should be carried out in order to generate a more comprehensive set of guidelines for the machining of miniature components which will assist the programmer in selecting appropriate parameters and tool materials.

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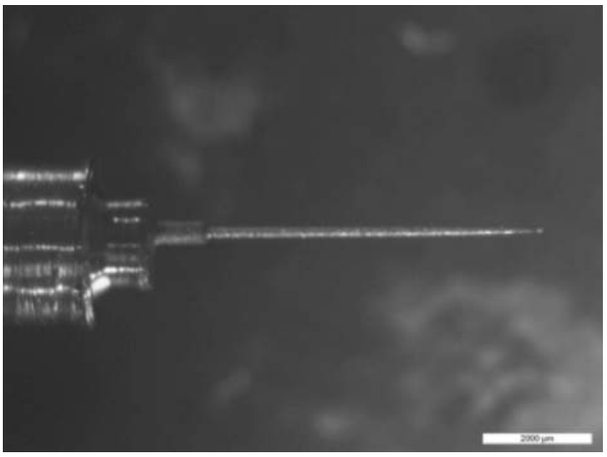

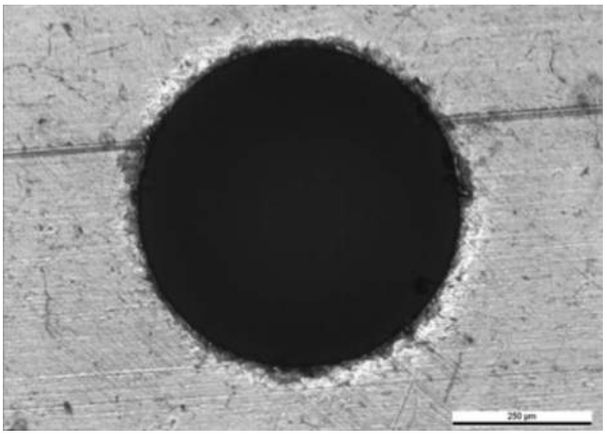

Design of a Proof-Of-Concept Surgical Instrument for Removing Metastases

Student: George Preca
Supervisor: Dr Ing. Philip Farrugia
Co-supervisor: Dr Aaron Casha

Introduction

Metastatic cancer is a form of cancer stemming from a primary tumour which propagates to different organs and/or to different sites within the same organ [1]. Almost 90% of cancer deaths are due to metastases making this a very dire problem [2]. Studies have indicated that upon surgical removal of metastases the chances of survival improve, so there is a clear need for a novel surgical instrument.

Project Objectives

In view of this context, the goals of this project are therefore to:

- Critically review the state-of-the-art surgical instruments for removing metastases.
- Generate a product design specification.
- Generate at least four different working principles of the surgical instrument.
- Model the candidate solution using Computer-Aided Design (CAD).
- Generate detailed engineering drawings of the final design.
- Fabricate a proof-of-concept prototype surgical instrument.
- Evaluate the prototype tool with typical stakeholders.

Project Methodologies

A critical literature review was carried out in order to pinpoint the strengths and limitations of the state-of-the-art surgical instruments, employed to remove metastases. The design problem was tackled by iterating through the basic design cycle [3]. A Quality Function Deployment (QFD) exercise carried out during problem analysis, led to the identification of the most important design requirements in the Product Design Specification. Solution synthesis followed, where a number of working principles were developed and ranked, thereby establishing the most suitable principal solution. The surgical instrument was then modelled using three-dimensional (3D) CAD software and a proof-of-concept prototype instrument was manufactured. A dynamic animation of the instrument was also generated to mimic its intended use during a surgical operation. The last phase concerned evaluation of the prototype instrument with medical Prof.essionals.

Results and Achievements

A proof-of-concept instrument was designed and fabricated (see Figure 1). The novel characteristics which collectively distinguish this instrument from the state-of-the-art are its:

- modularity which facilitates quick suction head changes during surgical interventions and;
- ability to grasp metastases safely enabling their precise manipulation, a task previously thought very risky due to the high risk of fracture.

The surgical instrument received positive reviews from surgeons, scrub nurses and sterilization technicians. One surgeon commented that "This is an important device because current instruments, which are not tailor made for this procedure, can cause fracturing of a metastasis".

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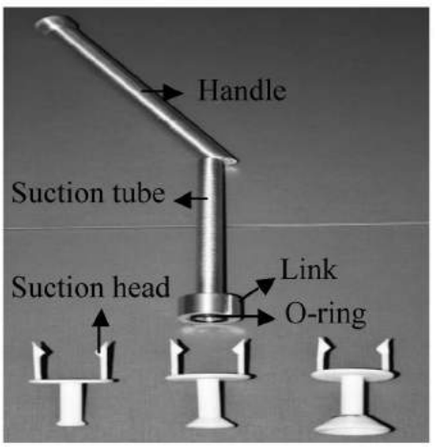

Environmental Factors in Factory Design

Student: Marc Rizzo
Supervisor: Ing. Emmanuel Francalanza

Introduction

Factory planning is primarily concerned with the flow of processes and information, the positioning of machinery on the factory floor and the setting up of auxiliary overheads that support the processes implemented (for example: ventilation systems or artificial lighting). The manufacturing engineer is usually concerned with traditional quantitative criteria such as shape ratio, material handling cost, adjacency score, space demand, flexibility and quality. This project proposes a methodology for the addition of an environmental perspective to the already well-established decision making process used to plan factories.

Project Objectives

The project's set academic objectives were targeted at the development of an environmentally focused tool to support the manufacturing engineer's decision-making process. The academic objectives were defined as follows:

- Investigate and outline the different steps of factory design and their possible impact on environmental factors.
- Develop means by which factory designers can be supported during the design activity to reduce the environmental impact of a factory.
- Develop and test a proof-of-concept tool based on these requirements.
- Evaluate the tool from a practical point of view.

Project Methodologies

Given today's increased need for fast and accurate information in the early stages of factory design, current methodologies are found lacking.

An environmental support tool with a concurrent engineering perspective that streamlines decision-making, requires minimal data input, performs calculations based on information that is readily available during all design stages, and reacts quickly to any changes, is desirable.

With this in mind, a methodology for calculating processing energy consumption during early design stages was established using a mix of product-related and manufacturing system information. A relevant framework (Figure X), together with this methodology, was then used to develop a software tool that could support factory designers. An evaluation of the tool was then carried out by means of case studies in order to analyse the fulfilment of project objectives.

Results and Achievements

Given the relatively innovative nature of this project, the need for validation and further study is extremely important in order to confirm the relevance of the methodology used. However, if relevant, this project may be used to influence how design-stage modelling of energy consumption in factories is viewed by justifying the use of a mix of product-based and manufacturing system modelling rather than the traditional route based exclusively on process modelling.

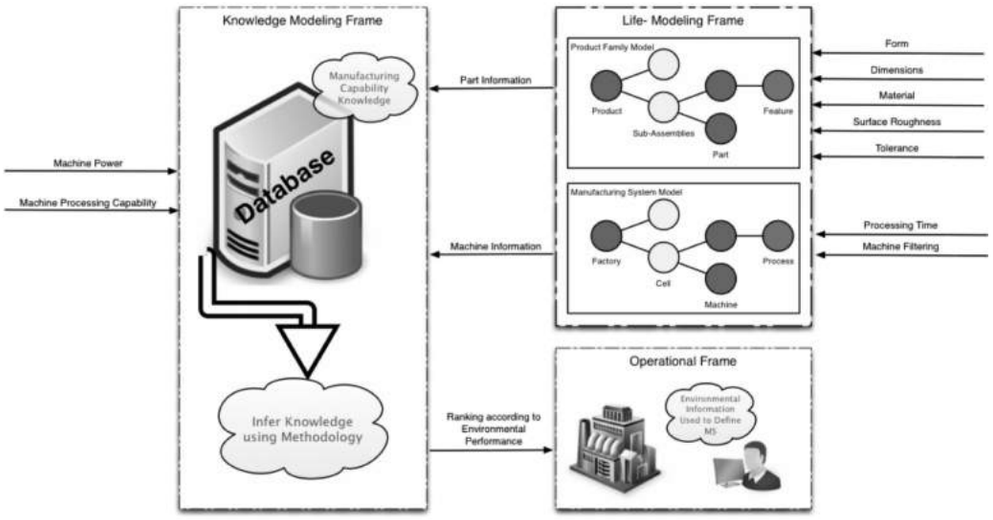

Figure [X] Developed Framework for Environmental Factors in Factory Design

Accurate Part Placement for Insert Moulding

Student: Marco Vella
Supervisor: Prof. Ing. Michael A. Saliba
Industrial Partner: Toly Products Ltd.

Introduction
This project is based on production of Sephora Mono cosmetic packaging, which is used as a container for eye shadow, as shown in Figure 1. These parts are produced by insert moulding. The process requires that preforms are positioned in an injection moulding machine and positional accuracy is a factor of paramount importance when placing the inserts. Misplacements can result in defective parts, as shown in Figure 2, and can also have other effects such as plastic getting into vacuum system resulting in tool breakdown.

Project Objectives
Through the appropiate literature and industry review, experimentation, and analysis, the project is aimed to evaluate in detail the features of the current process, and then to provide better alternatives to the current process. After shortlisting a number of solutions, a suggestion will be made for the preferred solution. Throughout the project, ongoing communication with Toly will enable the company to provide temporary adjustments as quickly as possible.

Project Methodologies
The aim of the experiments was to find the causes of the problems and which stages of the process are the most problematic. One experiment consisted of collecting a number of shots of insert moulding and comparing the defective parts, first with respect to their location inside the mould and then with their position in the previous steps. This would help in finding any assignable causes for the defective parts and detecting if any particular step is a major cause of the problem. Another experiment consisted of measuring the height, inside diameter and outside diamater of a sample of premolded parts, and to determine whether they are within the desired tolerances.

Results and Achievements
The causes of the problem were identified and three main solutions were identified. The first and most simple solution is the acquisition of new, better robots, thus requiring least change in technology. The second solution is an extension of the current process involving the addition of four grippers which will engage after the last robot movement, discovered to be a major cause of inaccuracy. The third solution would require the most significant change and would introduce a single machine for multi-component injection moulding.

Of the three solutions, the multi-component injection moulding machine is preferred, and would provide improvement in part quality and cycle time. This solution would mean that the preforms do not require material handling. Also, it implies the elimination of the robots used for part placement since a single moulding machine is used instead of two.

Figure 1: Sephora Mono product

Cycle Time Reduction of Thermoset Elastomer Injection Moulding

Student: Keith Zahra
Supervisor: Dr Arif Rochman

Introduction

Nowadays, injection moulding is a worldwide business that most companies adopt to use as a predominant manufacturing technique for polymer(s) elastomer products. The continuous development in reducing the cycle time of an injection moulding for thermoset elastomers is an increasing demand. By optimising the machine one would enhance the productivity, reduce wasteful operation and most importantly save time, which are a definite necessity in today's situation.

Project Objectives

The aim of the project is to investigate one of the injection moulding machines at Trelleborg Sealing Solution Malta (TSSM) and provide a solution to minimise the overall time after a whole complete cycle process. Possible approaches to improve such performance will be delivered soon after a complete investigation of the whole set-up will be implemented. The ultimate scope of the project, dependent on what approach would be adopted, the parts produced must deliver the same tolerable mechanical properties and without any critical defects.

The material studied in this research is a Nitrile Rubber (NBR). This type of rubber is one of the most frequently used at TSSM and hence it was chosen to be investigated. Moreover a two-cavity mould was used to manufacture NBR V-rings with a diameter of 40mm (V-40) illustrated in Figure 1.

Project Methodologies

- A literature review to identify the importance of different polymer categories and their distinguishable properties was prepared. Followed with an intense description of the main parameters, common defects and typical post-processes taking place during an elastomer thermoset routine.
- A thorough analysis of the moulding process on injection moulding machine Desma was conducted. Two issues were emerged of main concern: the demoulding time which varied along each process due to manual demoulding and curing time which took almost half the injection moulding cycle time. For both cases, alternative processes were generated.
- A conceptual design of an automating demoulding system which simplifies process was created.
- Different samples taking diverse approaches through injection cycle time and post-curing were experimented, tested illustrated in Figure 2 and compared. Four main tests were where deemed as important for a particular application such as v-ring to possess. These include: hardness, compression set, tensile strength and shrinkage.

Figure 2: Tensile Testing on a V-ring specimen

Results and Achievements

From the numerous tests conducted a better approach was chosen and verified the fact that improvements can be made upon optimising some parameters. A successful final product was achieved while retaining all customers' requirements despite the decrease time during injection. Through an increase in temperature and time during post curing, the reference product still succeeded in meeting a reduction in time within its normal routine shift.

Water Management in Sustainable Manufacturing

Student: Malcolm Zammit
Supervisor: Ing. Paul Refalo

Introduction

In the present scenario, freshwater resources are threatened with the inability to sustain the demand. Water scarcity is a global issue, especially in arid and semi-arid countries. Malta is termed to be in absolute water scarcity given that the demand is greatly exceeding the supply, therefore exerting considerable pressure on groundwater resources. This unsustainable scenario exhibits consequences affecting both the quantity and quality of our natural water resources [1].

Enterprises which expect to be more competitive must become more sustainable in their operations. Sustainable Manufacturing entails the production of products using processes which conserve natural resources, mitigate environmental impacts, safeguard human well-being, whilst being economically sound. Resources to be minimized include materials, energy, water and waste. Water stewardship is a relevant step towards sustainable manufacturing, especially in the local scenario where the realization of water conservation opportunities will contribute to a reduced pressure on local water resources.

Project Objectives

The project aims to promote sustainable manufacturing within local enterprises through a study of implementation of water management and identification of conservation initiatives. The objectives may be summed up as follows:

i. Evaluation of methodologies applicable to water management in industry,
ii. Identify local manufacturing enterprises, serving as case studies, on which the methodology is implemented,
iii. Assess the methodology as a means to promote sustainable operations and identify improvement opportunities for water utilization in the case studies.

Project Methodologies

The Water Footprint Assessment was selected as a systematic approach towards water management. This tool serves as a sustainability indicator which is considerate of direct and indirect water consumption on different levels. Aspects of the business level were adopted in order to implement the tool on a level of manufacturing enterprise. Figure 1 represents the order of execution of the methodology [2]. This method was implemented on two small and medium enterprises (SMEs) and a large enterprise from the local manufacturing sector; these were Seifert MTM Systems, a Pharmaceutical Company and STMicroelectronics (Malta) Ltd respectively.

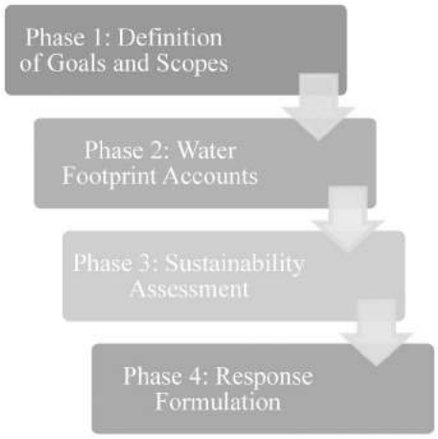

Figure 1: The Water Footprint Assessment Methodology

Results and Achievements

Following an understanding of the water flows inside the manufacturing systems of the respective case studies, the available water consumption data was analysed. The annual consumption volumes provided the operational water footprint. This result was then disaggregated according to water uses and the water sources opted for by the respective manufacturing system. This information provided the basis to evaluate the current water use against sustainability.

A number of opportunity areas and barriers to water management could be identified and discussed. Improvement opportunities indicated various possibilities for future work.

Acknowledgements

The author would like to acknowledge the support from the Malta Business Bureau (MBB)'s EU Life+ Investing in Water Project.

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Stability of Marine Vessels

Student: Shawn Agius
Supervisor: Dr Ing. Claire De Marco

Introduction
Even though advanced technology has seen the expansion of aesthetic qualities and design in multi-hull vessels, there is very limited research and study on the stability of multi-hull vessels to date. Consequently, this dissertation aims to give a comprehensive and detailed analysis on the transverse and longitudinal stability of both mono-hull and multi-hull vessels.

Project Objectives
To review the relevant intact stability criteria according to the International Maritime Organisation and Classification Societies rules;
To model the hull forms of mono-hull and multihull vessels, both analytically through a specifically created Matlab program and through use of the Formsys Bentley Naval Architecture software;
To design and build the model hulls;
To design and build the test apparatus to test the transverse and longitudinal stability of both mono-hull and multihull vessels in still water;
To compare the results of the analytical model, commercial software and experiments.

Project Methodologies
After reviewing the intact stability criteria of the 2000 High Speed Craft code issued by the International Maritime Organization [1], the stability theory required for the design and build of both the mono-hull and multi-hull vessels was outlined and used to model the metre Wigley hull form. The latter was designed using the Naval Architecture software called Maxsurf, where the generated lines plans were exported to a CAD software, to produce the female mould required for the production of the fibre-glass hulls.
To experimentally evaluate the curves of the designed mono-hull and multi-hull vessel, a scale of 1:30 was used to produce the three glass fibre reinforced Wigley hulls. In addition, the testing apparatus shown in Figure 1 (required to test the transverse and longitudinal stability of both vessels) was also designed and built to accommodate a total of fifteen different combinations of stagger and separation ratios for the tricore. The different hull configurations were tested in still water and the results were then compared with those obtained by Hydromax and the Matlab PrograMs Moreover, the intact stability of the designed multi-hull vessel was then assessed in accordance with the IMO standard.

Results and Achievements
When comparing the results of the righting lever , the generated Matlab programs gave positive results when compared to those obtained by the Hydromax software. Similarly, the experimental results were found to be comparable with those obtained by Hydromax. However, there were some exceptions, where the discrepancy in the location of the centre of flotation and the change in draught (which results upon increasing the angle of inclination) were found to have an increased effect on the accuracy of the results for the tricore.
Several conclusions were made on the different stability characteristics of both mono-hull and multi-hull vessels, where this study clearly showed that higher slopes and maximum values are obtained for the tricore, which continue to increase upon increasing the stagger and separation ratio. Consequently, the transverse and longitudinal stability of such multi-hull vessels is increased, leading to stiffer vessels capable of larger righting moments at lower angles of inclination.

References
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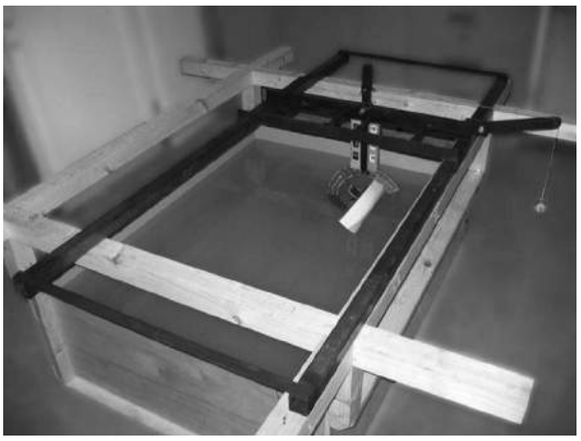

Figure 1: The experimental set-up used to heel the mono-hull vessel

Variable Compression Engine

Student: Kyle Alamango
Supervisor: Prof. Robert Ghirlando

Introduction
The compression ratio is one of the important parameters in an internal combustion engine which affects the efficiency. In most engines, this is fixed by the geometry of the engine. The compression ratio also affects the pressures reached in the cylinder. Ideally, the engine should run reaching a maximum pressure, where the fuel would not pre-ignite. This ratio is also dependent on the speed and on the throttle of the engine. Therefore, for an efficient engine, the compression ratio should change with respect to these operating conditions. This can be achieved by a number of methods, one of which is the variable compression opposed-piston engine.

Project Objectives
The main objectives of the project were:

- To continue the development of the variable compression engine currently under construction;
- To test the engine over the complete range of operating parameters;
- To compare the results with those found from the computer modelling of the engine.

Project Methodologies
Opposed-piston engines are characterised by two pistons operating in the same cylinder. Compression ratio can be varied by making the pistons run out of phase from each other and therefore increasing the clearance volume.

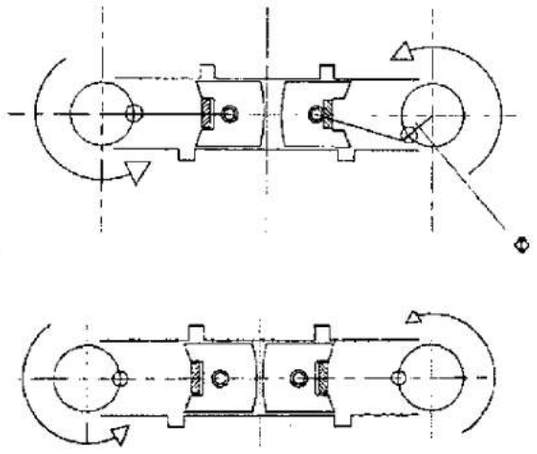

Figure 1: Showing the principle of the opposed-piston engine. Out-of-phase crankshaft (top), In-phase crankshaft (bottom)

The construction of the variable compression engine began in 1995. This was produced by joining two, two-stroke engines together. These were connected together from the cylinder head side with an aluminium flange. The crankshafts of the engines were connected using a chain mechanism. This could be varied to change the phase between the pistons and therefore changing the compression ratio. During testing the chain overheated and failed. In 1998, the chain mechanism was replaced with a pulley and toothed belt system. This method did not work successfully as the belt was slacking during operation. In 2008, a gear mechanism was built but was not completed in that year.

During this project, the variable compression opposed-piston engine was completed. Some tests on the engine were done but the engine had a problem due to overheating ending in reduction in power and stalling.

Results and Achievements
A compression test was performed on the engine and it was noted that the maximum compression ratio is 9.90 and can be varied down to 3.36. The mechanical power is the energy lost in the components of the engine such as the phase shifting mechanism and piston rings' frictional losses. This power was calculated and resulted as a loss of 1hp which is very high for this small engine. Some tests to find the optimum position of the spark ignition were carried out but the results were not consistent due to overheating and decrease of power. Further investigation was implemented to find the problem and it was considered that an air leak could be could be the cause. This would be produced due to differential expansion of materials. Finite element analysis and computation fluid dynamics were used to verify if the air leak was affecting the performance of the engine.

Semi – Displacement Hull Design and Performance Analysis

Student: Mark Azzopardi
Supervisor: Dr Ing. Claire De Marco

Introduction
A crucial consideration when it comes to designing motor – yachts is the power requirement to propel the hull forward. Once the hull form has been decided upon, it is necessary to determine the amount of engine power that will enable the hull to meet its operational requirements. With this knowledge in mind, the naval architect is permitted to select a propulsion plant, determine the amount of fuel storage required, and refine the hull's estimate of centre of gravity.

Project Objectives
This dissertation is concerned with designing and predicting the powering performance of a yacht less than 24 m. The aims behind this project are:

- To go through the design spiral stages of yacht design and establish the main hull parameters.
- To assess the hull performance with respect to the operational requirements.
- To determine the efficiencies along the power train.
- To assess the resistance effects when increasing waterline length.

Project Methodologies
In this case the process of the design was completed till the conceptual design stage, where the hull parameters were set and the NPL lines plan was digitised by the Naval Architecture software Maxsurf from Formsys Bentley (See Figure 1). This led to a preliminary twin engine installation – Volvo Penta D13 of 800 BHP each. Consequently the determination of the compartments and tank allocations were altered until level trim and zero heel were achieved. With the weight estimates located, the centre of gravity was established.
The required appendages were sized and their specifications were given including the shaft diameter, shaft length and its diameter and the shaft angle with respect to the hull.

Results and Achievements
The operational capability of this hull design was assessed for stability against the MCA Large Commercial Yacht Code at 100 % and 50 % loading in calm water conditions; the vessel surpassed the criterion limits.

5 prediction methods were used to determine the resistance which led to determine the efficiency of the hull at 16 knots along its power train. The hull length was also varied from 20m up to 24m which noted a significance decrease in resistance.

A further result achieved was the wave pattern generated by the hull at 16 knots (See Figure 2). The response of the hull design through Motion Sickness Incidence (MSI), of all rooms was classified as moderate throughout the whole speed range. Further tests such as roll decay simulation, determined the natural time period of roll which was as an average of 6 seconds.

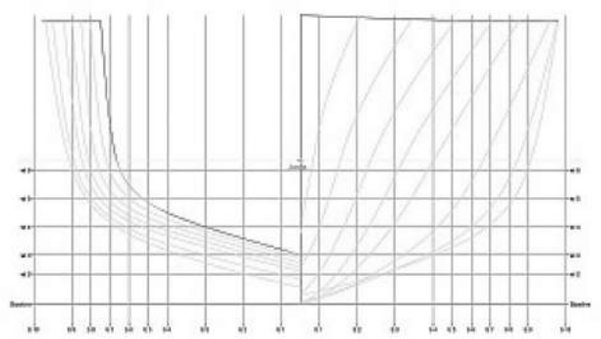

Figure 1: Lines plan.

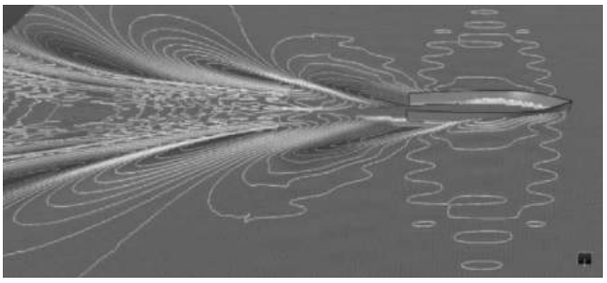

Figure 2: Free surface wave pattern.

Theory and Practice for Tuning and Modifying a Forced Induced Formula SAE Engine

Student: Jean Paul Azzopardi
Supervisor: Dr Ing. M. Farrugia

Introduction
Formula SAE is an established educational motorsport competition where university students are challenged to design and build a single seat car to compete in events which demonstrates their capabilities and understandings of several engineering streaMs The rules imposed, challenge the students to come up with a competitive and successful package. The powertrain rules state that a piston engine with a displacement not exceeding 610cc per cycle may be used. Most importantly, a single circular restrictor of 20mm placed between the intake throttle body and all other engine components is considered as one of the major power limitations [1]. To counteract this inevitable power loss, the Kawasaki ZX6R 600cc engine was previously converted to fuel injection and turbocharged. In this project, tuning and further modifications to the engine were carried out so as to obtain a more reliable and competitive setup.

Project Objectives
Familiarise with engine control units (ECUs) in turbocharged applications

- Study of injector flow rates
- Convert the engine to a full sequential configuration of ignition firing and fuel injection
- Charge cooling of the intake charge
- Preliminary engine mapping
- Familiarisation with valvetrain simulation using Valdyn and camshaft Prof.ile determination techniques

Project Methodologies
The Kawasaki engine was first mounted onto the dynamometer and resorted to its operational condition while familiarisation with engine control units was acquired. This can be seen in Figure 1. The turbo lubrication system was modified in order to allow proper testing of the engine and prevent any leakage to the manifolds. The engine was then converted to operate in full sequential configuration by properly installing a cam sensor. Signal conditioning circuits were introduced as to further enhance the quality of the signals for better recognition by the ECU. Further testing on the engine was performed after a charge air cooler was constructed in order to maintain a steady air temperature at the inlet. The Kawasaki valvetrain was modelled using Valdyn ® in order to initiate a study on cam design.

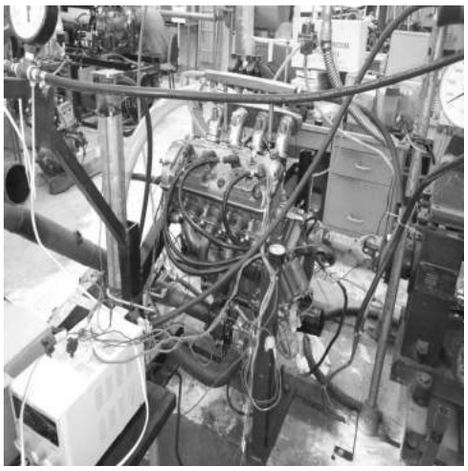

Figure 1- Kawasaki engine fitted to the dynamometer bed

Results and Achievements
A wider knowledge on electronic fuel injection and turbocharging was attained. Methods to exploit engine management with the aid of physical conversions and engine tuning were also achieved. The conversion to full sequential firing and injection resulted in a more reliable and competitive setup. The success of this conversion lies in the drastic improvement of idling and throttle response. Even though the injectors were considered to be of high flow rate, fuel mapping was allowed and plug fouling was eliminated. The charge air cooler constructed carried out its function properly, as the air temperature was kept constant during operation. This allowed for further testing and preservation of the engine from damage.

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Design and Build of an Aerodynamically Supported Marine Vessel

Student: David Baldacchino
Supervisor: Dr Ing. Claire De Marco

Introduction
A wing in ground effect (WIG) vessel is one that uses a phenomenon, experienced due to the aerodynamic interaction between the wings and the surface known as the ground effect in order to travel at high speeds. Travelling in the ground effect zone provides increased lift with reduced drag, thus making this craft highly efficient when compared to other airborne crafts.

Project Objectives
The aim of this project is to design and build a 1:10 scale model of a WIG accommodating and transporting 6 to 7 passengers, capable for high speed chases and emergency situations occurring in the Maltese waters and further ahead, as shown in Figure 1.

Project Methodologies
- Conduct literature review to better understand the development and technology of WIGs
- Analyse the theories used to design the WIG hull and wings
- Calculate all the dimensions and values to design and construct the model
- Construct the WIG model as shown in Figure 2
- Compare the results obtained analytically with those obtained using appropriate software
- Test the model
- Suggest effective design improvements to the model

Results and Achievements
Once the model was constructed, the result was highly satisfying. Both the main wing and tailplane were designed according to ground-effect specifications whilst the hull was designed for fast planning of the model.
The idea of using a catamaran instead of a monohull gave satisfying results as the model proved to highly stable in water. Also, when tested on dry ground, the model could hover due to an increase in pressure between the sponsoons of the hull.
The model was also tested in open sea water. Although, preferably a calm and smooth surface of the water was desired, this was not the case when the tests were conducted.
Once in water, due to the force of the engine, a forward moment on the model was developed and hence pushed the fuselage tips down in the water. This drastically increased the resistance of the hull and the model had difficulty to take off. On site tilting of the engine reduced these moments however the model still did not perform satisfactorily.
Repositioning of the engine was carried out so that the fuselage tips did not dip in the water due to the propulsive force of the engine and the model was re-tested. This modification proved to be a good idea since the front part was not in contact with the water, however this lead to an increase in draft at the back of the model and the main wing came in contact with the water surface. This resulted in the model not being able to take-off.
Both results were satisfying since a lot of knowledge was gained during both testing days and improvements will be implemented in a second model.

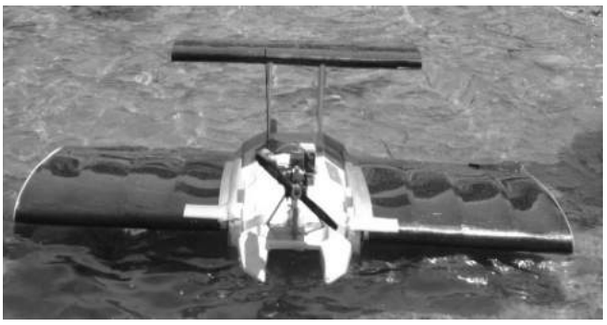

Figure 1: 3-D model visualisation

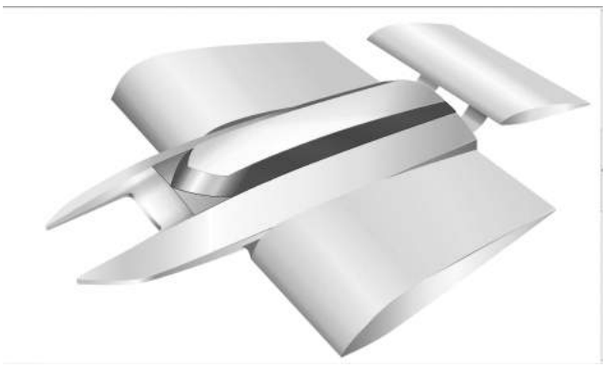

Figure 2: Constructed WIG model

Setup of Exhaust Ducting System and Testing of FSAE Engine

Student: James Baldacchino
Supervisor: Dr Ing. Mario Farrugia

Introduction

Past projects, in which engine testing was carried out, suffered in performance due to the fact that the exhaust was vented out of the laboratory by simply extending the exhaust pipe to the outside vicinities. This extension in the exhaust pipe induced a lot of restriction which results in a reduction in power, inaccurate results and a marked difference from the system, as installed on a working vehicle. So an exhaust venting system has been built which could vent the exhaust to the outside without inducing any restrictions, and keep up with the exhaust flow, even at the elevated temperatures of the exhaust gases. Testing the operating capability of the system was performed by installing a FSAE engine on a dynamometer and loaded to 15000rpm.

Project Objectives

- Use a CAD software to design the ducting for the exhaust system
- Installation of the exhaust ducting
- Mounting and aligning the engine onto the dynamometer
- Calibrate engine sensors
- Setting up the ECU
- Simulating the engine in WAVE and comparing results
- Building an operational test stand ready for FSAE students to use to map the engine for future competitions.

Project Methodologies

The following steps were carried out during the development of this project:

- Designing, manufacturing and installing the ducting system
- Calculation of the head loss of the system
- Selecting a centrifugal fan capable for the task at hand
- Installing and aligning the HONDA CBR600RR engine on the variable fill, water brake dynamometer test bed
- Designing and manufacturing the drive shaft and its respective adapters
- Calibrating the engine sensors
- Mapping the ECU
- Testing the engine, by carrying out steady state testing and sweep tests.
- Modelling the engine using a 1D software, WAVE by Ricardo.
- Compare results from the computer simulation to those obtained from the tests.

Results and Achievements

Results from the simulation were used to help in the calculation for the fan selection for the exhaust ducting system. After testing the engine for some time it was concluded that the calculation for the exhaust system selection was correct, and that the extractor fan had no problems in keeping up with the exhaust flow rate at the conditions it was tested. Additionally the wiring of the engine to the ECU and the calibration of the sensors was a success. The engine worked fine across the whole rpm range. The best torque for minimum timing advance and the least amount of fuel for maximum torque were performed for an rpm of 10000 by steady state testing. Similarly power and torque curves were obtained after multiple sweep tests. These results where then compared to the results obtained from the simulation, which resulted to be a very good match.

Figure 1: Complete Ducting system

Figure 2: Engine assembly completed

Design, Build and Test of a Drop Weight Impact Testing Machine for Marine Sandwich Panels

Student: Ryan Buhagiar
Supervisor: Dr Ing. Claire De Marco

Introduction
The study of sandwich panels is being given ever increasing attention in the world of engineering especially in the marine industry due to the need of constructing marine vessels with high strength to weight ratio in order to withstand static and dynamic loadings. With the achievement of light weight constructions, fuel efficiency and vessel's manoeuvrability can be enhanced.

Project Objectives
The aim of this project was to design and construct a drop weight impact testing machine. This machine was constructed according to the ASTM D7136/D7136M-05 Standard Test Method for Measuring the Damage Resistance of a Fiber-Reinforced Polymer Matrix Composite to a Drop-Weight Impact Event.

Project Methodologies
A literature review was first completed outlining the properties of a sandwich panel. A general sandwich structure construction consists of three different materials being the exterior facings, the core and the adhesive substance. Their main benefits include low density, high stiffness and sufficient strength, but sandwich panels are nowadays being used in everyday components, in order to benefit from other properties such as shock absorbing and flexibility. Impact testing is commonly carried out on sandwich panels using a drop weight impact machine which are associated with low velocity impact and with low energy level. For drop weight tests, load-time traces are plotted and converted to energy-time traces which can be related to the fracture developments taking place in the sandwich panel.
The machine was designed in a CAD software, and appropriate calculations were carried out to investigate the maximum load bearing capacity of the critical components. Some results were also calculated using finite element analysis.
The material was bought and the construction process of the machine was initiated. Several milling and turning processes were used in order to machine the required parts. The outer frame of the machine was mainly assembled by welding processes.
Several sensors were connected to a data acquisition card in order to measure the impact velocity and the contact force during the impact tests.

Results and Achievements
The structure was successfully built and the specimens of the sandwich panels were cut to the required dimensions. Several tests were carried out on different sandwich panels to verify that the whole apparatus is working properly. The graphs of contact force, indenter velocity, indenter displacement and absorbed energy against time were plotted for each tested specimen, to investigate the impact behaviour as the sandwich parameters are varied. It was noted that the maximum absorbed energy increases by almost times the increase in the sandwich panel thickness.

Figure 1: The constructed drop weight impact machine.

Figure 2: Sandwich specimen showing indentation.

Aid for People with Insufficient Muscle Strength in the Lower Limbs

Student: Marika Busuttil
Supervisor: Dr Ing. Zdenka Sant

Introduction

There are a number of conditions that might lead to weak muscles in the lower limbs. A period of inactivity following an accident may cause the muscle atrophy, aging leads to a decrease in the muscle strength, and number of other various diseases can also affect the muscle strength. Therefore people who have such conditions, can find it difficult to get up from a seated position, possibly leading to loss of their independence. An aid to make it easier to get up from a chair would increase their independence as well as foster their independent move and thus potentially prevent further atrophy.

Project Objectives

The aim of this project was the analysis of lower limb, the study of movement during the process of rising from a chair using the Vicon system available at the Biomedical Laboratory of the University of Malta. Based on the analysis of the muscular activity during the process of getting up from the chair to design an aid that would facilitate this process and allow to calibrate the required force to support the person who has an insufficient strength in the lower limb.

Project Methodologies

The first part of the project included the analysis of the getting up process as well as a market research. Three healthy subjects were involved in the study, which monitored the motion during a rising from the seats in different heights, by means of the motion tracking system Vicon. The six cameras of the Vicon system recorded the position of passive retroreflective markers placed on body segments while the surface EMG was used to monitor muscle activity.

The second part of the project applies the experience gained from the research that finally leads to a design an aid to facilitate the controlled rising from a chair. Products on the market were analyzed and new ideas were generated. The final design concept was chosen and the necessary calculations were carried out to support the creation of a detailed design and a CAD model.

Results and Achievements

The movement recorded in our laboratory was in agreement with results published from the previous similar research. The Figure 1 shows the muscle activity as monitored by means of EMG signals while a subject getting up from the seat at knee height. The three quadriceps muscles – the vastus medialis (VASMED), vastus lateralis (VASLAT) and rectus femoris (RECFEM) – produced a very similar signal. The signal reaches peak value when the person lifts off the seat that corresponds to the muscular activity of quadriceps, which are the main muscles providing the force for the knee extension. The bicep femoris is also activated whilst the person is rising, however it remains active for a longer period to maintain the stability of a subject at the standing position.

Figure 2 shows the detailed design. It is a portable seat with a set of strong springs that tilt it forward when the person is getting up, providing some of the force to lift the person's weight.

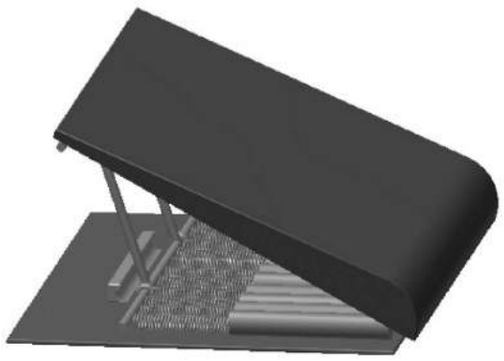

Figure 1: EMG signals

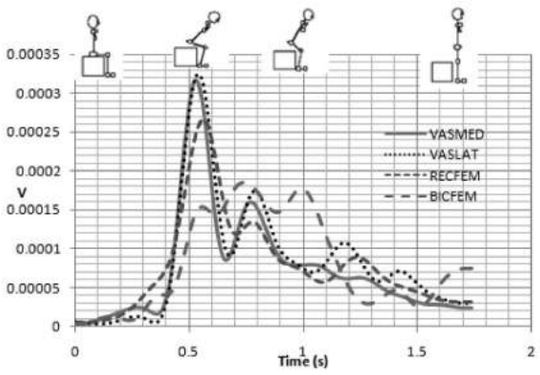

Figure 2: Detailed design

Conceptual Design of a High Speed Planing Craft

Student: Josef Camilleri
Supervisor: Dr Ing. Claire De Marco

Introduction
High speed recreational boats have been growing in popularity at a relatively fast rate throughout the world, including Malta. This can be mainly attributed to the beautiful coastline well indented with bays and sandy beaches surrounding the islands making such boats ideal for pleasure rides. This growth in popularity has created the market for new boat designs and technology development.

Project Objectives
The scope of this thesis was to develop a design concept for a modern and fuel efficient recreational boat to be operated safely and comfortably around the coast of the Maltese islands.

Project Methodologies
The goal of undertaking a new design is to turn the requirements of the prospective boat owner into the best possible technical and aesthetical solution. The first design task was therefore to define very clearly the boat's overall purpose and the owner's design requirements (which in this case is the author). This served as a general guide to the intent of the design. A market study was also conducted to gather information from existing boats in the same size range. From this information, a conceptual design for the boat was developed and a general shape of the hull was created within the naval architecture program Maxsurf.

To assess whether the proposed design is feasible, its performance had to be predicted using the relevant theory, tests methods specified in standards and the software Hydromax and Hullspeed. The performance characteristics include the boat's flotation and static stability, power requirements, dynamic stability, and seakeeping characteristics. The proposed design had two main drawbacks limiting its operational capabilities; at high speed the boat was running too high a trim angle which could lead to porpoising instabilities and, in rough seas the impact accelerations experienced were relatively high. To mitigate these weaknesses, the boat's beam and deadrise were modified which led to a boat with far better operational capabilities in smooth and rough seas. At this stage, a feasible design was believed accomplished.
To further improve the design, an optimization process was carried out using the parametric analysis technique. Two parameters were chosen to be optimized; the boat's length and longitudinal centre of gravity position. This resulted in a boat with further improved operational capabilities however its calm water efficiency was slightly reduced.

Once the design was finalized, a suitable engine was selected and a structural analysis was performed. The software AutoCAD and Google SketchUp were used to create a lines plan drawing and three dimensional views of the interior and exterior layout and the boat scantlings (see Figure 1).

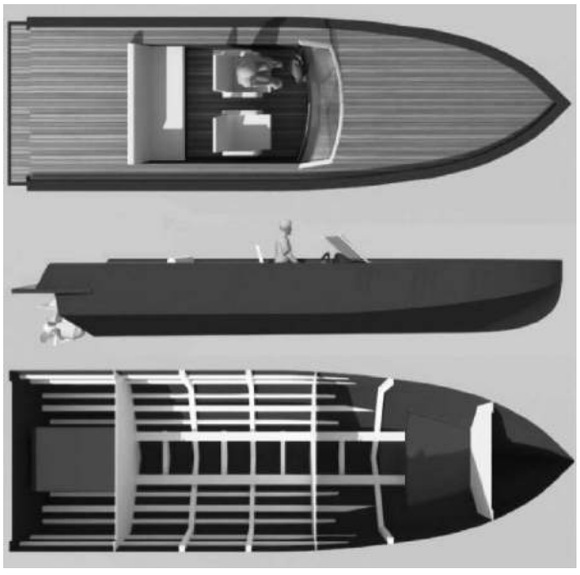

Figure 1 - Hull, scantlings and deck layout

Results and Achievements
The goal was to create a conceptual design for a high-speed recreational craft. This is believed accomplished however more work is required before the boat can be built. An important task which could be carried out in the future is to evaluate the proposed design using either model tests or numerical flow simulations.

Setup for Experimental Investigation of Water Injection In A S.I. Engine

Student: Glenn Camilleri
Supervisor: Dr Ing. Mario Farrugia

Introduction
As yet, the injection of water in a spark ignition engine is not a common practice. Having said that, there is evidence that this implementation has the potential to improve the automotive industry with regards to engine performance. In fact, water injection inside the combustion chamber acts as an internal coolant, knock suppressant and a way of reducing emissions such as the formation of nitrogen oxides at high engine temperatures. Since the injected water decreases the temperature of the internal components, the inducted air-fuel mixture has a lower tendency of abnormal combustion, such as pre-ignition. Thus, with water injection, a spark ignition engine may be operated at a higher inlet boost pressures without knocking, yielding a higher power output.

Project Objectives
The aim of this dissertation was to construct an engine setup to enable the investigation of water injection in the intake manifold of a spark ignition engine.

Project Methodologies
This project mainly involved the following:

- Mounting of the engine used to a dynamometer test bench as shown in figure 1.
- Design and manufacturing of the engine-dynamometer coupling which also served as a crankshaft encoder.
- Testing of the engine to obtain its performance characteristics in its original configuration.
- Design and manufacturing of an intake manifold (figure 2) that enables water and fuel to be injected under electronic control and hence replacing the original carburettor fuel induction system.
- Implementation of a load cell to the dynamometer setup to replace the older method of measuring torque with a mass balance.
- Installation of an Electronic Control Unit (ECU) as well as the required sensors to accomplish various readings that are required to monitor and manage the engine.
- Setting up of an air pressure circuit that is connected to the air intake of the engine to emulate the effect of forced induction at constant temperature.
- Obtaining the performance characteristic of the engine under various intake boost pressures.
- Water injection tests with and without intake boost pressures.

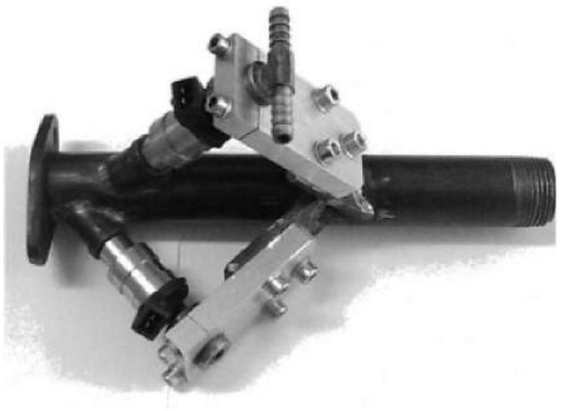

Figure 1: J.A.P model 6 engine with fuel injection

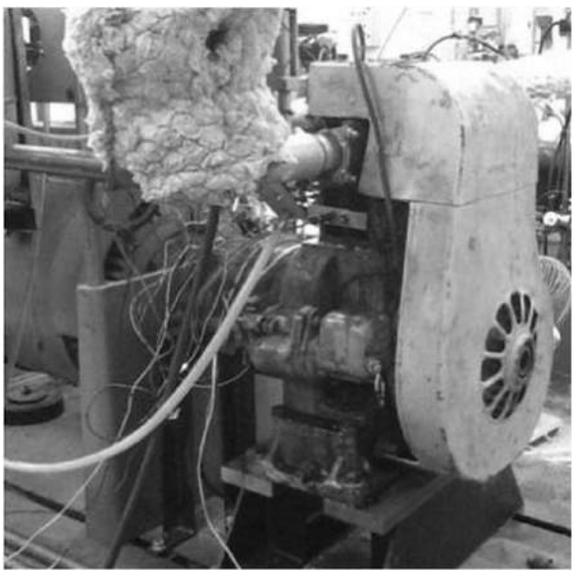

Figure 2: Manufactured intake manifold with fuel and water injectors

Results and Achievements
The manufactured components such as the intake manifold, crankshaft encoder - coupling and the load cell provided a robust setup for engine testing. In addition, the setting up of the fuel pressure system and installation of the crank and cam sensors with their respective signal analysis made the implementation of the electronic control module successful. Increasing the manifold air intake pressure to 140kPa, the brake power increased by more than twice the rated power of the engine.

Troubleshooting a Vapour Absorption Refrigeration System

Student: Mark Camilleri
Supervisor: Dr Christopher Micallef

Introduction
Vapour Absorption refrigeration systems have been in existence for quite a long time but their use is limited due to vapour compression systems being a more popular choice. Today renewable clean energy generation is becoming a preference to conventional energy generation due to consideration of the environmental impact. Clean electricity can be generated by several renewable sources, however the advantage of using a vapour absorption system, is the ability to obtain a refrigerating effect from exhaust heat, since vapour absorption systems utilize only low grade heat energy in order to work.

Project Objectives
The objectives of the project were to troubleshoot an existing vapour absorption test rig system which was built by a previous student and later modified by another student. Both students were unable to obtain a refrigeration effect when testing was carried out. The system requires the use of non-toxic fluids as the absorber and the refrigerant and therefore lithium-bromide and water are utilized in the system as working fluids.

Project Methodologies
In order to troubleshoot the existing system, it was essential to understand exactly how vapour absorption cycles operate. An in-depth research was carried out on the operation cycles and existing absorption systems were analysed in order to investigate how each component in the system operates. Studies on the Lithium-Bromide solution were also reviewed in order to ensure that the system operates in the optimal conditions for the solution not to crystallize.

The troubleshooting processes consisted of dismantling the different components of the system and checking and cleaning each component. The valves in use were cleaned and reused in order to keep the costs down. The original design of the evaporator was unsuitable since it allowed the refrigerant in liquid state to come in contact with absorbing fluid. This must be avoided otherwise the system does not work. The evaporator was redesigned in order to ensure that only vapour refrigerant comes in contact with the absorbent. A pump casing was designed and built to replace the existing leaking casing. The rest of the components were cleaned and fixed where required. The entire system was reassembled and flushed with water. The system was designed to work at near vacuum conditions. This required the use of a vacuum pump to remove all the air and water in the system before any testing was carried out and to ensure that there are no leaks present in the system.

Results and Achievements
Small leaks led to the vacuum pressure being lost at a very slow rate. No testing was carried out at the time this abstract was written out since the system would not work unless all the leaks are fixed and the required vacuum conditions are obtained. When the system is completely airtight, it will be tested by injecting the lithium bromide solution into the test rig and supplying heat to the system to initiate the cycle.

Figure 1: Image of the assembled refrigeration system

Biomechanical Analysis of Muscle Recruitment During Physical Activities

Student: Mona Lisa Camilleri
Supervisor: Dr Ing. Zdenka Sant

Introduction

As an athlete and coach, my main concern has always been to comprehend the effect of load on muscular recruitment which eventually results in fatigue. Fatigue is a subjective issue which varies from a person to another and is mostly dependant on the psychological state of mind and activity of the brain. The accepted way to study muscle fatigue is by using surface electromyography (sEMG). Electromyography is a basic functional tool to determine the muscle activity during contraction.

Project Objectives

- Analyse muscle fatigue through three different modes
- Surface Electromyography
- Muscle force
- Frequency spectrum
- Identify the effect of fatigue of isometric and dynamic muscle contractions through EMG signal analysis
- Compare the muscle fatigue between males and females who do regular physical activities against those that do not.

Project Methodologies

The first part of the methodology of this project is based on the acquisition of EMG data to analyse muscle recruitment patterns during the two types of exercises: isometric squats and lunges were performed by twelve voluntary subjects participating in the project. The subjects selected were further divided as those who are involved in regular physical activities and those who do not submit themselves to regular physical activities. The muscles investigated in this project were the Vastus Medialis, Vastus Lateralis, Bicep Femoris and the Medial Gastrocnemius muscles. In order to initiate fatigue a barbell weighing 25% of the body mass of the subject was used. The second part of the methodology deals with data processing and plotting voltage of EMG, muscular force and the frequency spectrum.

Results and Achievements

The effect of fatigue during the isometric squat was more dominant than during the lunge exercises. Athletic subjects exhibit more stable results than individuals that do not submit themselves to regular physical activities. However, some of the non-regularly physically active subjects showed a good constancy of their results thus the muscle fatigue was observed after longer interval than at others. If a person schedules simple physical activities into his lifestyle, then he is able to carry out the daily tasks and does not tire easily. If I'll analyse the results from the aspect of a coach, then results can be useful to identify the group of muscles that needs to be improved. In this way, one can prevent injuries. Muscle fatigue is based on the state of mind as it requires concentration and effort to sustain maximum isometric contraction. Some of the subjects complained of the muscle pain during the exercise and they were ready to terminate the test before the stipulated time. However, their results showed that longer time was needed to initiate the muscle fatigue. Hence, I believe that via EEG, muscle fatigue could be analysed in depth since muscle recruitment starts from the impulses generated by the brain and sent to the muscle.

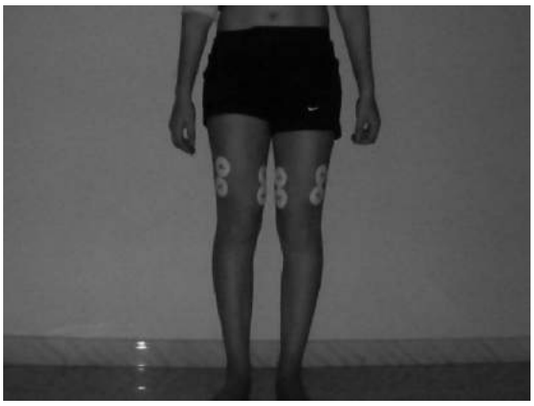

Figure 1: Surface EMG electrode placement of right and left Vastus Medialis and Vastus Lateralis

Energy Performance of the Manoel Theatre

Student: Rodianne Cassar
Supervisor: Prof. Robert Ghirlando

Introduction
The Manoel Theatre is a baroque theatre built in the eighteenth century which initially had a cooling system based on natural ventilation. Unfortunately over the years, this system was abandoned and the theatre is currently with no form of ventilation, which makes it impossible for it to be used in summer due to the excessive heat. This project is a preliminary study of the energy performance of the theatre and includes an analysis of any possible solutions to decrease the effect of the cooling loads, through natural ventilation.

Project Objectives
The energy performance of the Manoel Theatre was studied, analysing the present heating and cooling loads as well as its natural ventilation system. A model of the theatre was built to model natural convection which was then modelled using numerical computational techniques. This model was then adjusted to the dimensions of the theatre to observe the results. Different means of improving the thermal comfort of the patrons were then proposed.

Project Methodologies
The present conditions of the Manoel Theatre were studied and after performing research on how natural ventilation is installed in various theatres, the heating and cooling loads of the Manoel Theatre were determined. A model of the theatre was then build, as shown in figure 1, which comprised of two inlets and an outlet and it was heated to simulate the conditions of the theatre and to analyse the natural convection of such model. This model was then simulated using ANSYS ® Workbench to compare the temperature and mass flow rates with those of the experiment. Finally, the model was transferred to the dimensions of the theatre to apply the same conditions and analyse the results. Based on these results, suggestions for improving the natural ventilation of the theatre were made.

Results and Achievements
The heating load of the theatre during winter is 132.98KW while the cooling load during summer is 217.72KW. These results suggest that for winter,a high amount of energy is being lost from the building, which currently the theatre is surviving with. On the other hand during summer, the building is gaining heat which is resulting in excessive temperatures and high discomfort and hence the theatre is not used. The results of the experiment performed on the model suggest that although the velocities are very low, typically below 0.1 m/s, a change in temperature between the outlets and the inlets was observed, indicating that heat was rising towards the outlet. These results were compared to the CFD model and the same pattern of velocities and temperatures was observed. The model was then adjusted to the dimensions of the theatre and the same simulation was iterated to model this natural convection theory on the theatre. Finally, suggestions on how to implement this technique were given, keeping in mind that further studies are needed to determine the effect of such implementations on the theatre and its environment.

Figure 1: Experimental model of the theatre

Energy Recovery Micro-Turbine

Student: Nathaniel Cassar
Supervisor: Prof. Robert Ghirlando
Co-supervisor: Dr Ing. Tonio Sant

Introduction
This project is focused on the design of an energy recovery micro-turbine, which has the potential of extracting valuable energy from the brine discharge at Pembroke Reverse Osmosis Plant. To date the energy consumption in Malta is mainly derived from fossil fuels for all energy requirements and despite its continuous increase in price the demand is always gradually rising. In fact between 2000 and 2011 the electrical power generation in Malta increased by 13.3 per cent.

Project Objectives
The main objectives of this dissertation were:
To design a micro-hydro turbine system, intended to recover energy from the brine discharge stream at Pembroke Reverse Osmosis Plant..
To carry out a feasibility study, outlining the potential of the system and the cost of implementation.

Project Methodologies
The work undergone through this project can be divided as follows:

- A thorough literature review;
- To better understand the concept behind the term micro-hydro and its application both locally and globally.
- Background literature covering various aspects of existing hydro turbines.
- Theoretical research, focused on aspects of design and analyses of flow especially in regards to Pelton wheels.
- On site analysis to identify the most suitable installation site for the recovery machine; mainly characterized by the available space and power.
- A selection of the most compliant type of hydro-turbine which concluded in the selection of a Pelton wheel.
- Conduction of material selection procedures with a mindset to identify modern and compliant materials which can be adapted to a highly corrosive environment and possibly replace the more mainstream Stainless Steels especially in regards to the turbine runner.
- Design bly dsetadapted to a of a Pelton wheelses of flow of Pelton wheels. eam ones. of existing hydro turbines. appropriate of a micro-hydro turbine system which involved the design of a Pelton runner, an adaptable chute which efficiently conveys brine to the machine, and the supporting frame.
- Designation of a suitable power train composed of a step-up helical gearbox, a PMG and an inverter.
- Analysis of the overall output power and plant efficiencies.
- Conduction of a feasibility study.

Results and Achievements
The project results in the successful design of an energy recovery micro-turbine as illustrated in Figure 1 which may be implemented at Pembroke R.O. Plant. The theoretical maximum overall power output of the turbine is 1.64kW at a maximum brine flow rate of 24,000m3/day during the summer period, while during the winter period at a flow rate of 12,000m3/day the turbine produces an output of 542.7W, as depicted in Figure 2. This provides a total energy capacity of 7167.21kWh which at a tarrif rate of 0.164 € per kWh would result in a net saving of 1175.423€ per year.

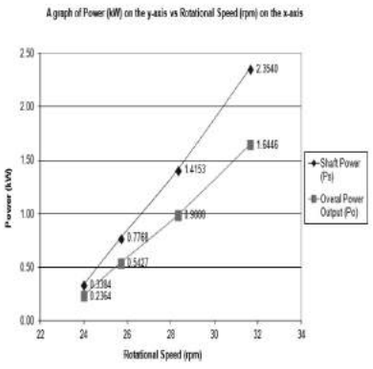

Figure 1 – 3-D model of the Energy Recovery Micro-Turbine

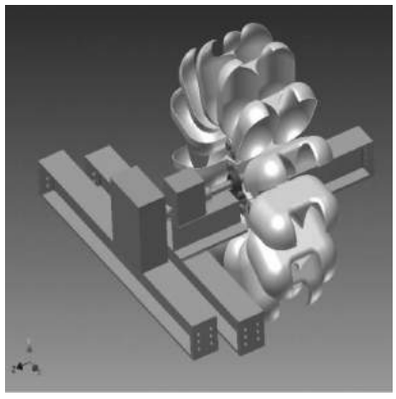

Figure 2 - Shaft Power and Overall Power Output Performance Curves

Wind Monitoring and Instrumentation Development for the Performance Testing of a Multi-Bladed Wind Turbine Rotor

Student: Christian Cordina
Supervisor: Dr Ing. Tonio Sant
Co-supervisor: Ing. Robert N. Farrugia

Introduction

The world is now aware that problems due to the dependence on oil and increasing carbon emissions must be solved. Because of this, there is a major need to develop technologies that rely on renewable sources of energy to generate electricity. Wind power is becoming an increasingly popular energy resource because it provides clean and environmental-friendly energy.

Project Objectives

- To equip and install a guyed monitoring mast with wind speed and direction sensors in order to investigate the air flow in an open field in the vicinity of the wind turbine;
- To determine the rotational speed and output power of the rotor and to design and construct a yaw sensor;
- To conduct preliminary estimates for energy yield characteristics and compare them to other three-bladed micro wind turbines of similar configuration.

Project Methodologies

The following steps were carried out during the implementation of the project:

- A detailed review on the theory behind wind turbines was performed in order to gain better insight and knowledge about this energy technology;
- A computer program modelling the aerodynamics of the multi-bladed horizontal axis wind turbine was developed in order to find the optimum coefficient of performance for the multi-bladed turbine;
- The installation of wind monitoring equipment was implemented in order to monitor wind turbine operation once this is assembled at the test site. A 1m copper finial was used to provide a ninety-degree protection cone for the top sensors.
- The analysis of the measured wind data over a few months at the test site was carried out from which preliminary predictions for the wind turbine energy yield for this period could be derived and compared to those for other micro-turbines of similar diameter.
- Although the purpose of the tail vane is to align the wind turbine to the wind, due to the inertia of the wind turbine, some misalignment is inevitable. A yaw error sensor was therefore needed to determine the amount of misalignment.

Results and Achievements

From the Blade Element Momentum theory, the optimal coefficient of performance of the multi-bladed turbine was found to be 26% at a tip speed ratio of 3.46. This was used to find the energy that the multi-bladed turbine would generate, taking into account an efficiency of 85% for both the inverter and generator. The multi-bladed prototype turbine (having a span of 3.4m) would have generated 229.74 kWh over the three month period, while a Fortis Passaat wind turbine with a span of 3.12 m would have generated 184.30 kWh.

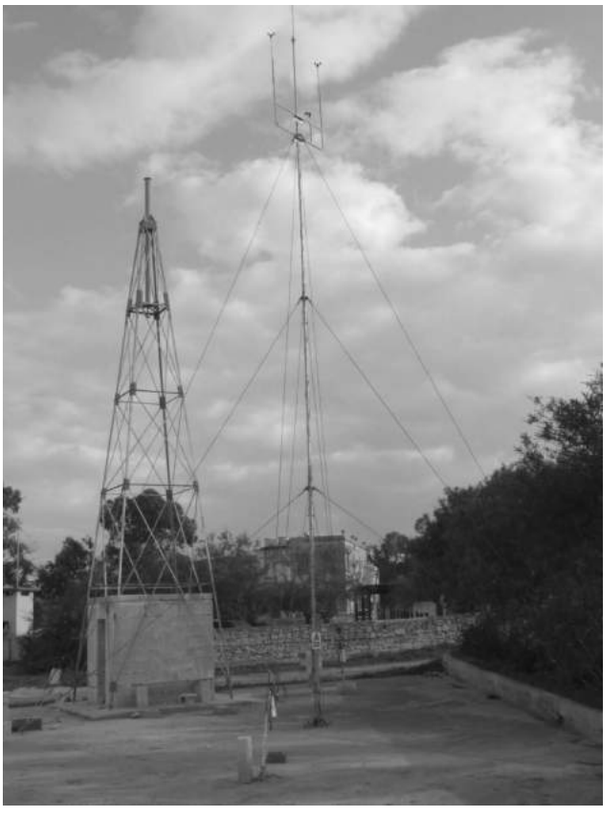

Figure 1: Lattice Tower and Wind Monitoring Mast

Aerodynamic Characteristics of a Selig S3024 Aerofoil at Low Reynolds Numbers

Student: Kurt Cuschieri
Supervisor: Dr Ing. Tonio Sant

Introduction

Wind tunnel testing in conjunction with computational modelling, such as computational fluid dynamics (CFD), is crucial in aerofoil design to ensure the required aerodynamic characteristics for operation are achieved. Tunnel testing can be performed using a mechanical or electrical approach. Various modelling algorithms are available for the CFD approach, each having their own set of advantages and disadvantages for particular applications.

Project Objectives

- To design and construct a supporting system for an aerofoil in the Square Section Wind Tunnel found in the Fluids Laboratory at the University of Malta;
- To determine the forces of lift and drag developed by, and hence their respective coefficients of, a Selig S3024 aerofoil at low Reynolds number for varying angles of attack using two different setups and compare the results;
- To design and construct a traversing system for a hot-wire probe and use this to analyse the flow-field around the aerofoil using hot-wire anemometry to establish the flow separation point/s;
- To compare the lift and drag coefficient and hot-wire results to a CFD analysis using ANSYS Fluent®;
- To compare the lift and drag coefficient and hot-wire results to an analysis using XFOIL®.

Project Methodologies

The first setup to be used for tunnel testing was developed in a previous project and was based on a spring balance system, whilst the second was designed to work with strain gauges on a series of cantilevers set to bend under the action of the aerodynamic forces on the aerofoil. The CFD analysis was set in 2D and involved thorough mesh independence and solver comparison exercises along with a validation study with published experimental data on similar aerofoils. The program XFLR5, which has a graphical user interface (GUI) and uses the XFOIL code as a solver, was used to construct a wing model to obtain results to be compared with tunnel and CFD results. Finally, the hot-wire system was designed and constructed and a number of data points were taken around the aerofoil to monitor the velocity and turbulence intensities at different angles of attack to identify flow separation points.

Results and Achievements

It was found that the data from the spring balance system was reasonably close to that from XFOIL. For CFD it was determined that a k-ε RNG solver with enhanced wall treatment was the most suitable and the results, as in Figure 1, were of the same order but of higher magnitude than those from the other methods. However, these agreed with existing aerofoil data. The strain gauge system gave unreliable readings due to a non-linear force-strain relationship obtained through calibration which was meant to be linear, possibly due to wiring or material handling issues. The hot-wire results clearly showed how flow separation affects airflow by sudden and significant drops in velocity and increases in turbulence. These points agreed with CFD, but not with XFOIL.

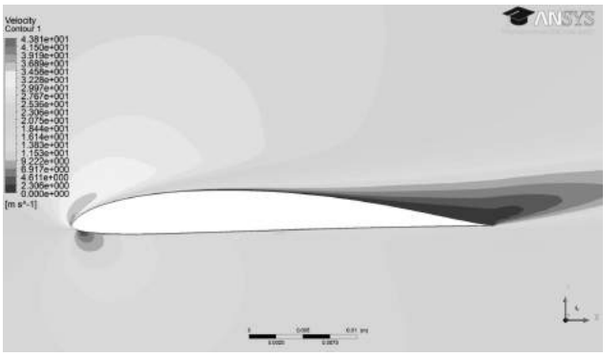

Figure 1 Example of a velocity contour plot for the CFD aerofoil.

The Use of Liquefied Petroleum Gas for Vehicles

Student: Alistair D'Agata
Supervisor: Dr Ing. Mario Farrugia

Introduction
Liquefied Petroleum Gas is a fuel much growing in importance in today's world with the high cost of other more conventional fuels. It is easily extracted as a gas and can be easily transported in a compact form as a liquid. This fuel having a favourable hydrogen to carbon ratio cuts harmful carbon dioxide emissions. The introduction of liquid phase injection improves engine performance and efficiency drastically over older vapour systems due to the better volumetric efficiency and charge density.

Project Objectives
This project aims to develop a better understanding of the use of liquefied petroleum gas for fuelling vehicles. Different types of autogas systems and their operation are described with their respective advantages and disadvantages. Solutions to lubrication issues due to the dry nature of the LPG fuel are discussed and the miscibility of different lubricating oils in liquid LPG investigated as a potential solution. A small centrifugal pump is to be designed and manufactured to flow the liquid phase LPG within a fuel system, to better understand how different system improvements affect the flow of LPG.

Project Methodologies
The project aimed to study and analyse the liquid phase LPG fuel injection systems and the challenges involved in their construction and operation.

- Literature review about the fuel properties and different types of autogas systems including the more advanced Liquid Phase LPG injection (LPLi) systeMs
- Testing the miscibility of different lubricating oils in the liquid phase LPG in a specially designed and built transparent container.
- Non-Linear Finite Element Analysis of pump lower casing.
- Design and Manufacture of the LPG flow pump
- Determining Pump Characteristics by flow testing and Computational Fluid Dynamics
- Flow testing the liquid phase LPG using the pump in a fuel supply system

Results and Achievements
Various different tests of the liquid LPG pumping system were attempted improving the setup each time. At first flow was not achieved due to a lack of proper net positive suction head (NPSH) at the pump inlet. It was important to reduce the frictional losses to the pump inlet. The tank height was raised to increase the NPSH of the liquid at the pump inlet. Using ice to sub-cool the LPG allowed the pump to achieve a consistent flowrate and proved that having a proper margin to vaporisation is very important in liquid systeMs

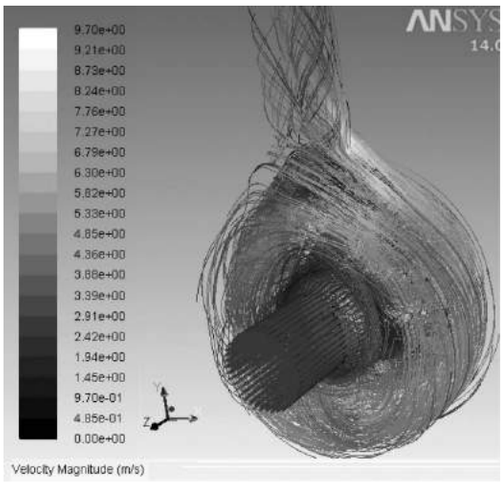

Figure 1 – CFD Analysis of Pump showing Fluid Flow lines

Figure 2 - Pump Connected Directly to Tank Outlet

A slow flowrate was achieved when the pump was connected directly to the tank outlet. In conclusion this study has revealed the importance of having a margin to vaporisation when pumping LPG fuel as a liquid and a positive NPSH must be achieved at a pump inlet to prevent cavitation.

FEA and Experimental Investigation of Resistance Spot Welding

Student: Yasmine Dalmas
Supervisor: Dr Ing. Pierluigi Mollicone
Industrial Partner: Methode Electronics Malta Ltd.

Introduction

Resistance spot welding has been widely used in the industry as an effective and efficient joining process for sheet metal. To achieve an optimum weld through the conventional methods of experimenting is neither economical nor efficient. With increasing awareness about quality, it is becoming more crucial to establish the reliability of a weld and to predict how it would behave under a typical service environment. Technological progresses and numerical methods have enabled such predictions to be achievable, and weld quality to be improved.

Project Objectives

The main objective is to achieve the optimum weld through non-conventional methods by using more effective means through a combination of experimental methods with numerical and statistical analysis. Finite Element Analysis (FEA) using ANSYS is used to observe which model best represents the spot welds.

Project Methodologies

The application of this weld is to join two metal components forming a cage that will be used in a power product at Methode Electronics Malta Ltd. The component is susceptible to suffer from shock loads that exceed a force of 1kN. The sheet metal used is a 3mm thick galvanized AISI 1050 steel. A three-dimensional model of the component is shown in Figure 3.1; the arrows specify where the welds should be allocated.

Manipulating various parameters in an attempt to find the ideal combination for the highest weld strength is best done through a Design of Experiments (DOE). DOE helps to take full advantage of the amount of information gathered from experimental studies whilst keeping the amount of data to be collected to a minimum.

The four setup parameters that are varied include the weld current, the electrode pressure, the weld time and the hold time. The electrode diameter is a controlled factor. In the case of a 3mm thick plate the corresponding weld nugget diameter should be around 8.66mm, with a corresponding electrode of diameter 9mm. [1]

With four critical variables identified for the welding process, the DOE should comprise of sixteen experimental trials. For more reliable results, each combination was repeated four times and therefore 64 specimens were to be fabricated in total. [2]

Results and Achievements

From the DOE the controlling factors which had an effect on the strength could be determined. It was concluded that the weld time and weld current are the two most influential factors, followed by the interactions between the two parameters and the interaction between the weld current and the electrode pressure.

Two spot weld models for the tensile-shear specimen were built using ANSYS, in order to observe which model best represents the welds. These two models are the elastic beam model and the umbrella model [3]. Stress plots suggest that stress concentration occur around the weld nugget, and thus the sheets are most likely to fail from the periphery of the weld.

References

[1] Zhang H. Senkara J., 'Resistance Welding: Fundamentals and Applications' Taylor & Francis, London, 2006.
[2] Jacqueline K. Telford. (2007), A Brief Introduction to Design of Experiments. Johns Hopkins APL Technical Digest. 27 (3), 224-232.
[3] C. M. Agius, "Fatigue Life Calculation for Spot Welded Structures", B.Eng. (Hons) dissertation, University of Malta, 2011

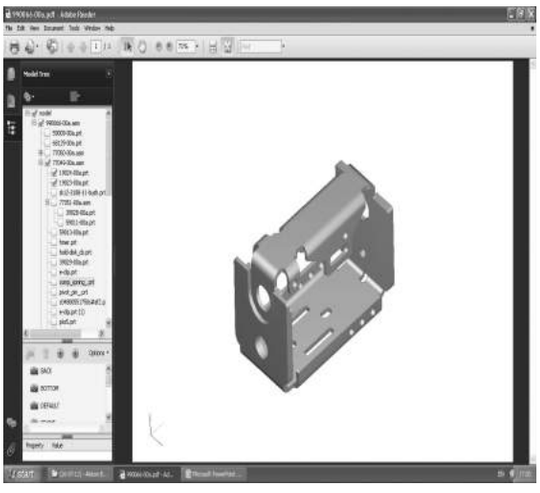

Figure 1: Three-dimensional model of assembled cage with designated location of spot welds

Experimental Measurements of Welding Induced Residual Stresses

Student: Ryan Debono
Supervisor: Dr Ing. Pierluigi Mollicone

Introduction
The process of welding induces thermal strains in the material, resulting in plastic deformation and therefore inducing residual stresses. These stresses can be measured using various stress measurement techniques. A good understanding of these stresses will positively aid to mitigate them.

Project Objectives
This project focuses on the introduction of thermal residual stresses throughout the process of resistance spot welding. The hole drilling method was used in laboratory experiments to determine the residual stresses present inside the material. The experiment consisted of two 2 mm thick mild steel plates joined together by one spot weld. The residual stresses of one plate were then measured at specific distances from the spot weld. Residual stresses were also measured prior to the spot weld. The objectives of this project are to:

- Familiarise with the Vishay RS-200 hole drilling equipment
- Determine the residual stresses prior and after spot welding, using the hole drilling method
- Analyse the sources of errors induced during the hole drilling procedure
- Determine the temperature distribution near the spot weld using thermocouples
- View the cross section of the spot weld nugget

Project Methodologies
The hole drilling method determines residual stresses by attaching a strain rosette to the component's surface and drilling a hole into the component through the centre of the rosette. The introduction of this hole causes the residual stresses in its vicinity to relax and therefore resulting in strain relief, which is measured by the strain rosette. The residual stresses are then determined from the strain measurements obtained using a set of equations. [1] The apparatus used for the hole drilling procedure was the Vishay RS-200 Milling Guide (see Figure 1). The function of the milling guide is to rigidly house the air turbine, (which drills the hole into the component). The base of the milling guide is securely bonded to the surface in order to restrict lateral movement. The milling guide can also ensure accurate alignment whilst drilling the hole through the centre of the rosette using a special microscope. This microscope can be housed in the milling guide instead of the air turbine. A total of nine holes were drilled, three prior to spot welding and nine after. This procedure was replicated on a second spot weld.

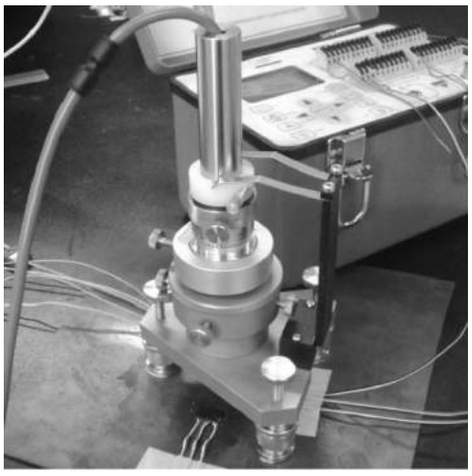

Figure 1 - The Vishay RS-200 Milling Guide

Results and Achievements
The residual stress results obtained from the hole drilling procedure were as expected, where high residual stresses were localised around the vicinity of the spot weld. The tangential stress determined showed high tensile stresses near the spot weld, which sharply decreased to compressive stresses and then moderately increased towards the vicinity of zero, away from the weld. The radial stresses also showed a trend which was expected, i.e. high tensile stresses near the spot weld, which decreased, almost exponentially, to zero.

References
ASTM International, Standard Test Method for Determinig Residual Stresses by the Hole-Drilling Strain-Gage Method, E837-08, 2009.

Characterisation of Bone Tissue

Student: Dylan Deguara
Supervisor: Dr Zdenka Sant
Co-supervisor: Dr Joseph Buhagiar

Introduction

Simulation of a biomechanical response via Finite Element Analysis (FEA) requires the knowledge of anatomy, physiology and mechanical properties of all important biological components involved. Thus, simulation of any problem related to orthopaedics calls for the definition of material properties, mainly Young's modulus and Poisson's ratio. In order to define these material properties, the proper knowledge of the bone hierarchal structure and its composition is needed. Thus the appropriate method of bone characterization can be adopted. Furthermore the correct strategy of harvesting of the bone specimens and their storage depends on the selected method of characterization and the way the material properties of the bone are preserved. The suitable method of bone characterization is always selected according to the aim and the knowledge of pros and cons of each available method.

Project Objectives

Provide an overview of types bone tissues and testing methods stating their advantages and disadvantages.
Create a methodology for preparation of a specimen and testing of bone tissue.
Provide a characterization of swine bone tissue using available testing equipment.
FEA analysis of the collagen – matrix structure of the lamella, the Haversian system (osteon), and of the diaphysis of the bone under the compression.

Project Methodologies

Femur of the back leg of the swine was used to harvest twelve specimens and prepare them for nanoindentation test while diaphysis was prepared for the compression test. All specimens were frozen and stored the appropriate way, to preserve its mechanical properties. The nanoindentation test of a wet bone required setup of a liquid cell, as seen in figure 1, prior to the test that was carried out in order to find the Young's modulus and the hardness of the bone. The compression test was carried out with the use of strain gages, as seen in figure 2, to obtain the Poisson's ratio of the bone.

Results and Achievements

The transverse and longitudinal micro strains were obtained from the compression test. From the measured data, a value of 0.30262 for the Poisson's ratio was calculated. The Young's modulus was computed by means of the Oliver Pharr method from the nanoindentation results. [1] The Hardness was directly measured by the machine.

Test Number	Specimen	Mean Young's Modulus (GPa)	Mean Hardness (GPa)
1	Top First Specimen	16.7	0.59
2	Middle First Specimen	21.1	0.98
3	Bottom First Specimen	63.2	3.05
4	Top Second Specimen	7.05	0.34
5	Middle Second Specimen	159.56	9.99
6	Bottom Second Specimen	3.66	0.18

Table 1: Nanoindentation Results

References

[1] Oliver W.C., Pharr G. M., 'An improved technique for determining hardness and elastic modulus using load and displacement sensing indentation experiments', 1992, Vol. 7, No. 6, pp.[1564-1583]

Figure 1: Nanoindentation of bone in liquid cell setup

Figure 2: Compression testing of diaphysis of bone

Performance Analysis of Wind Anemometers of Floating Structures

Student: Claire Ellul
Supervisor: Dr Ing. Tonio Sant
Co-supervisor: Ing. Robert N. Farrugia

Introduction

During the last years, the wind energy industry has shifted its interest to offshore wind energy due to the lack of available land onshore. Due to the extremely high costs incurred, research is being focused on the development of floating offshore wind farMs This allows the exploitation of greater water depth at a lower cost. Prior to the development of a wind farm, site assessment has to be carried out to study the wind resource available in the area. This is performed by erecting meteorological towers containing a number of anemometers and wind vanes. Research regarding the performance of different anemometers whilst floating is being made due to the significantly lower costs incurred if these anemometers could be mounted on a floating platform.

Project Objectives

The aim of the project was to analyse the performance of three cup anemometers and a hot wire anemometer (HWA) when subjected to different wind speeds and different floating conditions. Moreover, calibration of the three cup anemometers was to be carried out by following the standard procedure included in the IEC 61400-12-1.

Project Methodologies

In order to be able to analyse the performance of different anemometers, the following steps were followed:

Literature review in the field of cup anemometry and hot wire anemometry and their behaviour when subjected to turbulent flows

Design and manufacture of different mountings for the different anemometers which take into account the attachment to the Tension-Leg Platform (TLP)

Design of a number of experiments using a range of wind speeds and different wave conditions

Design of an experiment where the anemometers were kept fixed and exposed to varying wind conditions such as a ramp or a step input in wind speed to analyse their behaviour to different wind conditions

Results and Achievements

When quantifying the response of the different anemometers subjected to floating conditions, it was discovered that the HWA sensor exhibited the best response in terms of both phase shift as well as the detection of the peak-to-peak amplitude of the surge signal. However, the response of this anemometer degrades at higher wind speeds due to the increased levels of noise contaminating the signal.

With regards to the cup anemometers, it was found that the lower the surge frequency of the TLP the better is the response of the sensors. This phenomenon is experienced by all the three cup anemometers tested. Moreover, at high surge frequencies, it was noted that the response of the sensors improves at higher wind speeds.

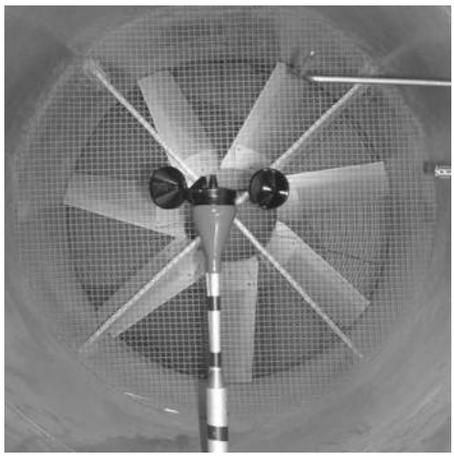

Figure 1: The C3C Cup Anemometer during the Calibration Procedure

Figure 2: The A100LK Cup Anemometer when subjected to Floating Conditions

Progressive Ply Failure Analysis of Fibre-Reinforced Composites

Student: Nicholas Farrugia
Supervisor: Dr Ing. Duncan Camilleri

Introduction
Composites have nowadays replaced more conventional materials. Complex analytical and numerical models are required to predict the structural response of composite materials due to their nonisotropic and inhomogeneous material properties. The progressive failure of a laminated composite material is a complex phenomenon. As one ply fails (first ply failure), stress is redistributed and further lamina failure is required to reach the ultimate laminate failure load of the composite structure. The finite modelling technique required to predict the ultimate failure load is referred to as progressive ply failure analysis (PPFA).

Project Objectives
The project objectives include:

- Literature review of current state of the art progressive failure analysis of composite structures
- Analysis of various failure criteria applicable to composite structures
- Develop an algorithm to predict the development of damage and progressive failure
- Testing of typical composites to validate numerical models

Project Methodologies
This study was divided into two sections. In the first part, tensile, compressive and shear tests were conducted on e-glass fibre polyester resin composite specimens to establish the respective moduli and strengths. The specimens and tests were constructed and performed according to ISO and EN standards.

An algorithm was developed and implemented into ANSYS using APDL script to simulate the structural response of a composite beam subjected to bending. The material properties obtained from the afore mentioned experiments were used to carry out these simulations. The results obtained from these numerical models were compared to the results obtained experimentally from three-point flexure tests carried out on the composite specimens.

Results and Achievements
Progressive ply failure analysis (PPFA) makes use of reduction factors to reduce the material properties of failed lamina. Various failure criteria can be used to determine whether a lamina fails or not. In this study, only the Tsai-Wu failure criterion was used. Furthermore, two different sets of reduction factors were investigated and it was concluded that the greater the number of reduction factors, the lower the predicted ultimate load of the composite and the less the deflection at ultimate laminate failure.

Furthermore, a 2D and a 3D model were used to carry out the numerical analysis. The 2D model resulted in a very conservative prediction of the ultimate load, as failure was more abrupt than in the 3D model case.

A comparison of the numerical models with the experimental results indicated that the material properties used in the numerical analysis were not accurate. Thus, the results obtained from the simulations carried out in ANSYS differed from the results obtained in the experiments. In all cases, however, all the graphs indicated minor ply failure as the load increased hence suggesting that the predominant failure mode was matrix failure.

Due to the complexity of the PPFA, several factors have to be taken into consideration to ensure accurate results, including the boundary conditions, the mesh size, the loads applied, the failure criteria used and the reduction factors applied.

Finite Element Analysis (FEA) on Novel Wind Turbine Structural Components

Student: Gary Galea
Supervisor: Dr Ing. Pierluigi Mollicone
Industrial Partners: Econetique Ltd, Alurwind Ltd

Introduction

This research sought to investigate the structural response of the self-adjusting torque vertical axis wind turbine (SATVAWT) components. Stress analysis was carried out using finite element (FE) software ANSYS on the blade and its supporting mechanism. This project is part of a larger project, SATVAWT, co-financed by the Malta Council for Science & Technology through the National Research & Innovation Programme 2011

Project Objectives

The main project objectives were:

- Literature review regarding VAWTs;
- Blade structural analysis;
- Blade support mechanism structural analysis;
- Analysis of different load cases for blade and its support mechanism;
- Possible recommendations for the blade and its support mechanism.

Project Methodologies

A CAD model of the blade and the support mechanism was generated in Autodesk Inventor. These models were then imported in ANSYS using import commands in Mechanical APDL and Workbench.

Figure 1: SATVAWT Geometry

Two models for the blade were developed. These models had the same blade geometry except the thickness, where Model A had shell thickness of 1.5 mm whilst Model B had shell thickness of 3 mm. Both models were subjected to the same loads and their relevant performance was analysed for five different load cases. The investigation of the stress development in the blade was of prime importance to determine its integrity under the different loading scenarios. The deflection of the blade was also vital because it determined the success of the SATVAWT concept.

The blade support mechanism was also split into two models. One model was made to represent the part of the mechanism which attaches with the blade and another model was made to represent the rest of the mechanism which attaches to the main turbine structure. The model which attaches with the blade had components made of different materials. These materials were: carbon fibre composite, aluminium and steel. Since Carbon Fibre is orthotropic, a more detailed analysis was performed to better understand the stress development and direction.

Results and Achievements

From the simulations, it was determined that under normal operation, the blade with 1.5 mm thickness deflected 40 mm more than the blade with 3 mm thickness. In all load cases, the 3 mm thick blade was noted to deflect less than the 1.5 mm and hence, that a 1.5 mm thick blade would be better suited for the turbine since it deflected more and its stresses were still within an acceptable range provided that the composite layout would be done properly.

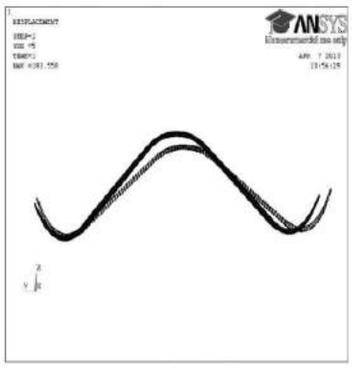

Figure 2: Blade deflection with 1.5 mm thickness (Normal Operation)

For the blade support mechanism, it was observed that a wind speed of 42.5 m/s would generate substantial stresses. Recommendations on improvements for the mechanism design were made based on the analyses results.

Performance Analysis of Floating Vertical Axis Wind Turbines (VAWTs) using the BEM Approach

Student: Matthew Galea
Supervisor: Dr Ing. Tonio Sant

Introduction
In the last few years, the wind energy industry shifted its interest to the development of offshore wind farms, which may provide significant benefits. In this field, VAWTs are being studied in more detail since they may offer several advantages with respect to the more established HAWTs. These include the capability to operate with winds from any direction, as well as offering increased stability due to the heavy equipment being mounted below the turbine.

Project Objectives
The aim of the project was to determine the possible effects that the surge motion of a Tension-Leg Platform could have on the power performance of a full-scale floating Straight-Bladed VAWT (SB-VAWT). For this purpose, different momentum based numerical models were developed using MATLAB® to simulate the turbine performance under both steady and unsteady conditions. The project also involved the design and construction of a SB-VAWT scale model which could be tested in the wind tunnel situated over the wave generator located in the Fluids Laboratory.

Project Methodologies
In order to predict the power performance of a floating SB-VAWT, the following steps were taken during the project:

- Literature review of the current BEM models used for VAWT predictions
- Development of different numerical models based on different BEM models
- Implementation of Dynamic Stall models to improve predictions
- Derivation and implementation of Dynamic Inflow models in order to account for the time lag response of the flow field around the turbine when exposed to varying wind conditions

The numerical models compute the surge motion by simulating a sinusoidal variation in wind speed. In this way the variation of loads and power with time are obtained.
A scale model of a SB-VAWT was constructed in order to validate the results obtained from the numerical models. The final assembled model together with some of its main components is shown in Figure 1. Due to unavailability of the testing facility the experiments with this model were not conducted but can be performed at a later stage.

Results and Achievements
The numerical models were verified and validated with results found in literature. The models were found to give realistic results, but the dynamic models, which predict the response of the turbine in the time domain need to be validated against experimental results or results obtained from more sophisticated models, such as CFD or Vortex Wake models.

From various simulations, it was observed that the surge motion of the TLP can have significant effects on the average performance of the turbine. Increasing the peak-to-peak surge velocity (by increasing surge amplitude or frequency) results in a larger difference in the average power performance of the turbine. For particular ranges of TSR, the power developed under floating conditions resulted to be even higher than that obtained when the turbine was operated with a fixed base.

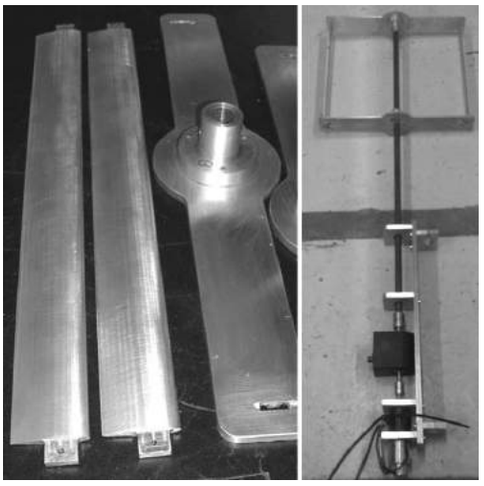

Figure 1: Turbine blades (left) and final assembled SB-VAWT physical model (right)

Sound Propagation Models for the Prediction of Environmental Noise Levels

Student: Raisa Galea
Supervisor: Dr Ing. Duncan Camilleri

Introduction
The main aim in sound propagation modeling is to predict how the sound from a source will travel and reach the receiver. Sound emitted from industrial zones or major roads is of annoyance to the neighbouring residents, especially if the sound level exceeds 70 dB[1] as stated by the WH, and if the noise persists during the night.

Project Objectives
This project had its main focus on the use of the ISO9613 standards, and in validating test results with the aid of this standard. This was done to check whether the theoretical predictions in these standards are closely related to actual values obtained from the tests. Thus, in this project outdoor sound propagation was investigated by the employment of three main methods: in field tests, MATLAB program, and Olive Tree Lab – Terrain Software.

Project Methodologies
Tests were performed using ISO9613 requirements and producing a sound field of a white and a pink noise. The sound pressure level of these noises was calculated by taking 5 readings at different angles at 1.5m away from the source. The values obtained were then used to calculate the sound power level of the source. The results from these tests were then validated by the use of ISO9613.

A user friendly input program was also created using MATLAB, incorporating the ISO9613-2 in order to calculate the sound received when inserting a number of sound barriers. 'Figure 1' shows the input window the user has on screen to input the information, as required. The user is to determine the source, receiver and barrier positions, as well as the temperature and relative humidity. These are important due to the atmospheric effects on sound.

The third method used was the Olive Tree Lab – Terrain software, an-already available software bought for this purpose.

Results and Achievements
From the results obtained in this study it can therefore be concluded that the theoretical methods gave different results from those obtained from in-field testing, in most cases with such differences being only minor. Despite these discrepancies in the results from the three methods, the ISO9613 is still useful to predict sound as it gives out higher values than in reality and so sound barriers can be effectively designed. Sound barriers have to surround the source and have the adequate surface density, the higher this density the less is the sound passing through them. Improvements may be done to the MATLAB program by calculating reflections separately instead of taking the fixed value.

References
[1] World Health Organisation, Fact Sheet No. 258, Revised February 2001

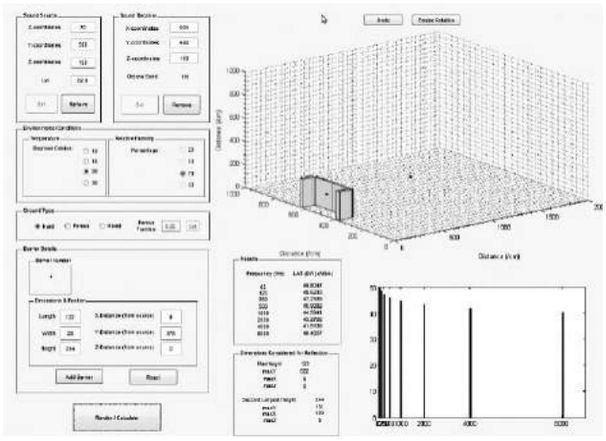

Figure 1 - MATLAB Sound propagation software GUI

Investigating the Performance Characteristics of a Hot-Film Probe

Student: Thelma Gauci Minuti
Supervisor: Dr Christopher Micallef

Introduction

Wind tunnels are essential tools in fluid mechanics since they are used for experimental verification of simulations and models. Flow parameters such as velocity uniformity, instantaneous local flow velocity and turbulence intensities can be studied by thermal anemometry. This makes use of instruments such as the hot-wire or the hot-film sensor. The hot-wire consists of a thin wire connected to small prongs, whereas the hot-film is made of a thin film deposited on an insulating cylinder. Due to convection, these sensors cool down and the signal acquired gives an indication of the velocity of the flow.

Project Objectives

- Carry out a literature review on thermal anemometry
- Design, construction and set-up of a test rig to accommodate the probes and permit traversing
- Measure the flow velocities and turbulence intensities in the Square Section Wind Tunnel (Figure 1) with the two sensors when a wire-mesh screen installed at the inlet.
- Repeat measurements after removing the screen and compare results.
- Traverse the probes along the width of the test section to investigate the velocity and turbulence intensities at different positions.

Figure 1: Wind tunnel and experimental setup

Project Methodologies

The requirements for the traverse system were determined and a test rig was designed and constructed accordingly. The traversing system had to move along the x-direction to cover the whole width of the tunnel's test section.

The hot-wire and hot-film sensors do not give the velocity directly, but they transmit a voltage signal which has to be converted to velocity. This is accomplished by deriving an equation, forming a relationship between the voltage signal acquired by the sensors and a reference velocity measured by a Pitot-static tube. This is called a calibration curve and it is used to convert the voltages to velocity values.

After calibration, the actual testing of the wind tunnel began. Readings were taken at different positions with a wire-mesh screen attached. Then another set of readings were taken at the same positions without the screen. The velocity and turbulence in the flow at the two experiments were calculated and compared.

In the next test, the sensors were moved to 11 different positions in the test section. The velocity Prof.ile and turbulence intensity were plotted on a graph.

Results and Achievements

The results of the first test showed that the wire-mesh screen has a significant effect on the flow in the wind tunnel. In fact, when the screen was not installed the turbulence intensity and velocity recorded were higher.

The results of the second test indicate that the flow in the test section is not equal at different positions. The velocity at one side of the test section is higher than that on the other side. The tests also showed that as expected, the turbulence intensity is higher near the walls.

Testing and Optimisation of GRP Pressure Vessels Subject to Internal Pressure

Student: Jana Grech
Supervisor: Dr Ing. Duncan Camilleri

Introduction

Laminated fibre reinforced composite materials are composed of a number of laminae strategically oriented to maximise the overall strength-to-weight ratio of the laminate. The orientation of each lamina is defined by the direction of its fibre reinforcement and is set to match a particular loading configuration in order to achieve the optimum mechanical performance. The predetermined lay-up sequence of glass reinforced polymer (GRP) pressure vessels is typically obtained through filament winding which makes use of computer controlled systems to wind fibres at a prescribed angle around a mandrel [1]. The ability to design a material customised towards satisfying particular load configurations with maximum strength capability and low weight makes composite pressure vessels (CPV's) an attractive alternative to their steel counterparts. Customisation of a composite material is achieved through use of analytical and numerical models which are subsequently validated by a repeated number of experiments.

Project Objectives

- To design and commission a testing bed that subjects GRP pressure vessels to an internal pressure whilst monitoring the change in volume and strain developed.
- To generate analytical and numerical models capable of predicting the design load of the tested CPV's.
- To validate the theoretical results by comparing them to those obtained experimentally.
- To use the theoretical models for optimising the CPV's such that they meet the design requirements with less material.

Project Methodologies

The first-ply failure strengths (FPFS's) of numerous CPV's were predicted via finite element models generated in ANSYS 14.0 and an analytical program developed in Excel. Failure of a single lamina was considered to constitute failure of the entire laminate such that the FPFS is equivalent to the design load of the composite material. [2]

Following a series of preliminary tests, the test set-up shown in Figure 1 was designed for static pressurisation of several specimens having free-end closures. Linear variable displacement transducers (LVDT's) and strain gauges were employed to obtain volume and strain measurements respectively at pressures recorded via a pressure sensor. Results were documented by means of a data acquisition system so that a safe distance could be maintained between the operator and specimen during testing.

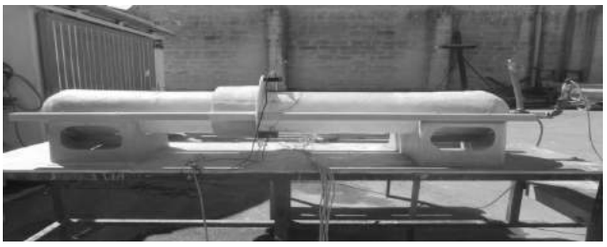

Figure 1 – Test set-up for a GRP test specimen with free-end closures.

Results and Achievements

For safety reasons, testing was conducted to a maximum pressure of roughly 3.5MPa. For rupture of the 1MPa CPV under study to occur and its FPFS to be recorded during testing its thickness and hence strength capability had to be substantially reduced. In this way the strength predictions of the theoretical methods could be compared to those obtained experimentally. The analytical method was proven inadequate for modelling the true anisotropic behaviour of the vessel giving rise to conservative results. The numerical and experimental results, however, exhibited considerable similarity such that FEA was then employed to optimise the original CPV.

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Design of an Assembly Workshop Crane

Student: Amy Grech
Supervisor: Dr Ing. Martin Muscat

Introduction
The scope of this dissertation is to design a crane which would be appropriate to install inside the assembly workshop, located within the Faculty of Engineering, at the University of Malta. The assembly workshop will be used to support the fabrication and assembly of student projects. Three cranes were designed as potential solutions. The Faculty of Engineering could then decide on the most adequate solution.

Project Objectives
A review of commercially available crane designs was done in order to choose three solutions. The dimensions of the cranes were obtained using the dimensions of the workshop and an engineering analysis, which was performed using analytical techniques and the Finite Element Analysis software, ANSYS 13.0. Detailed drawings and a Bill of Quantity for each crane design was done. The crane capacity is 1000kg.

Project Methodologies
The Free Standing Bridge Crane was the first chosen solution. Its components are labelled in Figure 1a. The crane was designed using I and H cross sections based on European standards [1]. For all crane designs, the load would be lifted and lowered using a manual chain hoist. The load would travel along the bridge using a hoist trolley. The bridge would travel on wheels on the runways. Manual crane operation was chosen for all designs since the crane would be used occasionally. Joint connections would be done using bolts. The deflection of the beams and columns were obtained. They had to abide with deflection criteria according to standard [2] in order to obtain the dimensions of the cross sections of the crane members. This method was used for all crane designs. The effect of temperature and semi-rigidity of joints between the column and runways were considered in the analysis. Influence line analysis and buckling analysis on columns were performed.

The second chosen design was the Mobile Gantry Crane (Figure 1b). The cross sections of the crane members are I-sections. The crane would travel on four wheels to enable maneuvrability. The Free Standing Jib Crane was the chosen third option (Figure 1c). A hollow circular cross section was chosen for the column and an I-section for the arm, which rotates about a pivot. The column is connected to the foundation. The dimensions of this crane were established. Mechanical joints were considered for the analysis.

Results and Achievements
The dimensions of the crane designs were obtained. The crane operation and joint design were considered. Detailed drawings and a Bill of Quantity were done. The recommended crane design within the assembly workshop is the Mobile Gantry Crane. It is a versatile solution, due to its mobility and has null contact with the building. It is also the cheapest solution.

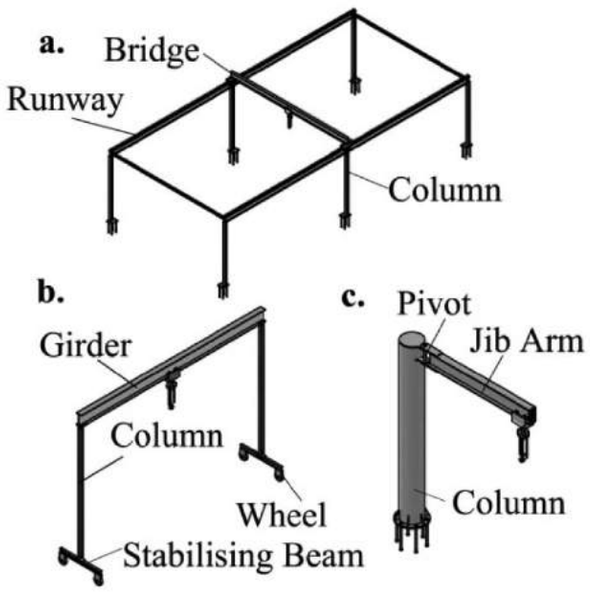

Figure 1: a. Free Standing Bridge Crane;
b. Mobile Gantry Crane;
c. Free Standing Jib Crane

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Analysis of Ship Structures

Student: Michael Grixti
Supervisor: Dr Ing. Claire De Marco

Introduction
In the last two decades, maritime developments have occurred at a very fast rate. Significant changes in size and types of ships have led to different ways in which design and analyses of ship structures are carried out. A ship constructor aims to produce a structure that is capable of withstanding the sea loads experienced during the ship's life time at sea. The ship structure chosen for analysis was that of a bulk carrier consisting of a complex structure made up of several structural members which are responsible for withstanding the stresses generated on the ship.

Project Objectives
The main objectives of this project can be summarised as follows:

- To research on the various types of ships used for cargo transportation and their respective structures. Also, research is carried out on how ship structures are analysed.
- To virtually design a bulk carrier midship section based on an already verified design.
- To test the model drawn and to verify that the results obtained all fall within the requirements of the ship classification societies.
- To propose some variations to the original design and retest the model checking that the results fall within the requirements.
- To suggest any improvements one could have done in the analysis approach and also in the modifications carried out on the bulk carrier design.

Project Methodologies
Structural analysis can be defined as the study of the effect the loads make on the structure under investigation. The results of this analysis are generally given in the form of deformation and stresses which are then compared to the criteria established by the standards.

In this thesis, the ship structure under investigation is the midship section of a Capesize bulk carrier and two main approaches were chosen for its analysis.

The first step was to analyse the structure using the mechanics of materials approach where the section modulus together with the moment of inertia were determined. This was done for the original design and also for the modified proposed designs.

The ship structure was also analysed further using the finite element approach which is very reliable although somewhat restrictive, (fig 1). This gave out results in the form of stresses and displacement values which were then compared to the IACS ship structural rules. Success conditions were determined by results that compared well to these criteria.

Results and Achievements
The main objective of this dissertation can be said to have been fulfilled i.e. to analyse and verify an established design of a bulk carrier. The results obtained where verified with the IACS standards and also with values given by the software Mars 2000. As regards the objective of analysing the effect of different spacing of the stiffeners on the bottom structure, the first proposal design gave quite encouraging results making it an ideal candidate.

One must also mention that in this dissertation, the stresses only were analysed on Ansys Workbench software. Studies regarding buckling and torsion would have further collaborated in the strength check of the structure.

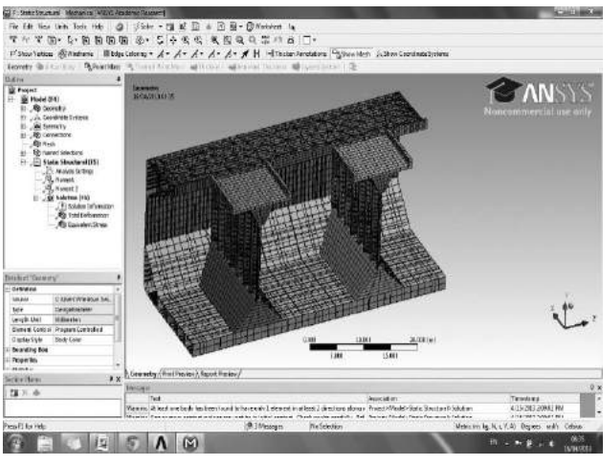

Figure 1: Figure showing the bulk carrier model in Ansys Workbench with the meshing.

Optimisation of Thermal Cages Heat Transfer Performance

Student: Daniela Marie Micallef
Supervisor: Dr Ing. Duncan Camilleri
Industrial Partner: Methode Electronics Malta Ltd.

Introduction

The products that are considered in this thesis are a current project within Methode Electronics Malta Ltd. More specifically these are referred to as dataMateTM products. The SFP Four-Port Cages is the product analysed in this study [Figure 1]. The cage is a one-piece structure, made of a stamped and formed metal to offer the best performance for EMI shielding, and can be used in either copper or optical applications. It is a multi-port SFP cage which can be used for designs that require high density.[1] The operating conditions of such systems are of 3W of power per port, ambient temperature of 55oC and airflow of 500 linear feet per minute. The current product comprises of pluggable transceivers, loopback testers, smart DAC cables as well as the cages mentioned in this study.

Project Objectives

The study was carried out in order to investigate different ways of how to improve the heat transfer performance of an SFP (Small Form-Factor Pluggable) assembly., which forms part of the data connection system .The five optimisation methods that were considered included the material, geometry, the surface finish, the interface as well as the joining method.

The main scope of this study is to reduce the 'hot' surface temperature of the SFP assembly down to 65oC. This is to be achieved by means of numerical simulations, prototype manufacturing and also lab verification.

Project Methodologies

This study mainly focuses on the different heat sink designs, materials and joining mechanisms that can be applied in such operating conditions. Theoretical background with regards to the heat transfer in heat sink models was also discussed and the necessary calculations with regards to the convection co-efficient of the fins, heat generation and thermal heat flux were developed. Analysis of different heat sink designs and materials was conducted in three different ways; theoretically by making use of the appropriate equations, experimentally by making use of a thermal imaging camera and by Finite Element Analysis using the ANSYS Mechanical Software.

Results and Achievements

The obtained results from the theory and ANSYS Mechanical were verified by means of experimentation, and a co-relation in the obtained results was observed in the three different cases. Various heat sink designs and materials were then modelled on ANSYS Mechanical. The respective temperatures on the assembly as well as the heat flux were compared to each other, with the ultimate goal of finding the optimum heat sink design for such an application.

The best resulting design comprised of a folded heat sink geometry having a copper base in contact with the cage. The best material for the heat sink identified is referred to as CarbAlTM . Attaching a thermal pad made of a graphitic material in the interface between the cage and the heat sink was found to enhance the heat transfer rate of the interface.

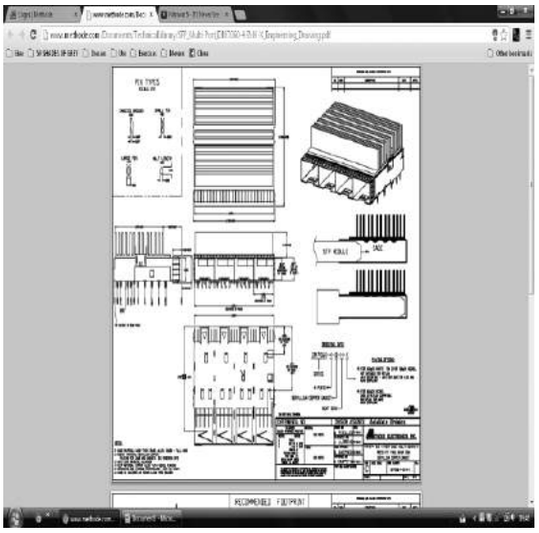

Figure 1 - Representation of the Small- Form-Factor-Pluggable inserted in the cage[1]

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Measurement and Analysis of the Hydrodynamic Forces on Model Offshore Support Structures for Deep Offshore Wind Turbines

Student: Marisa Micallef
Supervisor: Dr Ing. Tonio Sant

Introduction
Wind as a source of energy technology has been one of the major developments in the twentieth century as it has been one of the favoured alternatives to the burning of fossil fuels. Offshore wind energy is favoured to onshore as the sea surface is smoother and, hence has less surface roughness, resulting in lower turbulence and a smaller wind shear and promoting longer turbine life. Wind speeds offshore are well known to be considerably larger than onshore. Fixed wind turbines have been installed up to water depths of 45m supported on bottom mounted structures such as, jackets and tripiles.

Project Objectives
The main objectives of this project were to measure horizontal hydrodynamic forces on model offshore wind turbine support structure. To find forces from experimental, analytical procedures and, software simulation using ANSYS AQWA®. To construct a model consisting of four monopoles oriented in a squarish manner. The idea was based on the concept of the tripile structure patented by BARD engineering. This model had the capability to mount the monopoles at different distances from each other in order to study the possibility of any shielding effects.

Project Methodologies
First a literature review in the field of hydrodynamics was carried out. A four monopole model support structure shown on Figure 1 was designed. Design conditions were based on the validation of slender members and a Keulegan Carpenter number greater than 6 in order to make correct use of the Morison equation. Experiments on a single monopole and the four monopole model were carried out using the wave generator and producing Stokes second order deep water waves. Horizontal hydrodynamic forces were measured using a purposely designed jig. For the analytical results, the Morison equation was implemented. The hydrodynamic coefficients were obtained as described by the DNV (2011) standard. A shielding factor was also included with the calculations as suggested by the API (2005) standard. ANSYS AQWA® was used to provide simulations for the horizontal hydrodynamic forces.

Results and Achievements
Results from the analytical approach and ANSYS AQWA® software matched well. However, due to restrictions imposed by the wave generator a KC number greater than 6 could not be reached. Yet, results from the monopole testing converged with analytical and AQWA® results on increasing the KC number, hence validating that the Morison equation predicts better results for KC numbers beyond 6. The wave generator also restricted the amount of shielding that could be reached between the monopoles and, no shielding regime as described by the API (2005) standard could be met. For the four monopole model, results from theory and AQWA® to experimental ones had a greater discrepancy than the monopole case. It was observed that when the monopoles were oriented at larger distances from each other, the discrepancy between theoretical and experimental results increased. Such, condition might have been the cause of reflections from the wave tank itself.

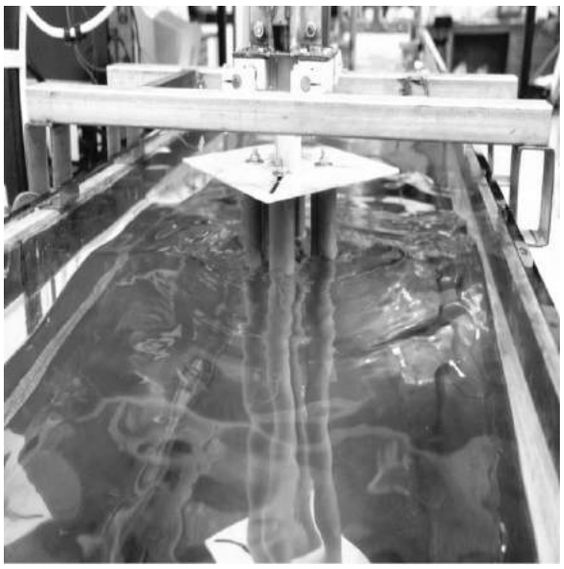

Figure 1. Testing of the deep offshore wind turbine support structure model in the wave tank generator.

The Effects of Cleaning Processes on Reverse Osmosis Membrane Performance

Student: Luke Pace
Supervisor: Prof. Ing. Robert Ghirlando
Co-supervisor: Prof. Maurice Grech

Introduction

This dissertation will focus on the effects that chemical cleaning of fouled membranes has on the performance of a seawater reverse osmosis (SWRO) system. Membrane module cleaning is already performed by the Water Services Corporation (WSC), in all its RO plants. This project will study its effectiveness and attempt to improve it without increasing costs or damage to the membranes and plant components.

Project Objectives

The main objectives of this project are to:

- Modify and repair the existing SWRO Testing Rig in the Department so that it could accommodate the various cleaning solutions and methods to be tested;
- Test the membrane under different cleaning solutions, temperatures, and concentrations, and review and compare the results obtained;
- Compare the performance metrics of a clean membrane, a membrane which has been used, and a membrane which has been used and then cleaned by different processes.

Project Methodologies

Testing was performed on a new reverse osmosis membrane, a fouled membrane, and a fouled membrane which had been cleaned. This was done to compare the performance characteristics between the different membrane samples in order to be able to identify the improvements which can be obtained from membrane cleaning.

- The tests performed were as such:
- Seawater testing on the new and fouled membranes
- Mechanical cleaning of the fouled membranes followed by seawater testing
- Chemical cleaning of the fouled membranes followed by seawater testing

Results and Achievements

When comparing the water flux, J1, of the membrane samples during the sweater test, it is very evident that there is a large difference between a new RO membrane and one which has been thoroughly used. Figure 1 below displays the differences in water flux between the three tests according to the cell sample, in which Test 1 shows the results from the new membrane, Test 2 the results from the Lapsi membrane, and Test 3 the results from the Pembroke membrane.

On the other hand, when mechanical cleaning of the fouled membranes was employed, a significant increase in water passage was observed, whereby an improvement in water flux of 48.78% was obtained from the Lapsi membrane, while an increase of on average 182.95% was obtained from the Pembroke membrane after cleaning.
The chemical cleaning test was, as expected, not as effective as the mechanical cleaning. An improvement of on average 23.90% was seen from the Lapsi membrane, while an increase of on average 65.89% was obtained in water passage through the membrane from the Pembroke sample.

When the used (fouled) membrane samples were viewed under a Scanning Electron Microscope at a magnification of 2000X, micro cracks were made visible, along with patched of agglomerated fouling. Upon further investigation, it was discovered that this fouling mainly consisted of metal oxides, and thus further testing would concentrate on cleaning by acids.

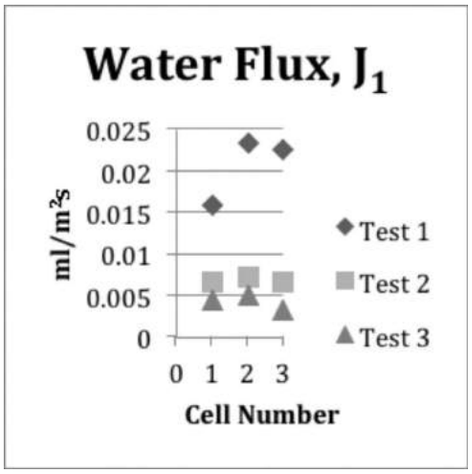

Figure 1: Water Flux variation between the New and Fouled Membranes

Investigating free surface modelling capabilities in Fluent

Student: Ronato Said
Supervisor: Dr Ing. Christopher Micallef

Introduction
During the last few decades, interest in CFD has rapidly grown in many industries and sectors of engineering. This dissertation focuses on ship hydrodynamics and its relation to CFD. An investigation will be held on the drag force acting on a hull. The DTMB 5415 naval combatant was selected together with relevant data that will be used to validate the simulation results.

Project Objectives
The main objective of this dissertation is to investigate the free surface modelling capabilities using Fluent. This objective will be accomplished by modelling the hull of the DTMB 5415 combatant. To do so it is required to prepare the geometrical model, generate an adequate mesh, set up an appropriate procedure and implement it in Fluent. Before executing the main objective, the concept of CFD must be understood and defined. Several investigations of similar hulls expounded in related literature have to be examined, aided with the establishment of a platform of basic knowledge on the subject.

Project Methodologies
Once the geometrical model was downloaded from the SIMMAN workshop, Solidworks and ANSYS design modeller were used to modify and clean the hull to ease mesh generation. In ANSYS mesher, several meshing attempts were carried out to obtain a grid that features good quality aspects. The Cartesian cutcell method and the hybrid method were both tested and experimented with. Ultimately, a hybrid mesh resulted to be the best method since the skewness and orthogonal quality were within a good range. The mesh was exported to Fluent where the volume of fluid method was implemented and a total of twelve simulations were performed. Each simulation represented the hull moving at a different velocity. The parameters input in Fluent were all based on the studies of previous investigations which used Fluent together with the volume of fluid method to model multiphase flows.

Results and Achievements
The simulations were tested with both transient and steady state approaches. Even though no changes were expected with time, the simulations which achieved the best results were solved using a transient approach. The simulation results were validated with experimental results and verified using a grid independence check. The simulations were stopped when the convergence criteria was reached. The first five simulations representing the hull moving at slow velocities failed to produce a proper free surface as initially expected and all had an error greater than 40%. The remaining simulations generated adequate results having an average error of approximately 20% from the corresponding experimental values. Waves protruding from the hull are seen on the free surface generated by these simulations.

Figure 1: DTMB 5415 Hull

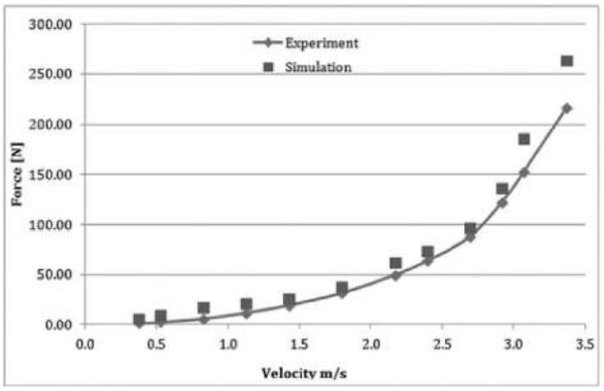

Figure 2: Simulation vs. Experiment

The Effect of Water Filtration on Pump Performance in a Swimming Pool Cleaner

Student: Jonathan Saliba
Supervisor: Dr Ing.Tonio Sant
Co-supervisor: Prof. Luciano Mule' Stagno

Introduction
Current embodiments of Swimming pool cleaners either require a high amount of power input equal to that of the pool pump itself or very costly because they utilise highly specialised automatic control systems and materials.

Project Objectives
The aim of this project is to test an alternative working principle for the cleaning of swimming pools that involves pumping and filtration. The effect of the filtration energy requirements on the pumping system are analysed through experimentation.

Project Methodologies
After a patent search for current embodiments of swimming pool cleaners it was concluded that among the different types of pool cleaners, robotic swimming pool cleaners have the lowest power consumption at around 100W at a particle retention size of 2 micrometres.

The task of the swimming pool cleaner was defined into sub-functions: to move along the surfaces of the swimming pool and collect the debris which is passes over. Physical principles that could that may fulfil these sub-functions were listed in a morphological chart. The most promising combinations of working principles were chosen and the final configuration that possessed the characteristics that showed potential of lowering the power consumption was adopted.

This configuration consists of a stacked filtration system where a coarse filter medium precedes a finer filter that captures the particles which are down to a few micrometres in size. The two media are held in place in canisters which direct the flow of water into and away from them. The pressure for filtration is provided by a 12V bilge pump. Tests were done to find whether a single or two pumps in series to each other should be used to create the required pressure at the lowest power consumption possible.

A prototype was constructed for testing this principle. The coarse filter medium used was fashioned from PPNW cloth material. The coarse filter canister is made from a 10-litre plastic container that includes a lid. The fine filter medium used was a 24 cm diameter general grade filter paper. The canister for the fine filter medium is made from glass-fibre reinforced polymer that was formed on two plastic funnels of 22cm diameter.

The bilge pumps of single and double configuration were tested by varying the pressure at their discharge and measuring the flow rate. The pressure drop across the coarse and fine filters was measured for increasing flow rate of water. Debris in the form of granulated limestone was loaded onto the coarse filter. The resulting data was used to create the system curves and pumping curves (quadratic equations that plot head against flow rate).

Results and Achievements
By finding the intersections of the system curves and the pumping curves, the optimal impeller speed was chosen to be 6V for the configuration of two pumps in series. This setting has the closest intersection of the system and pump curve to the point of best overall efficiency for the two pumps in series which operates at 22W. The effect of the increase in debris mass in the coarse filter canister causes little variation of the overall efficiency of the pump with data suggesting that it increases from 10.3 to 11.1%.

Finite Element Modelling of Spot Welded Components

Student: Delia Sciberras
Supervisor: Dr Ing. Martin Muscat

Introduction
Resistance spot welding is widely used in mass production industries to join components made out of cold formed sheet metal parts. Proper modelling is required for the purpose of structural optimisation and to be able to produce accurate stress and strain fields around the spot weld.

Project Objectives
The aim of the project is to use the finite element analysis approach for the design and analyses of spot welded specimens which will be validated by experiments.

Project Methodologies
Literature review of design for spot welded structures was conducted which included assessment under static and fatigue loading. Besides, review of commercially available software to analyse spot welded structures was also done. The stress analysis approach was used for three different spot welded specimens mainly for Tensile-Shear, Double Hat-Section Prof.ile and I-Section Prof.ile specimens. The simple finite element models considered in this dissertation are the single elastic beam model, the rigid beam model, the umbrella model and the nine point contact model. Figure 1 depicts the finite element spot weld models used in this project. Experiments were conducted for all specimens and obtained results were compared to the results yielded from the finite element analysis approach. Another section in the dissertation outlines a method on how to perform fatigue testing on spot welded joints in accordance with MSA EN ISO 14324:2003.

Results and Achievements
For the Tensile Shear specimen, the results obtained from the finite element model were compared to those obtained from experiments. The strains encountered away from the spot weld had the same magnitude for all spot weld models. However, as the spot weld was approached, the strain values obtained from the single beam models yielded a higher negative magnitude when compared to the remaining spot weld models. Experimental results were also superimposed and although the same trend as the FE models was noted, discrepancies in strain magnitude were still apparent. These were attributed to the fact that the strain gauge closest to the spot weld was detached due to the warping of the specimen. The Double Hat specimen was investigated for simple bending. The highest stress encountered was in the direction along the length of the beam as expected. However, a stress of a smaller magnitude was also encountered in the x-direction, which was attributed to the Poisson's effect. I-Section beam Prof.ile specimens were also fabricated and tested under lateral loading. During this study, it was confirmed that the shear formula produces inaccurate results for thin walled structures. Theory suggests that along the inner flange of the I-Prof.ile Specimen, the shear stress encountered should be equal to zero since they are free boundaries. All finite element models yielded a zero stress, but the shear formula yielded non-zero stresses, confirming its limitations. In this dissertation it was concluded that the elastic beam model should be preferred as it gives a better representation of physical spot welds.

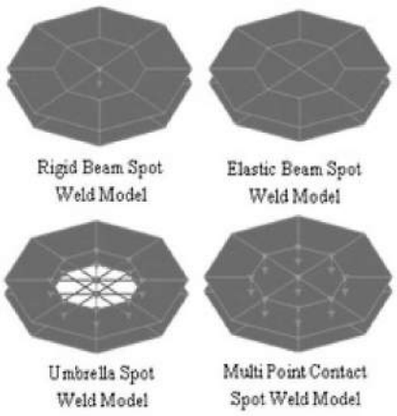

Figure 1: Finite Element Spot Weld Models

Experimental Testing of Fusion Welded Structures Subject to Thermal Tensioning

Student: Omar Shamala
Supervisor: Dr Ing. Duncan Camilleri

Introduction

Aluminium and its Alloy's use has increased over time, and now applications can be found in shipbuilding as well. This material is quite strong, thus thin plates are used in industry.[1] The problem arises when such materials are welded. They are so thin that they deflect after welding, and this is a problem. [2]

Of the several methods that exist to reduce this deflection, one of them involves heating of the plates with butane gas flames (Figure 1) while welding. This process reduces deflections and keeps plates as flat as possible. This process is called "Transient Thermal Tensioning" (TTT).

Figure 1 - Butane Gas Flame

Tests that were performed in the past show that TTT works and deflections do reduce considerably. [3] All the configurations used show that when the external heating is applied behind the welding gun, TTT is successful. Thus, this project will attempt TTT with butane flames following the MIG welding gun.

If this research is successful, this technology can be used in shipbuilding and it will become much easier to weld thin plates together without having severe deflections.

Project Objectives

- Update the Welding Rig at the University of Malta to be able to deliver Thermal Tensioning, read temperatures from the plate and read the plate deflection
- Test Transient Thermal Tensioning(TTT) on Aluminium Alloy Plates that are used in Shipbuilding
- Find the best way to deliver Thermal Tensioning

Project Methodologies

- Built heating nozzle holder
- Install Thermocouples to read temperatures from the plate
- Install Channels to safely transfer wires
- Draw up a procedure to perform the welding and TTT
- Test several configurations of heating while welding, like position of flames and maximum temperature to heat the plate
- Come up with the best way to apply TTT to reduce deflections (Figure 2)

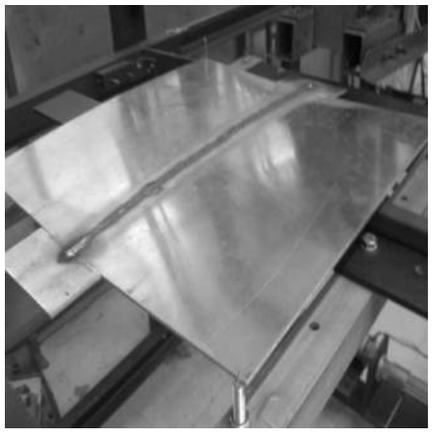

Figure 2 - Welded Plate with visible deflection

Results and Achievements

So far the results showed that deflections were not reduced with a peak temperature of 200oC and heating at the side of the plate, 4cm behind the welding gun. Several more configurations will be attempted and soon the results will be positive.

Most probably, the best procedure will be the one that has a lower peak temperature, that is, 150oC, and the welding gun should be at about 8cm behind the welding gun. Other configurations will be tested afterwards and the ideal heating process will be determined.

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Contact Analysis using the Finite Element Method

Student: Rudie Vella
Supervisor: Dr Ing. Pierluigi Mollicone

Introduction
Surface roughness is almost inevitable for many engineering surfaces. The effect of surface roughness on the behaviour of contacting solids is usually detrimental as it may promote increased local stress levels.

Project Objectives
The aim of this project is to review analytical, finite element and experimental methods used to model contact between rough surfaces, and adopt and implement such methods to a universal contact problem of two cube specimens having the same geometric dimensions, same material properties and roughness at the top faces under the action of a compressive force.

Project Methodologies
Four sets of specimens with different levels of surface roughness were fabricated by means of grounding and sand blasting processes.

The analytical Greenwood and Williamson model [1] was applied to the current contact problem by reducing it into an equivalent deformable rough surface and a smooth-rigid surface. The summit height of the surfaces' asperities were modelled by a Gaussian distribution. The contact area and total contact pressure were calculated by determining the probability that an asperity makes contact and substituting it into the equations of Hertz contact problem.

The reduced equivalent contact problem was modelled in the finite element analysis software ANSYS. The rough surface was created by generating equally spaced keypoints at a height above a reference plane following a Gaussian distribution.

The experimental investigation, whose setup is shown in Figure 1, involved applying a compressive load to a set of rough specimens and measuring the contact area by using Fuji Prescale HS pressure-sensitive film, which produces a stained image when under pressure to show the pressure distribution at the contact interface.

Results and Achievements
The percentage real contact area increases with increasing level of applied load and decreases with increasing level of surface roughness. For a resulting large percentage real contact area, the nominal area is approached asymptotically with increasing level of applied load. On the other hand, it was found that for a small percentage real contact area, the contact area increases linearly with increasing applied load, as shown in Figure 2.

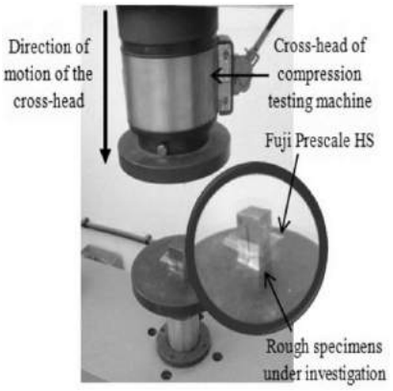

Figure 1: Setup of experimental investigation.

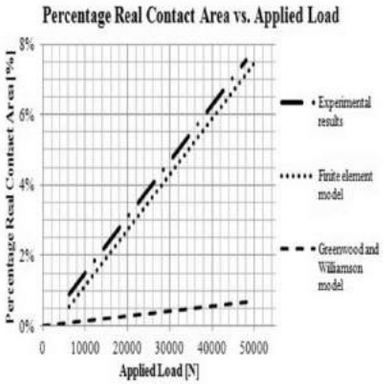

Figure 2: Results for a rough specimen.

The contacting surfaces were found to undergo plastic deformation. As a result, the analytical model yielded an underestimated real contact area and an overestimated average contact pressure since it does not take into account the transition from elastic to plastic asperity deformation.
The finite element model was found to be very accurate when compared to the experimental results.

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Influence of Bone Material Model on Spine Behaviour

Student: Alain Vella
Supervisor: Dr Ing. Zdenka Sant

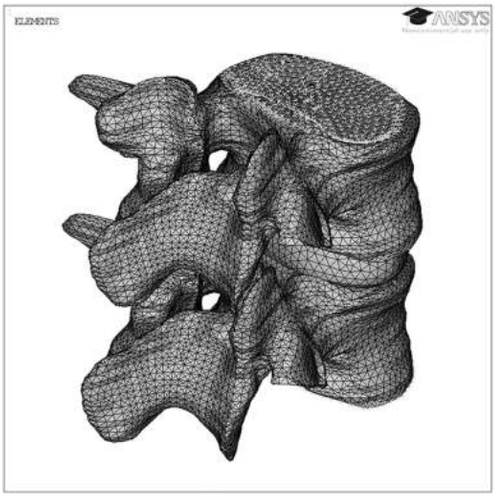
Introduction
Spinal finite element models are helping to overcome the limitations of current medical practice by predicting the effects of osteoporosis, intervertebral disc degeneration, and orthopaedic implants [1]. The accuracy of such predictions could however be increased if models were to incorporate the microstructural complexity of native bone tissue (Figure 1) [2].

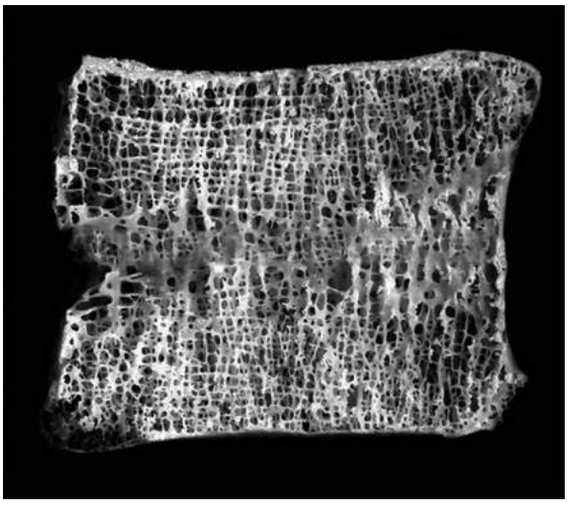
Project Objectives
Generation of spinal segment finite element models incorporating varying degrees of bone material complexity
Comparison of results from each model and the determination of the effect of bone material properties on spinal behaviour

- Compilation of guidelines to aid the creation of standardised models
- Proposals to better integrate spinal finite element modelling into clinical workflows

Project Methodologies
The strategy used for the project is centred around the integration of microstructural bone material properties into a finite element model of a spinal segment (Figure 2). In partnership with Vienna University of Technology, the patient-specific bone properties were derived from spinal CT images. This data was extracted through a relationship linking the specific intensity of each pixel on the CT images to distinct microstructural bone material properties. The latter were subsequently mapped onto the finite element model on an element-by-element basis according to the corresponding pixel on the CT images. This enabled the definition of a heterogeneous material property distribution within the model. The elements in the model were also given specific orientations to reproduce the anisotropy of natural bone imparted by its particular architecture (Figure 1). Such a strategy made it possible to portray bone much more accurately than other conventional spinal finite element models using homogeneous isotropic bone properties. Once the spinal model simulated physiological loading, the results were compared to those of a conventional model and the effect of using a more accurate bone material representation was determined.

Results and Achievements
The results confirm that using image-based bone properties in models increases their prediction accuracy. This is key in improving analyses of healthy and pathologic spines as well as of orthopaedic implants. A set of guidelines has also been compiled to aid future generation of standardised image-based spine models. These are ultimately aimed at improving the integration of the finite element modelling process into clinical workflows to better use its powers for patient care.





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Design, Fabrication and Testing of a Small Hoist and Frame

Student: Christina Vella
Supervisor: Dr Ing. Martin Muscat

Introduction

Recently, living in apartments is becoming more popular in Malta. Some apartment buildings are not equipped with a passenger lift. Hence, gas cylinders which are commonly used for heating and also for cooking, need to be carried up stairs by the owner or by the deliveryman of the gas company. Another fact is that space is also restricted in many homes and most of them do not have a garden or terrace. This leads to the fact that people use their roof for outdoor events especially during summer. In this case, many people decorate their roofs by creating roof gardens which require re-potting of plants. This means that buckets of soil or compost mixtures will be required to be lifted up to the roof.

Project Objectives

- To design, fabricate and test a small hoist and frame which is intended to be used as a lifting equipment to facilitate the task of moving up a domestic gas cylinder when it is full of gas and 10 litre buckets of soil onto the roof.
- The hoist and frame must be designed in a way that it can be easily assembled and dismantled by a single person.
- The equipment must be designed to be lightweight, compact and simple to be stored easily when it is not being used.
- To design a free standing system.
- To design a hoist and frame according to the existing standards which are related to the requirements of the machinery directive.

Project Methodologies

- An intensive research was carried out on crane standards and safety issues, followed by a market research on cranes and hoists.
- Design of a Small Hoist and Frame:
  - Sketches of early stage ideas of different hoist configurations
  - Evolution of the hoist configuration:
    - Ideas from a jib crane configuration
    - Base ideas and modification of base
    - Position of winch and counterweight
    - Modification of design to be easily stored, assembled and dismantled
  - Materials selection and calculations
  - Computer-Aided Design Model of the Hoist Structure as shown in figure 1
- Fabrication of the steel hoist structure
- Testing of the hoist

Results and Achievements

- A design of a hoist and frame to lift a gas cylinder and 10 litre buckets of soil.
- Buckling of the strut was analysed using ANSYS.
- Fabrication of a small hoist and frame which can be easily assembled, dismantled and stored.
- Fabrication of the hoist included cutting, filing, drilling, bending, turning and welding. Finally, the all the fabricated steel parts were galvanised.
- Testing of the hoist structure using strain gauges.
- Deflection of the boom when lifting a gas cylinder was measured using a dial test indicator.
- The hoist structure was assembled and dismantled while timing the procedure. It was done in a short period which shows that assembling and dismantling the hoist is efficient and easy to do.

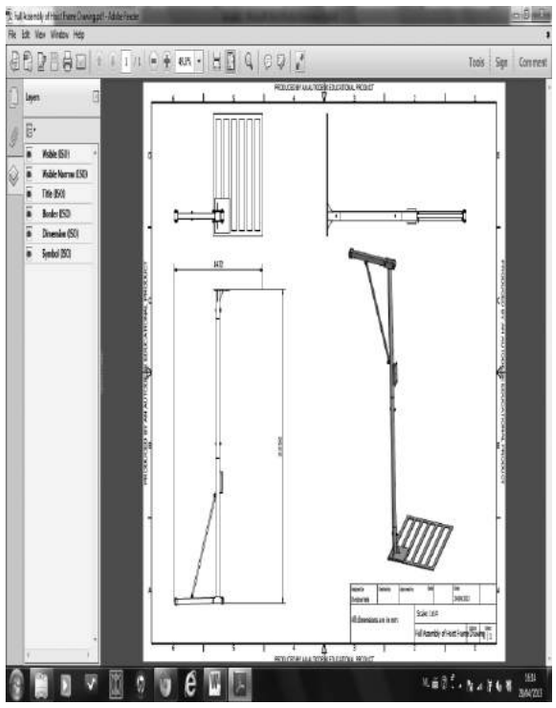

Figure 1: CAD model of the hoist structure

Experimental Investigation on the Effects of Voltage on a Domestic Refrigerator

Student: Stefan Xerri
Supervisor: Dr Ing. Mario Farrugia

Introduction
The ever increasing cost of energy is encouraging more research on developing appliances which consume less energy. It is claimed that energy consumption can be reduced by supplying a lower voltage to domestic appliances. Small refrigeration units, also employ a suction-line heat exchanger to increase their performance, thus reducing energy consumption.

Project Objectives
The main aim of this dissertation was to determine the effect of lowering the voltage on a domestic refrigerator in terms of energy consumption. The effect of voltage on cycle parameters such as temperatures, pressures and flow rates were also investigated.
In this dissertation the capillary-tube/suction-line heat exchanger of a domestic refrigerator was also removed to determine its effects on the refrigeration cycle.

Project Methodologies
A 150 litre refrigerator was placed inside an enclosure, slightly larger than the refrigerator, to simulate practical life conditions and reduce air currents around the refrigerator. This was important as the experiments were not carried out in a controlled environment. A constant voltage was supplied to the refrigerator using an uninterrupted power supply. The energy consumption of the refrigerator was determined over 24 hours using procedures adapted from the ISO 15502 and JIS C 9801 standards. Both these standards specify door opening frequencies, food loading conditions and refrigerator temperatures to accurately determine the consumption of a refrigerator. Voltage on the refrigerator was varied from 190V to 250V in steps of 15V, once every 24 hours to determine the energy consumption.

During testing it was noted that ambient temperature has a large influence on the results obtained. So to investigate the effect of voltage on cycle parameters, voltage was varied within a short period when the temperature was deemed stable.

After the effect of voltage was investigated, the capillary-tube/suction-line heat exchanger was removed and the cycle parameters were noted again. Comparison was made between the cycle with the heat exchanger and without it.

Results and Achievements
Voltage was found to have no influence on the temperatures, pressures and flow rate. A slight drop in compressor rotational speed was noted with each voltage drop. A compressor of a rotational speed of around 2900 RPM registered a drop of 60RPM with a voltage drop from 250V to 170V. Energy consumption did vary slightly with voltage drops as a result of the instantaneous power being lower at lower voltages, while the cycle time remained practically constant. Figure 1 presents the results obtained, factoring out the effects of ambient temperature on the energy consumption. It is noted that the decline in energy consumption is relatively small. When considering this drop in terms of money, it results in practically no saving.
When the capillary-tube/suction-line heat exchanger was removed from the refrigerator a drop in the coefficient of performance was noted. The refrigerating effect reduced considerably and as a result longer compressor on times were recorded.

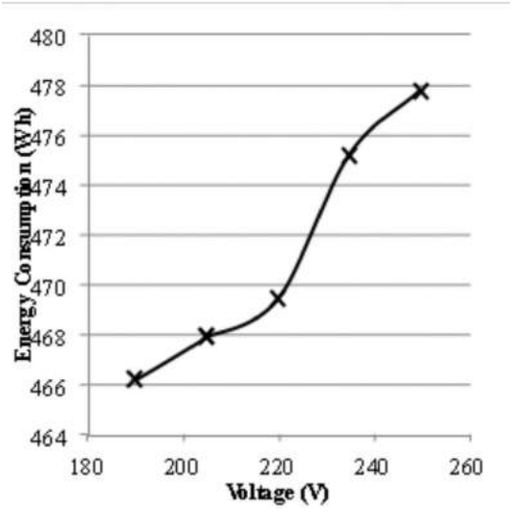

Figure 1: Energy consumption reduction as a result of voltage drop.

Catalytic Converter Use on SI Engines

Student: James Zahra
Supervisor: Dr Ing. Mario Farrugia

Introduction

The reciprocating internal combustion engines play an important part in the everyday society. During the process of combustion, the internal combustion engine converts fuel to mechanical energy. In an internal combustion engine, ignitable air-fuel mixture is induced in a cylinder which is later compressed and ignited by means of a spark. During the combustion process, the chemical energy of the air-fuel is ignited thus creating pressure. This increase in pressure is in turn converted into mechanical energy and further chemical energy in the forms of gases, which exit the engine primarily through the exhaust manifold. The untreated emission of these gases into the atmosphere however results in the major air pollution of the environment.

Project Objectives

The project's main objective was to understand how a catalytic converter works under the normal operation of a spark ignition engine. In addition, the three-way catalytic converter (TWC) was to be implemented on an engine, coupled with a dynamometer. Once mounted, the catalytic converter was to be tested under particular operating conditions, meaning particular engine speeds and loading parameters and amend the schemes accordingly.

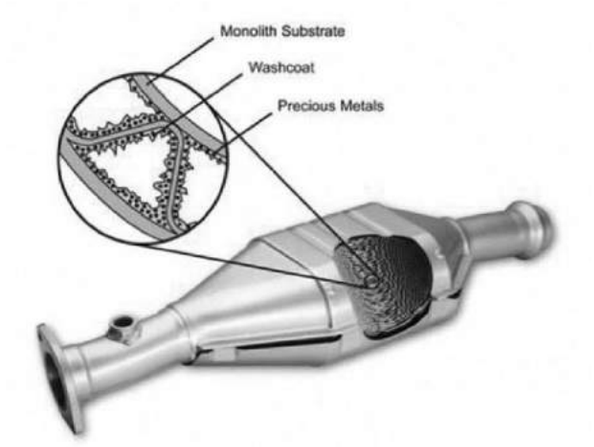

Figure 1: Three-Way Catalytic Converter Internal Honeycomb Structure [1]

Project Methodologies

A three-way catalytic converter was fitted onto the exhaust system of a 1.4 litre Ford petrol engine. During operation, the air-fuel mixture was varied from rich to lean and back repetitively by means of a signal generator. Exhaust upstream and downstream of the three-way catalytic converter was extracted and later analyzed by means of an exhaust analyzer, where graphs of hydrocarbons (a toxic gas found in the exhaust fumes) were later plotted. All readings were recorded once the three-way catalytic converter was seen to accomplish light-off via exhaust temperatures, which were read by means of a K-type thermocouple.

Results and Achievements

From the investigations performed, the switching function of an oxygen sensor enables the three-way catalytic converter to achieve best conversion efficiencies when the AFR is fluctuated from rich to lean but close to stoichiometric. It was also observed that longer lean periods resulted in higher conversion efficiency rates. It was concluded that the air-fuel window need not be too small of a range as small AFR fluctuation ranges tend to decrease the conversion efficiency of the three-way catalytic converter. In conclusion, it was found that high speeds (close to 4000 rpm) do not require relatively high cycle frequencies, but require switching cycle frequencies close to those applied when the engine was operated at lower speeds and loading parameters.

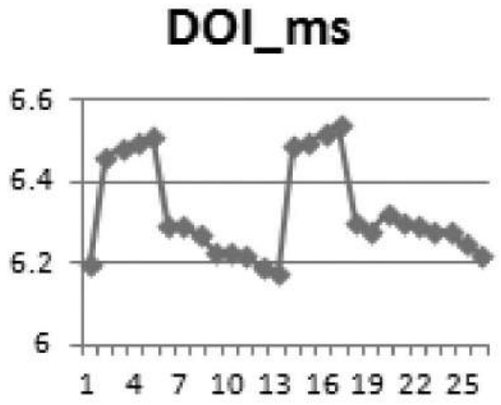

Figure 2: General Representation of Injector Duration AFR Sweep

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Free-Piston Engine

Student: Kyle Zammit
Supervisor: Prof. Robert Ghirlando

Introduction
The present-day internal combustion engines have been eminently successful in delivering power by converting the reciprocating motion of the piston into rotary motion of the crankshaft. Research within the automotive industry has been on-going to develop engines with higher fuel efficiency and lower emissions. A specific area of research is dedicated to the free-piston engines, which differ from the conventional engines in that they have no crankshaft. Less components, reduced weight, lower cost, and the ability of running on several different fuels are some advantages of free-piston engines. However, the operating principle of the engine brings a big challenge in having a good control system for its operation.

Project Objectives
A free-piston engine of the dual piston type based on a two-stroke, spark ignition, dual carburettor motor cycle engine was built by a previous student; however it failed to start. The main objectives of this project were to build a computer model of the free-piston engine using the Ricardo Wave software, complete the development of the engine, and to test the engine over a range of operating conditions.

Project Methodologies
To complete the development of the engine, several adjustments had to be made. In particular, the start-up process of the engine which incorporated a small compressor had to be improved significantly.
The following steps were carried out during the course of this project:

- A literature review to gain knowledge about free-piston engines, two-stroke engines, and compressors.
- Good understanding of the work carried out by the previous student
- Dismantling of the engine to completely analyse its operating principle
- Building a computer model of the engine using Ricardo Wave software
- Designing and implementing engine upgrades to complete development, and re-building the engine
- Designing and building an electrical circuit to electronically control the engines' spark ignition and operation of the pneumatic solenoid valve that control the air compressor side of the engine.
- Starting up of the engine

Results and Achievements
Proving to be more time consuming and more difficult than anticipated due to the requirement of a complex control strategy, the computer model of the free-piston engine could not be fully accomplished as desired. The two-stroke engine used for the free-piston engine project was modelled on the conventional operation of the crankshaft. Since no engine data could be found as it was old, and due to several assumptions taken, the generated models' validity is limited but sufficient to be used to compare the performance of the engine.

The modifications briefly included internal modifications to increase the compression ratio of the engine; re-welding of several components to eliminate air leakages; a custom copper head gasket; re-surfacing of badly conditioned cylinder heads; and most importantly electronic control of the engines' spark ignition and operation of the pneumatic solenoid valve.

Despite all the efforts made to modify the engine to gain its full functionality, the engine is still failing to run. Even though the engine (see Figure 1 below) improved significantly, certain aspects of the engine design which are believed to have a negative effect on the performance could not be addressed as these changes required almost complete re-designing of the engine from scratch.

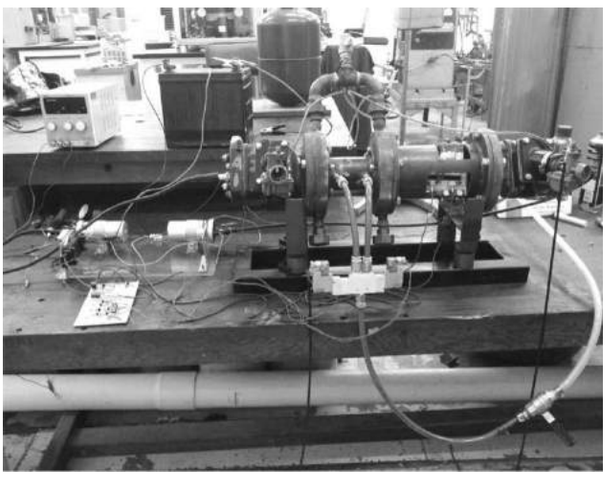


Figure 1: Free-Piston Engine Setup

Stress Analysis of a Wind Turbine Nacelle

Student: AnneMarie Zammit
Supervisor: Dr Ing. Martin Muscat

Introduction

The increasing awareness in the use of renewable energy has motivated the development of this project.

The traditional Maltese multi-bladed Chicago type wind-driven water pumps used for irrigation purposes have been neglected due to the introduction of more efficient water pumps. The main idea is to replace the abandoned and damaged windmills with a new turbine concept having a new rotor design with higher aerodynamic efficiency whilst still maintaining the design as similar as possible to that of the Chicago type windmill. This turbine should be able to generate electricity and possibly connected to the electrical grid.

Project Objectives

This dissertation is a continuation of previous works carried out on the fabricated wind turbine prototype by Farrugia (2011) and Axisa (2012). The objectives are to:

- study the design load cases to which the wind turbine is exposed;
- analyse the worst load cases;
- model the nacelle structure in Finite Element Analysis (FEA) software in order to perform stress analysis to check whether it can withstand the loads acting on it;
- study and check the design of the nacelle for the converted windmill;
- check whether the stresses in the nacelle structure are below the allowable stress to ensure safe operation;
- check on the maximum deflection of the nacelle;

Project Methodologies

The nacelle structure was modelled using ANSYS Mechanical APDL Finite Element (FE) software using a solid three-dimensional SOLID187 element (Figure 1). A bottom-up approach was used to create the geometric model of the nacelle. The material properties of the nacelle were obtained through a tensile test. Boundary conditions, loads due to the weight of the nacelle's components and reactions on the nacelle were applied to several FE models with different mesh densities. The worst load cases experienced by the nacelle as per EN 61400-2:2006 were identified and applied to the FE models. Results for the different load case scenarios were obtained to check whether the stresses induced were below the allowable strength of the material to ensure safe operation. Factor of safety for loads and materials were taken into consideration along the rules of EN 61400-2:2006.

Figure 1: FE model of the Nacelle Structure

Results and Achievements

The loads acting on the nacelle occurring when the rotor is parked whilst facing the wind direction at the wind's expected extreme value, and when the rotor is rotating in normal conditions, do not impose any threats to the nacelle structure since the stresses induced are below the allowable stress. Localised concentration of high stresses occur at stress concentration points due to the type of FE model used and could be ignored since these load cases are not a fatigue load case. Stresses above the allowable ultimate stress are induced when a gyroscopic moment resulting from yawing of the nacelle at maximum rate is applied to the nacelle. Possible ways to reduce the induced stresses were considered and reported in the thesis.

Study of Degradation and Stabilisation of Corroded Aluminium in an Aircraft

Student: Yanika Agius
Supervisor: Dr Ing. Stephen Abela
Co-supervisor: Mr Daniel Vella

Introduction

The Malta Aviation Museum houses a fairly large collection of artefacts related to aviation; most of which have a connection with Malta. One of these exhibits is a Douglas DC-3, which was handed over to several owners until finally it was left abandoned in a field in Ħal Far. At present, the aircraft is in a worn out state and is in dire need of attention. Consequently, the aircraft was chosen as case study for this project.

Project Objectives

- To identify the composition of the alloy/s used to manufacture the aircraft.
- To look into corroded areas of the aircraft in an attempt to identify the cause leading to general degradation.
- To identify fatigue cracks; a likely indicator of fatigue failure.
- To devise and implement a stabilisation technique to inhibit further degradation.

Project Methodologies

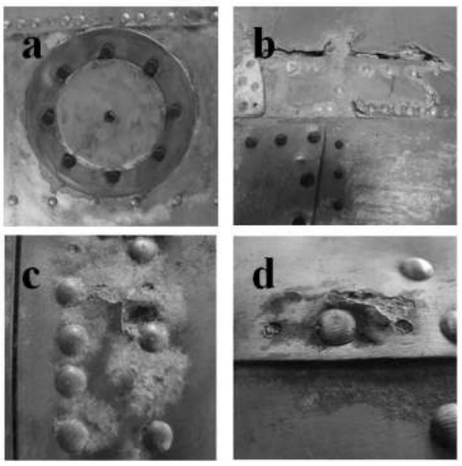
Characterisation was carried out on three samples of the aircraft to identify the composition of the aircraft's alloy/s using Energy Dispersive Spectrometry (EDS) coupled to Scanning Electron Microscopy (SEM). The appropriate stabilisation method could then be established. The method used by Bailey [1] was adopted: the artefact was immersed in a solution of citric acid, sodium hydroxide and water as shown in Figure 1. This setup was left for a period of five months so that deleterious ions are extracted from the artefact, thereby hindering further degradation. Specific sites on the aircraft where analysed and photographed so as to study the degradation mechanisms the aircraft has suffered from.

Results and Achievements

The alloy grade was found to be an aluminium 2024 grade as previously stated in a study by Polmear [2]. The stabilisation was considered to be successful since during the five month period over which the study was performed, chlorides and sulphates were increasingly being extracted from the artefact. Analysis of the aircraft was carried out to identify the main corrosion mechanisMs Galvanic corrosion was evident in two instances as depicted in Figure 2(a) and Figure 2(b). Figure 2(a) shows galvanic corrosion due to the use of steel bolts on aluminium while figure 2(b) shows galvanic corrosion due to contact between steel and aluminium, sacrificing the aluminium alloy. Moreover crevice corrosion is also illustrated in Figure 2(a) showing that crevice and galvanic corrosion may be simultaneously observed. Fatigue cracks are visible in Figure 2(c) and 2(d), which also suffered from exfoliation corrosion over time.

Figure 1 Artefact immersed in solution for the stabilisation process

Figure 2 Examples of degradation mechanisms on the aircraft



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Characterisation of PIRAC-treated Titanium Alloy

Student: Thelma Bonello
Supervisor: Dr Ing. Glenn Cassar

Introduction
Powder immersion reaction assisted coating (PIRAC) is a relatively new process which has recently been employed on metals. PIRAC has been proposed as a suitable technique capable of outstanding improvements in terms of improvement in tribological performance. However, in present studies, the resultant surface and mechanical characteristics together with bulk metallographic changes are only analysed by employing a limited amount of characterisation techniques.

Project Objectives
The objective of this dissertation is to study the suitability of PIRAC for the alpha+beta titanium alloy Ti-6Al-4V by using a wide variety of surface and mechanical characterisation techniques.

Project Methodologies
In this work, the tools used to characterise PIRAC-treated coupons are rotating-bending fatigue tests, X-ray diffraction (XRD), Knoop and nanoindentation testing, nanoscratch testing, optical microscopy, scanning electron microscopy (SEM) in combination with electron dispersive spectroscopy (EDS) and electron backscatter diffraction (EBSD).

Results and Achievements
Following XRD, it was concluded that alpha and beta peaks, characteristic of Ti-6Al-4V, are suppressed in the bulk during PIRAC nitriding to allow the formation of a hard thin layer of TiN and Ti2N together with some presence of Ti3Al intermetallic. The thickness of this modifier layer was later found to be approximately 4µm.

Indentation and scratch tests have proven that PIRAC-treatments induce high hardness. Indeed, all PIRAC-treated samples were invariably much harder than the untreated benchmark. They were also characterised by very high coating adhesion as the treatment affects Ti-6Al-4V via diffusion. Failure of the diffusion coating occurred only in certain instances. The exact location of these instances (if any) were pinpointed using line EDS. The failure location was also studied by using SEM imaging. Failure of the coating could be seen as cracking-spallation transition at the bottom of the scratch track.

In general, fatigue strength, S, is reduced with nitriding temperature whilst the cycles taken to failure, N, are prolonged. Nevertheless, the treatment performed at 800°C/4hrs exhibited better fatigue performance than the 700°C/48hrs treatment (Figure 1). This peculiar behaviour is explained by the longer treatment duration. Cracking for Ti-6Al-4V failure initiated either from the sub-surface (observed in treated samples) or less commonly from the surface (untreated samples). Surface crack nucleation is shown in Figure 2.

SEM analysis has uncovered elongated alpha grains in untreated Ti-6Al-4V. Grain elongation is attributed to extrusion of the material upon manufacturing. For high temperature PIRAC-treatments a rounder grain morphology was observed. This is attributed to grain recystallisation- a condition typical in the mill-annealing. After recrystallisation the grains are strain-free. In both instances, intergranular beta phase was observed.

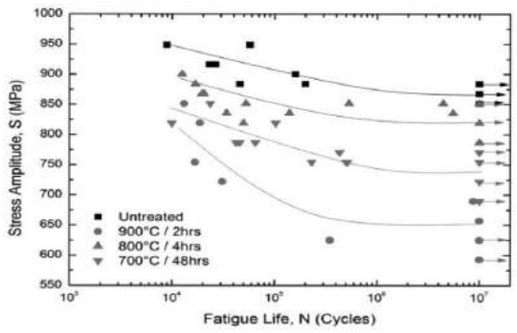

Figure 1: S-N plot for PIRAC-treated coupons. Arrows indicate samples which did not fail.

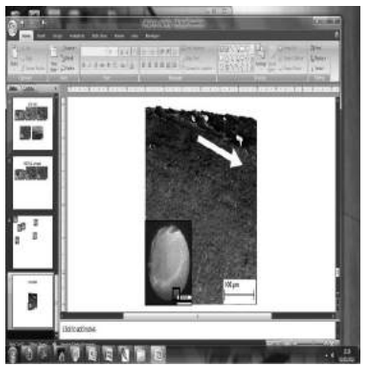

Figure 2: Surface crack nucleation for untreated Ti-6Al-4V. Failure direction is delineated by the arrow.

Tribological Enhancement of Biomaterial Surfaces through Surface Engineering

Student: Nicholas Brincat
Supervisor: Dr Bertram Mallia

Introduction

The degradation of medical implants in vivo is a concern. Often degradation happens at the surface of the implant, limiting their service lifetime and may result in increased body burden or implant failure necessitating a revision surgery. The average age of a patient undergoing a medical implant surgery is decreasing, putting higher demands on the implant materials. Surface engineering provides a way to modify implant surfaces and tailor them to better withstand the harsh environments inside the human body. This work, investigates a number of surface engineering treatments for two biomedical alloys. Thermal oxidiation treatments (TO) of Zirconium-Niobium (Zr-2.5Nb) biomedical alloy and magnetron sputtering (MS) of thin (~5µm) coating on 316LVM biomedical stainless steel substrates have been successfully carried out. The surface treatment characteristics and properties have been the subject of this investigation.

Project Objectives

The main aims of this project were to evaluate and compare the microstructural properties, scratch resistance, hardness, morphology and corrosion resistance of both treated and untreated biomedical surfaces.

Project Methodologies

- Literature review on application and performance of surface engineering in the biomedical industry.
- Preparation of the treated surfaces.
- Microstructure evaluation using a Scanning Electron Microscope (SEM) as illustrated in Fig. 1 and X-Ray Diffraction (XRD).
- Mechanical properties evaluation using nano indentation testing.
- Evaluation coating deformation response using nano scratch testing.
- Investigation of corrosion resistance of the treated materials, simulating body fluid conditions (full strength Ringer's Solution) using a three electrode configuration.

Results and Achievements

Two as delivered substrate materials (316LVM and Zr-2.5Nb alloy), eight MS coated 316LVM and one TO Zr-2.5Nb alloy were investigated. For the MS coated surfaces, four were CoCrMo based coatings while the rest where CrN based. The ranking for corrosion resistance was based on current densities displayed during potentiodynamic testing and open circuit potential (OCP) following immersion in test solution. Scratch resistance evaluation was based on the extent of coating damage following nano scratch testing. All deposited coatings exhibited lower current density values with respect to the untreated 316LVM, however the CoCrMo based coatings exhibited nobler behaviour compared the 316LVM, whilst the CrN based coatings were less noble. The untreated Zr-2.5Nb alloy showed even lower current densities than those exhibited by the various MS coatings in this study. The TO treated Zr-2.5Nb showed nano hardness values comparable to certain CoCrMo coatings, and had a scratch response which were better than most CrN based coatings. The current density at OCP exhibited by the oxidised surfaces, was a thousand times smaller than that for the untreated 316LVM. The latter was being used as a benchmark. This made the TO layer by far the best candidate for corrosion resistance.

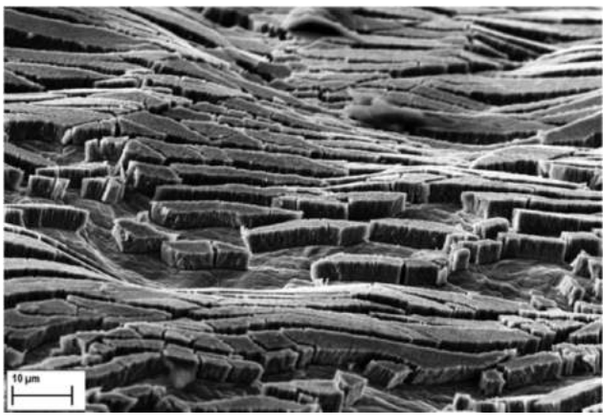

Fig. 1 SEM image showing a fractured CrN coating on 316LVM substrate

Effect of Gas Nitriding on Commercially Pure Titanium

Student: Michelle Cortis
Supervisor: Dr Joseph Buhagiar

Introduction

Due to the excellent combination of advantages, titanium became popular in many applications and one of the industries that make great usage of titanium and its alloys is the biomedical industry. Commercially pure titanium's titanium's biocompatibility and good corrosion resistance has motivated its use by the medical industry but problems can arise due to the low wear resistance. Gas nitriding is viable surface engineering treatments that can be applied in order to overcome titanium's tribological limitation.

Project Objectives

The aim of this project is to characterise and study the surface of gas nitrided commercially pure titanium. Characterisation was performed using the following techniques; X-ray diffraction, Scanning Electron Microscopy, nano-indentation, nano scratch and in-vitro corrosion testing.

Project Methodologies

The substrate used was a Grade 2 commercially Pure (cp) Ti. Gas nitriding was conducted at five different temperatures and time periods at BorTec GmbH & Co. KG, Germany. The mean surface roughness Ra was measured using a Mitutoyo Surftest 501 surface measuring machine for both untreated and treated samples with a tolerance of ±0.01µm. Cross sectioning was carried out on the samples in order to be able to determine the surface layer thickness of the gas nitrided layer. By cross sectioning, the samples were observed under an optical microscope to measure the compound layer and a resultant image is Figure 1. Phase constituents in the as-received nitrided samples and also the untreated samples were analysed using a Rigaku Ultima IV XRD with CuKα radiation (λ= 0.154nm). Surface Hardness of the samples was measured using Nano Indententaion with a Berkovich triangular-pyramidal diamond tip indenter. Nano Scratch Tests were done in order to analyse the adhesion of the coatings [19] using a MicroMaterials NanoTest machine equipped with a Synton-MDP 60° conical indenter with radius 10 µm. Corrosion testing was done via potentiodynamic scans and all tests were conducted in 300 ml of Ringer's solution at a constant temperature of 37±1°C which mimics the body fluid.

Results and Achievements

This work resulted in a clear demonstration of an overall increase in corrosion resistivity and hardness, due to nitriding of commercially pure titanium. When the temperature is below the beta transus, the microstructure of the nitrided layer consists of a compound layer over a diffused layer. The compound layer is composed of cubic TiN and tetragonal Ti2N and this imparts an increase in hardness and corrosion property. This compound layer is further supported via a thick α-Ti nitrogen-rich diffused layer.

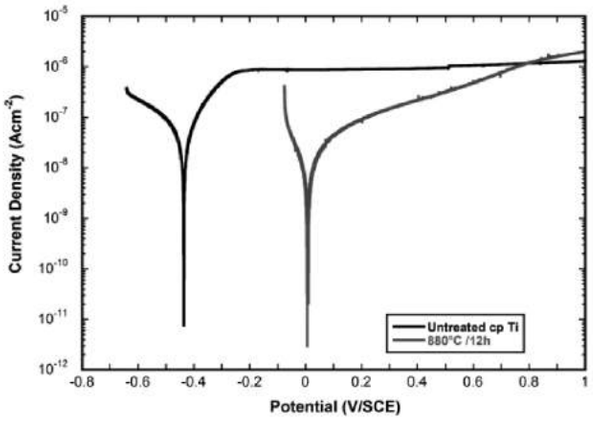

Figure 1: Potendiodynamic curves for untreated commercially pure titanium and treated commercially pure titanium at 880°C/12h in deaerated Ringer's solution. Nitrided sample shows a lower current density (till 0.8 V) and a shift in corrosion potential implying a rise in corrosion resistivity.

Tribocorrosion of Surface Treated Biomedical Alloys

Student: Sarah Farrugia
Supervisor: Dr Bertram Mallia

Introduction

Tribocorrosion is an irreversible transformation encompassing simultaneous chemical and mechanical interactions provoking degradation. It attracts a wide spectrum of research domains, including the biomedical industry for the use of medical implants in the human body. Zirconium alloys and Stainless steels are used in orthopaedic implants for their strength, toughness, corrosion resistance and good biocompatibility. Their high corrosion resistance is owned to a passive film that forms spontaneously on their surface. This passive film is damaged or removed during the simultaneous action of mechanical wear and corrosion in a tribocorrosion environment. This results in wear-accelerated corrosion. The demand to extend the lifetime of components has led to the exploration of surface treatments including Physical Vapour Deposition (PVD) and thermal oxidation. The merit of PVD nitride and carbide coatings is that it changes surface properties without modifying the underlying material. This results in significant reduction on friction coefficient and enhanced corrosion resistance.

Project Objectives

Throughout the course of this work six samples were investigated: U/T (untreated) AISI 316LVM biomedical stainless steel, U/T Zirconium Niobium (Zr-2.5Nb) biomedical alloy, Oxidized Zr-2.5Nb and three magnetron sputtered PVD coatings on AISI 316LVM stainless steel: Chromium Nitride (CrN), Cobalt-chromium-Molybdenum (Co-Cr-Mo) and Cobalt-Chromium-Molybdenum with Carbon (Co-Cr-Mo-C). The aim of this work was to evaluate the corrosion-wear behaviour of the above mentioned as-delivered and surface treated biomedical alloys in simulated body fluid (Ringer's solution) against an alumina ball in reciprocating sliding configuration.

Project Methodologies

Sliding-corrosion-wear testing was carried out using reciprocating sliding tribometer configured with a three electrode electrochemical setup. The samples were tested in Ringer's solution to mimic the environment in the body. The corrosion-wear testing was performed under different electrochemical conditions to be able to assess the damage incurred by mechanical and chemical means. The wear scars produced by the tribometer were measured using Prof.ilometry and further investigated with microscopy techniques.

Results and Achievements

The following are the main results of this work: (1) the coatings exhibit superior corrosion-wear resistance than the untreated 316LVM Stainless steel and the least damage was obtained for the CrN coating and the Oxidized Zr-2.5Nb; (2) corrosion-wear material loss was generally dominated by the synergistic interaction of wear and corrosion phenomena; and (3) coating defects play a significant role on degradation mechanisms as they may act as initiation points to subsequent cracking and delamination of the coatings. Figure 1 shows Scanning Electron Microscope (SEM) images of U/T 316LVM stainless steel which shows delamination wear damage and roughening of the wear scar and CrN coated 316LVM displaying minimal polishing wear damage.

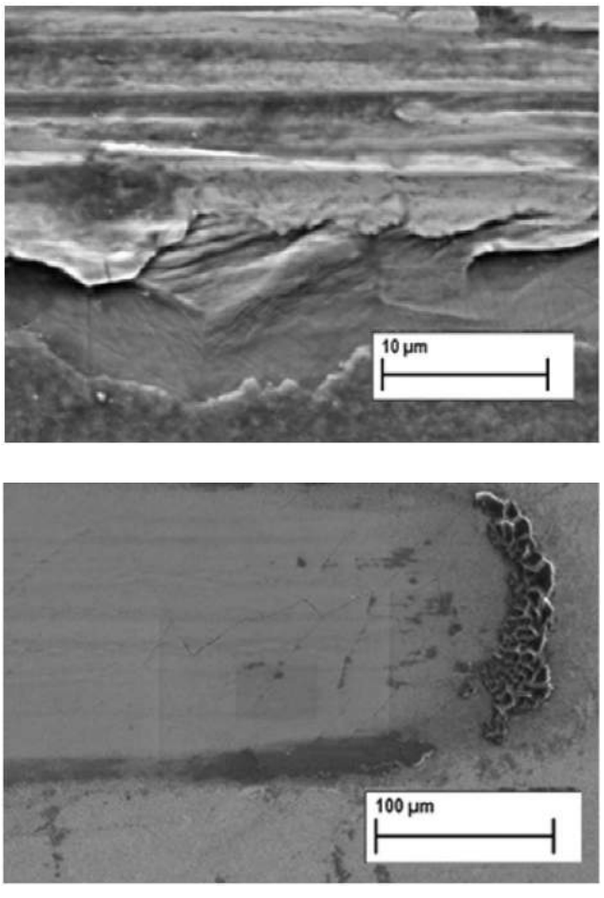

Figure 1: SEM secondary electron image of scar on: (a) U/T 316LVM and (b) CrN coated 316 LVM after corrosion-wear testing against alumina ball

Study of Mechanical Properties and Fracture Analysis of Single Layered Graphene using Molecular Dynamics

Student: Nathan Gatt
Supervisor: Dr Ing. Glenn Cassar
Co-supervisor: Dr Matthew Borg

Introduction

Graphene, a single-atom-thick sheet of sp2-bonded carbon atoms, has been hailed as a miracle material with numerous potential applications. However, in order to widen the utilization of this material to novel applications it is imperative to understand how this responds to the presence of material defects when subjected to a load. Direct observation and measurement at the nanometric scale may be very difficult and the results can often be questionable. A study emphasizing on how a single sheet will behave when subjected to a tensile load using computer simulation techniques is used. Molecular dynamics is to be used since it is an important tool which helps to understand what goes on in the nano-scale and the atomistic phenomena where experiments (e.g. measurement of resolution) are limited.

Project Objectives

- To modify a currently available open-source molecular dynamics software in order to include material modelling of graphene at the solid state.
- To model graphene sheets under axial loading and compare the material properties (stress, strain and Young's modulus) to similar simulations found in literature.
- To understand the effect of different loading orientations on the material response depending on crystal structure orientations, zigzag and armchair.
- To introduce material defects such as vacancy sites in the sheet and measure the difference in the properties compare to the benchmark pristine carbon sheet.

Project Methodologies

A molecular dynamic simulation based on the Morse, angle bending and Lennard-Jones potential energy functions with the Berendsen thermostat technique implemented in the Velocity Verlet (as numerical integrator) was developed in order to investigate the mechanical properties of pristine and defective single layered graphene sheets under stress and compare the results with existing literature. The loading was exerted in both the zigzag and armchair directions to examine the effect of loading for both pristine and defective sheet with a strain rate of 6.6 by applying a velocity of 5 ms-1

Results and Achievements

From the results obtained, the armchair is stronger in all scenarios than the zigzag orientation. From the defects testing, in accordance to the type of defect, it was observed that Young's modulus is effected by the presence of defects and their orientation. It was also noted that failure occurred prematurely relative to a pristine sheet for all cases as expected, but failure from the actual defect did not occur in all scenarious, such as single vacancies and single edge defects, and so the sheet failed like a pristine sheet would. Finally, the failure mechanism was discussed (as in in Fig.1)

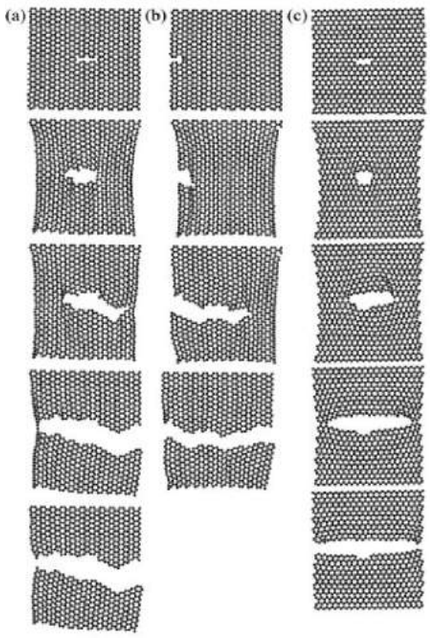

Figure 1 – Failure mechanisms for:
(a) AC triple vacancy;
(b)AC multiple edge defect;
(c)ZZ triple vacancy.

Investigation on the Degradation of Kolsterised® Biomedical Stainless Steel

Student: Christian Grima
Supervisor: Dr Joseph Buhagiar

Introduction
The outstanding corrosion resistance of austenitic stainless steels has led to a broad range of application possibilities. One major application limitation of this alloy remains that of tribological systeMs This is due to the inherently poor tribological behaviour of stainless steels. For this reason, biomedical grade stainless steels for intrahuman use have been predominantly limited to temporary fixation devices such as bone plates and screws.

The ease of fabrication and lower cost of biomedical grade stainless steels when compared to other biomedical metals in use, like cobalt-based and titanium alloys, render stainless steels into an attractive alternative. Their tribological properties are lately being enhanced by various surface engineering techniques. Particular attention is paid such that an increase in hardness, and hence in wear resistance, do not come at the cost of a weakened corrosion resistance. Low temperature thermochemical surface alloying processes have been proved to generate a layer at the surface, known as the S-Phase layer, which portrays an increased surface hardness without any detriment to the corrosion resistance of stainless steels.

Project Objectives
The effect of the commercial thermochemical treatment known as Kolsterising® K-33 on AISI 316LVM biomedical grade austenitic stainless steel is examined in this study. The principal aim of this study is to investigate the effect of Kolsterising® on medical grade ASTM F138 austenitic stainless steel. A comparison between the untreated and Kolsterised® material is given, with particular attention to the mode and degree of degradation that might be portrayed.

Project Methodologies
The S-Phase layer formed was studied via characterisation techniques such as optical microscopy, glow discharge optical emission spectroscopy, X-ray diffraction, scanning electron microscopy and energy dispersive spectroscopy. Several hardness tests were conducted to establish the hardness of the S-Phase layer formed at the surface while corrosion and tribocorrosion tests were particularly aimed at mimicking intrahuman performance.

Results and Achievements
The control and Kolsterised® material behaviour within the human body vis-à-vis corrosion and tribocorrosion performance has been mimicked by a number of in vitro studies. Results have shown that the Kolsterising® treatment was not only effective in increasing the hardness and wear resistance of the AISI 316LVM stainless steel, but also its corrosion resistance within a saline solution which is representative of the physiological saline found in the human body. In fact the noticeable pitting attack observed on the untreated material, as shown in Figure 1, did not show on the treated specimen after corrosion testing.

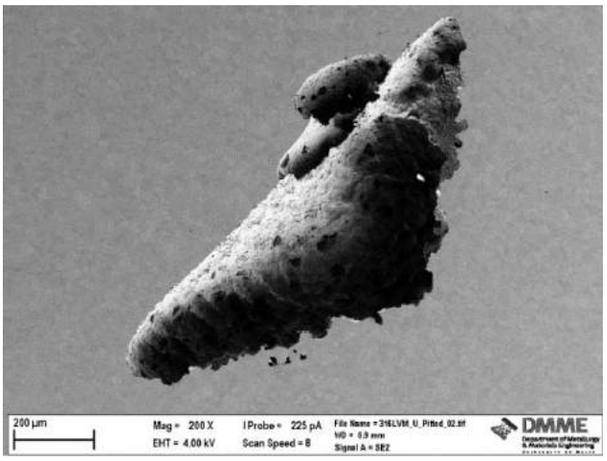

Figure 1 – Surface image by secondary emission SEM of a pit on an untreated 316LVM flat coupon subjected to electrochemical corrosion testing

This study also Prof.fers significant information relating to corrosion resistance of the material in both untreated and treated conditions when subjected to harsh environments that don not relate to the biomedical sector. In fact the untreated and Kolsterised® material successfully survived a 500 hour salt spray fog test without showing any signs of corrosion.

Metal-on-Metal Implant Failures: Alleviating the Problem

Student: Shaun Maniscalco
Supervisor: Dr Joseph Buhagiar
Co-supervisor: Mr Malcolm Caligari Conti

Introduction

Metal on metal (MOM) prosthetic implants have been widely used by orthopaedic surgeons to perform total or half hip replacement. Such prostheses tend to have the interfaces replacing the joint made out of biomedical cobalt-chrome alloys since such materials exhibit biocompatibility whilst possessing superior corrosion and wear resistance, strength, ductility and fatigue properties when compared to other alloys. Following recent concerns with the use of metal-on-metal implants due to release of toxic ions from cobalt chromium biomedical alloys due to the release of corrosion-wear products, the creation of the hard S-phase on such alloys is investigated to determine its capability to alleviate the problem.

Project Objectives

The leading aims of this project were to determine whether the tribo-corrosion properties of Kolsterised® ASTM F-1537 Co-Cr alloy are superior to the untreated counterpart, following the analysis of the microstructure, corrosion and mechanical properties resulting from the Kolsterising® treatment.

Project Methodologies

Following sample preparation and treatment by Bodycote Hardiff GmbH in Germany, several characterisation techniques including X-Ray diffraction, glow discharge optical emission spectroscopy and nano-indentation were employed. The corrosion properties of the untreated and treated samples were compared by subjecting samples to 500 hours of salt spray testing. Tribo-corrosion testing was performed using a linear reciprocating ball-on-flat tribo-corrosion tester, were both the ball and the flat sample are made of cobalt chromium alloys in untreated and treated combination. Such testing was performed at different potentials in order to analyse the combined effect of corrosion and wear. Tests were performed in Ringer's solution and other parameters were set to replicate as closely as possible the body conditions.

Results and Achievements

From the tests performed it was conclude that:

1. The Kolsterising® treatment applied to the F-1537 Cobalt Chromium improves the mechanical properties of the surface significantly without degrading corrosion resistance. The most remarkable enhancement observed was the increase in the hardness from 4.94 GPa of the untreated sample to 15.89 Gpa following Kolsterising®. A cross section of the sample following treatment can be seen in figure 1, where the top part not showing any grains indicates the presence of the S-phase.
2. Kolsterised® samples showed higher resistance to corrosion activated wear, resulting in a reduction in volumetric loss, whilst a significant reduction in abrasion damage was observed, as can be seen in figure 2. A relative reduction in wear debris left on the wear track was observed in Kolsterised® samples. Results indicating a decrease in volumetric loss reflect a decrease in metal deposits if the material was employed in hip joint replacement implants, reducing the risk of the patient encountering metallosis.

Such results highlight the potential of Kolsterised® Co-Cr for use in MOM implants, encouraging further research to increase their short lifetime by such treatment.

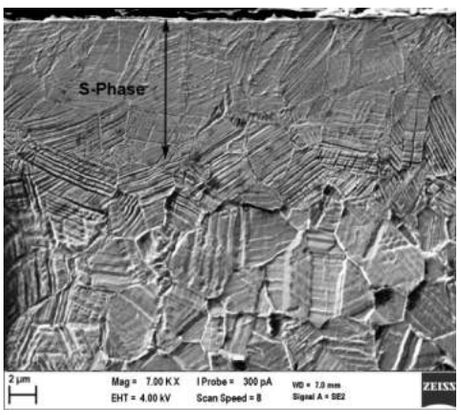

Figure 1Wear tracks on the a) untreated and b) treated samples following tibo-corrosion testing

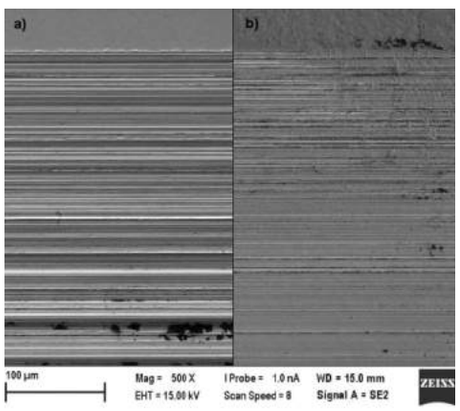

Figure 2 Secondary electron image of the Kolsterised® sample cross-section.

Study Of Corrosion Response of a Surface Engineered Aerospace Grade Titanium Alloys

Student: Antonella Scerri
Supervisor: Dr Ing. Glenn Cassar
Co-supervisor: Dr Joseph Buhagiar

Introduction

Titanium alloys are attractive materials and their use in the aerospace industry is a result of the superior properties when compared to other metals. Their excellent combination of properties include high strength to weight ratio, low modulus of elasticity and excellent corrosion resistance. However these alloys have poor tribological properties such as poor abrasive wear resistance, low hardness values and high coefficient of friction. Thus for an improvement, titanium has to be surface treated. Aircraft landing-gears and engine turbine blades are two applications of titanium alloys and degradation of such components lead to catastrophic failures. Hence the study of the corrosion response of both untreated and surface treated titanium alloy samples is crucial for well maintaining titanium alloy components.

Project Objectives

In this study the corrosion behaviour of triode plasma nitrided, oxinitrided and titanium nitride coated titanium alloy Ti-6Al-4V, which already has been proved to improve tribological properties, is investigated.

Project Methodologies

Literature review on surface engineering of titanium alloys, particularly related to their effect on corrosion resistance.
Electrochemical corrosion studies in a strongly reducing acid.
Microstructure evaluation using optical microscopy, scanning electron microscopy (SEM), and X-Ray diffraction (XRD) before and after the corrosion tests are carried out in order to deduce any morphological changes in the coupons' surface.

Results and Achievements

From this work it could be concluded that when compared to the untreated Ti-6Al-4V, the triode plasma nitrided, oxinitrided and titanium nitride coated alloy proved to be more corrosion resistant. However the untreated alloy still showed a passive behaviour and a high corrosion resistance in the strongly reducing acidic 4M hydrochloric acid solution. In addition to this, it was also found that the corrosion resistance of nitrided alloys, in the same acidic solution, depends on both quality and thickness of the nitride layer; the thicker the film, the better its performance. Following the triode plasma nitriding treatments, a compound layer is formed near the surface region, as shown in Fig. 1, which consists of TiN and Ti2N. Hence the underlying titanium substrate is protected and as a result, the corrosion resistance of the alloy is increased. Furthermore, when compared to the TiN layer, the Ti2N layer showed a higher corrosion resistance. With regards to TiN coatings, for the underlying titanium to be shielded against chemical attack, a well-adherent coating without any residual stresses and with relatively no defects such as pin holes or microcracks is needed. Fig. 2 shows an SEM image of the corroded TiN coating layer, where small pits were created and parts of the coating were completely removed exposing the underlying titanium substrate.

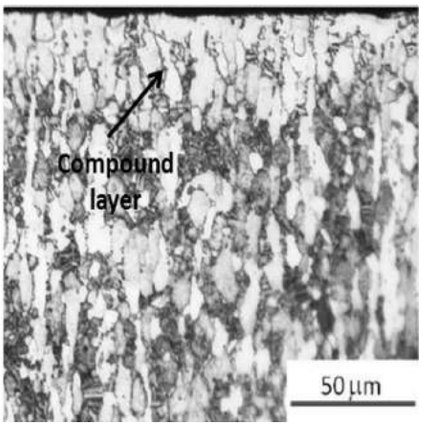

Fig.1. Micrograph of near-surface region of nitrided Ti-6Al-4V coupon at 700 °C for 4 hours.

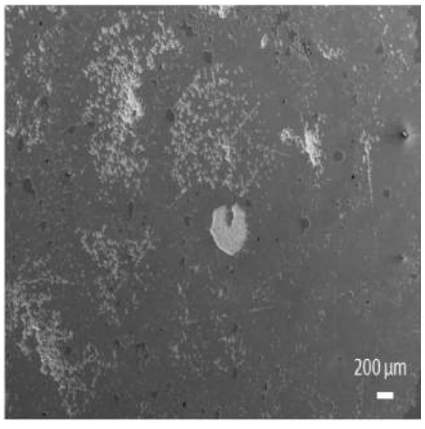

Fig. 2. SEM image showing corrosion of the TiN coated Ti-6Al-4V alloy.

Effect of Ceramic Conversion Treatment on the Corrosion Behaviour of NiTi

Student: Naomi Annette Vella
Supervisor: Dr Joseph Buhagiar

Introduction

Nitinol is an intermetallic alloy consisting of nickel and titanium that displays both the shape memory effect and pseudoelasticity. Since its discovery, the alloy has found a wide range of applications, especially in the medical device industry due to its unique properties. Since this alloy will always be in contact with body fluids when implanted, it must have excellent corrosion resistance together with good biocompatibility. Although NiTi instantly forms a natural chemically protective oxide layer when exposed to a weak oxidizing environment, it is still not sufficient to prevent corrosion and hazardous Ni ion release[1]. Enhancing the alloy's corrosion resistance and biocompatibility can be achieved by strengthening and increasing the thickness of the passive oxide layer through surface treatment. One such technique is the Ceramic Conversion Treatment which involves heating the material up to certain temperatures above 300°C for a specific amount of time in air.

Project Objectives

The aim of this project was to investigate the corrosion properties of the untreated alloy and evaluate the effect of three different ceramic conversion treatments on such properties. Hardness, surface roughness, scratch resistance, shape memory recoverability and deformation capability of the three surface treatments were also evaluated in order to deduce different characteristics between the three oxides obtained from the treatment.

Project Methodologies

A review of the literature published to date on NiTi and its corrosion properties was carried out, where oxidation treatments to enhance the corrosion behaviour of this alloy was also taken into consideration. The material supplied was cut into discs of using an abrasive water jet cutter. They were then ground to a polished finish by means of metallographic abrasive papers. When completed, they were all degreased in isopropanol and ultrasonically cleaned. A number of samples then underwent ceramic conversion treatment in an air furnace, whilst a few where left untreated. The three treatments conducted were; 400°C for 50hours, 650°C for 1 hour and 700°C for 0.5hours. Metallographic and characterization techniques were employed to understand the composition and structure of the oxide layer formed by the different treatment conditions. The mechanical properties of the ceramic layers were obtained by carrying out nano-hardness, nano-scratch and deformation tests. Pitting and crevice corrosion resistance of the untreated and treated NiTi was studied using a potentiostat and a crevice corrosion jig respectively, where both were carried out in a simulated physiological solution at a temperature of 37±2°Cto mimic body conditions.

Results and Achievements

The results obtained show the surface layers mainly consisting of rutile TiO2 with slight Ni3Ti and NiTiO3 in the intermediate layers at higher temperatures, which were detected by XRD and line EDX. The high temperature treatments, 650°C and 700 °C, exhibited poor properties in both the nano-scratch test, refer to Figure 1, and under deformation, where spallation occurred, due to a thicker oxide present. Corrosion resistance is affected by the uniformity of the oxide layer and not thickness, therefore the 400°C for 50hours treatment exhibited the best behaviour overall.

References

[1] Maitz, M.F., Surface Modification of Ti-Ni alloys for Biomedical Appliactions, in Shape Memory Alloys for Biomedical Applications, S.M. Takayuki Yoneyama, Editor. 2009, Woodhead Publishing LTD: Cambridge. p. 173-188.

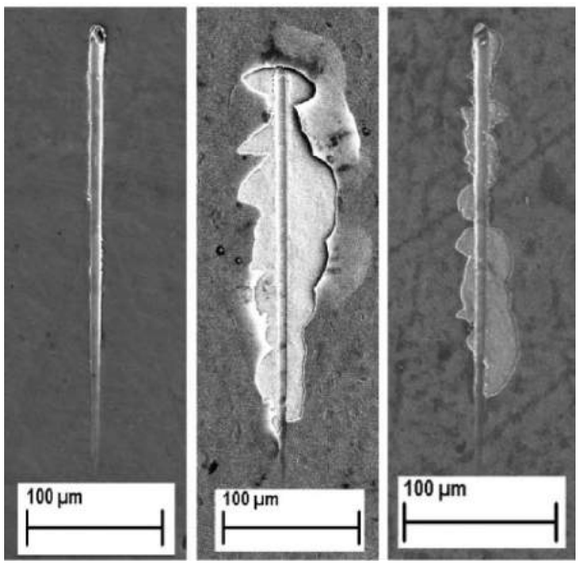

Figure 1: Comparison of Nano-Scratch Tests, from left the T400H50, T650H1 and T700H0.5. Severe spallation can be evidently seen in the last two treatments.

Laser Generated Tool Grade Stainless Steel in Corrosive Environment

Student: Kurt Zerafa
Supervisor: Dr Bertram Mallia
Co-supervisor: Ing. Maurizio Fenech

Introduction

The laser cladding facility at the DMME is currently being used to develop methodologies to restore damaged tools by depositing martensitic grade AISI 410 stainless steel. Initial experiments on the clad walls (Figure 1) displayed lack of load bearing capacity and material homogeneity. Reinforcement by the addition of Cr3C2 (chromium carbides) and appropriate heat treatments were found to improve the mechanical properties of the material. [1] The effect on the ceramic particle additions on the corrosion resistance of the stainless steel clad walls has not yet been studied and is investigated in this present work.

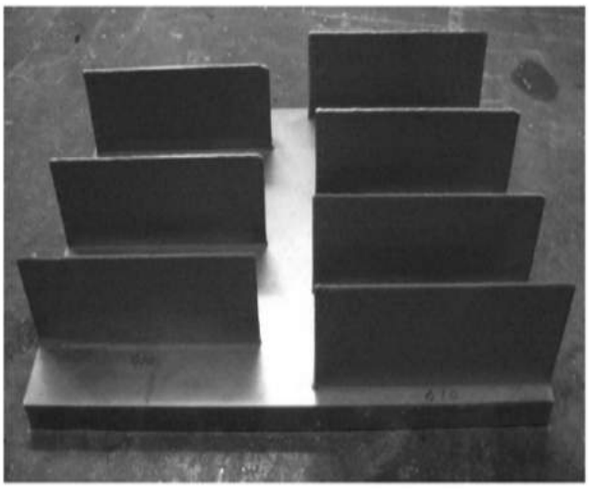

Figure 1: A number of laser generated walls with different chemical composition. [1]

Project Objectives

The aim of this study was to investigate the effect of Cr3C2 additions and heat treatment on the corrosion resistance of AISI 410 martensitic tool grade stainless steel. This aim was realised via the following objectives:

Prepare clad wall specimens with a mirror surface finish for corrosion evaluation

Conduct electrochemical corrosion testing in 0.1M NaCl solution

Compare clad wall microstructure with corrosion behaviour

Compare the corrosion behaviour against a commercially available martensitic tool grade stainless steel (AISI 420 Stavax Supreme)

Project Methodologies

A literature review on martensitic stainless steels, basics of electrochemistry, corrosion testing procedures and corrosion mechanisms was carried out.

This was followed by the construction of an electrochemical cell where electrochemical polarization corrosion testing on the clad wall samples with different Cr3C2 additions and benchmark material (AISI 420) was performed. Open circuit potential (OCP), potentiodynamic polarisation (PD) and cyclic polarization (CP) testing in 0.1M NaCl was carried out to investigate how Cr3C2 additions affected the corrosion resistance of the clad wall specimens.

The tested regions were characterised using a Nikon optical microscope (OM) and a Zeiss Merlin Field Emission Scanning Electron Microscope (SEM). The OM investigation gave an overview of the corrosion process and determined interesting sites for more in depth analysis using the SEM in secondary electron mode at higher magnifications. This procedure was vital to define the relationship between the corrosion resistance and the microstructure of the clad wall specimens.

Results and Achievements

The main results and achievements from this project are the following:

The introduction of the ceramic particle reinforcement has a substantial negative impact on the overall corrosion resistance of the material, generally owing to high amount of chromium carbides which were reducing the amount of chromium in solution. Therefore the samples containing low levels (0, 1 and 3%) of Cr3C2 additions were seen to have the best corrosion resistance properties.

The laser generated specimens were found to possess better corrosion resistance than the Uddelholm Stavax Supreme which was chosen as the benchmark material

Better corrosion resistance was observed in almost all calculated parameters when the wall specimens were tempered at 200˚C instead at 575˚C.

References

[1] C. Busuttil, "Bulk Mechanical Properties of Laser Generated Tool Grade Stainless Steel," B. Eng. Dissertation, University of Malta, Malta, 2012.