

FACULTY OF ENGINEERING



# FINAL YEAR ENGINEERING PROJECTS EXHIBITION

6 & 7 JULY 2012  
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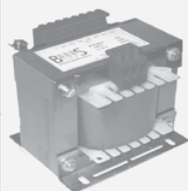


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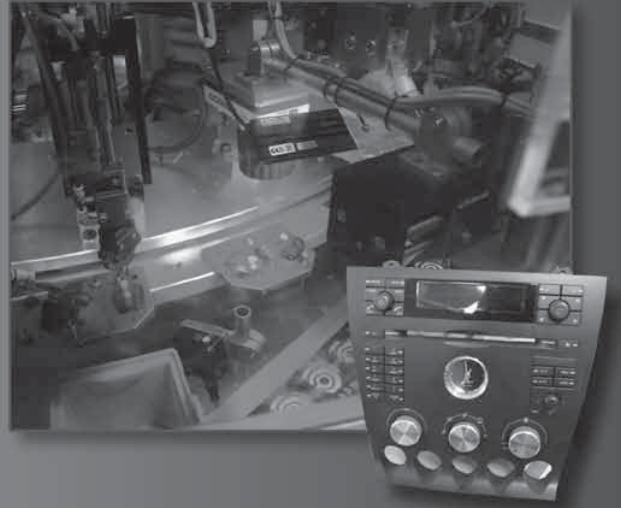
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# Foreword

## **Dear Reader,**

I am privileged to write the foreword to this publication, which presents the final-year projects that students reading for the B.Eng.(Hon.s) degree at the Faculty of Engineering of the University of Malta undertook and completed during the academic year 2011-2012.

In this booklet each student briefly describes her or his project, giving an overview of their achievements and how these were attained. On browsing these pages you will directly realise that a diversity of topics are tackled by our students in their work, spanning so many different aspects of our engineering profession. Work on these projects spreads over both semesters of the final-year, and culminates in the dissertation, a document of around 100 pages, the creation of which requires the skills acquired by the students over the course of the engineering degree. These include a capability for technical research, the design and actuation of experiments, the application of scientific methods and the analysis and interpretation of data to attain valid engineering conclusions. This document and the presentation of their work in the exhibition catalogued in this booklet seal the formation of our graduate engineers.

Practically over the duration of the exhibition our students become our alumni, and will proceed to study at postgraduate level or start their professional careers. We welcome those who return to study at Masters or Doctoral level in our Faculty; are proud to see those who peruse their studies abroad do well; and look forward to work as colleagues with the graduates who start their professional careers directly.

In conclusion I once again thank all the staff of our Faculty, and in particular the PR team headed by Dr Pierluigi Mollicone; and of course our students, without whose work and contribution this booklet, and the exhibition, would not be feasible.

**Dr John C Betts**



# Current Funded Research Projects

## **Cleaner flight operations in departure and approach in Maltese Airspace**

Funding Protocol: MCST R&I 2011

Project Acronym: CLEAN-FLIGHT

Description: The project focuses on the optimisation of flight profiles of commercial aircraft flying in and out of Malta to minimise carbon emissions in Maltese airspace. New and emerging technologies in flight trajectory optimisation and weather information management will be used to design and develop a new ground-based concept involving stakeholders such as operators and ANSPs to coordinate optimal flight operations and enable pilots to fly better trajectories for minimal fuel burn and reduced emissions.

Project Ref.: R&I-2011-021

Start Date: August 2011

Duration: 24 months

Project Budget: €151,093

UoM Funding: €102,509

## **Amplifying Innovation in Manufacturing**

ERDF 083 Research Tender

The 600k ERDF 083 project – Research Services for Amplifying Innovation in Manufacturing started in April 2010. It is constituted of three research projects related to manufacturing, which collectively contribute towards Europe's Strategic Vision for Manufacturing for 2020. The projects are:

- Energy Efficiency in Manufacturing
- ICT in Manufacturing
- Innovation in Manufacturing

The Department of Industrial and Manufacturing Engineering has been responsible for the third project and its overall research goal has been to amplify the degree of innovation in product design and manufacturing. Two initiatives have been taken to accomplish this goal, namely:

- Developing an Industrial Collaboration Framework for Amplifying Innovation in Manufacturing (IC-FAIM). The objective of this initiative has been to amplify innovation and creativity in manufacturing through improved product development stakeholder collaboration.
- Developing a Life-oriented Product Development Simulation Framework for Amplifying Innovation in Manufacturing (LS-FAIM). The objective of this initiative concerned the amplification of innovation and creativity in manufacturing via the prediction of consequences through the simulation of product life phases and the visualisation of product and manufacturing system performance measures during manufacturing system design.

The framework developed in each initiative has been implemented into an AIM portal which can be accessed by relevant stakeholders in industry. The AIM portal has been evaluated using real product design and manufacturing case studies at the project partners, which included Rayair Automation Ltd., Techniplast Ltd., FXB Group of Companies Ltd., Toly Malta Ltd. and Playmobil Malta Ltd. The evaluation results demonstrated that the AIM portal has been found beneficial by the industrial stakeholders in amplifying the degree of innovation in their products and/or manufacturing processes.



## A Design Tool for the Evaluation of Module Interfaces

Funding: Bench fees: €6000

Time Span: 1st October 2011-1st February 2013

The objective of this research is to provide the user with a life oriented design tool which supports the user in the evaluation of module interfaces. Following the early synthesis of design concepts, the user is usually required to evaluate and subsequently select the most suitable design concept. At this stage the engineering designer is usually required to appraise multiple design concepts with respect to conflicting criteria. Over the years numerous evaluation techniques have been proposed by academia in order to support the user during this critical stage. Yet, numerous studies have indicated that most of the concept evaluation techniques which have been proposed as a result of academic research are not being employed by engineering designers in real life decision making scenarios. This was partially attributed to the fact that these concept evaluation techniques do not provide a balance between the ease of use and the ability to produce clear yet valid results.

This research is proposing a 2 stage hybrid concept evaluation (2SCHE) approach which is shown in Figure 1. The proposed approach employs multi criteria decision analysis (MCDA) in order to systematically evaluate module interface design concepts with respect to conflicting criteria. This approach provides the user with a concept evaluation approach which is easy to use yet capable of providing clear and valid results. The objective of this research in the near future will be to implement this approach into a computer support tool. With this computer design tool the user will be in a better position to evaluate module interface design concepts with respect to various life cycle phases.

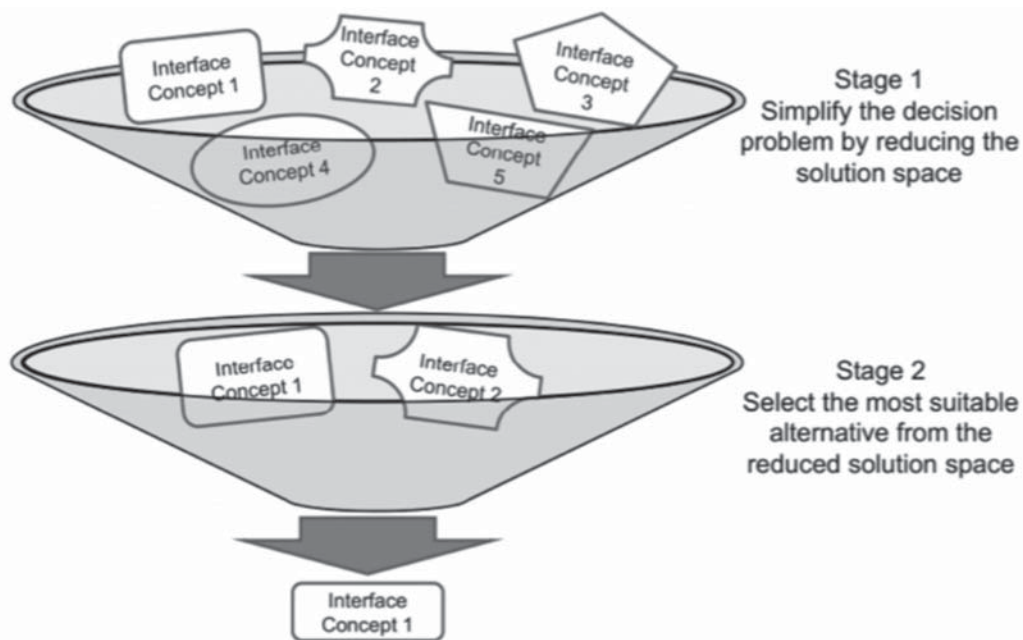


Figure 1. Proposed (2SHCE) approach.



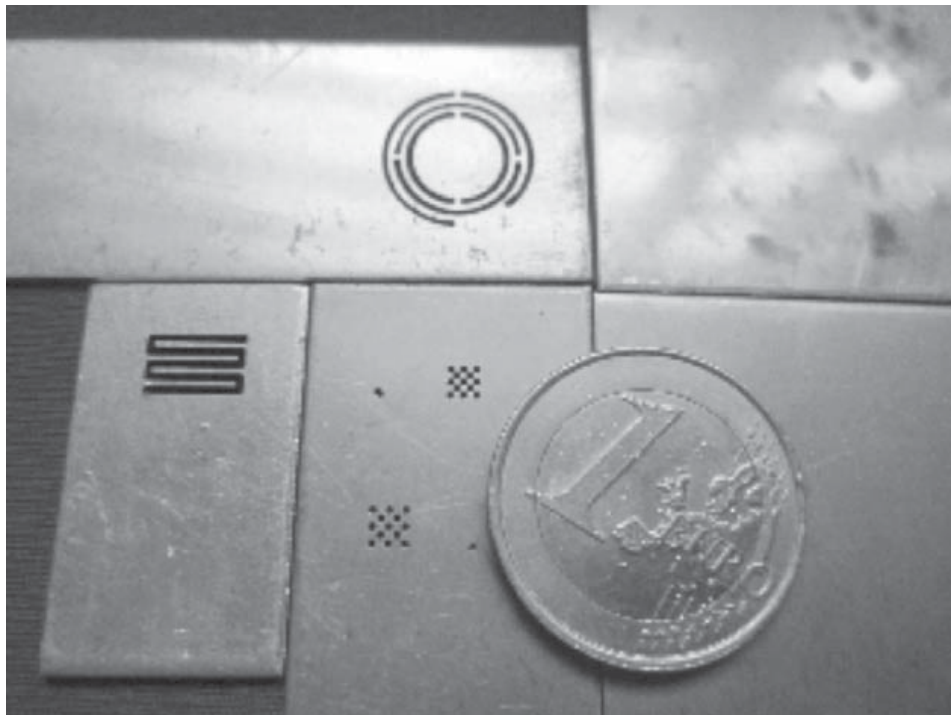


## Design Support for Micro Fabrication

Funding: Bench fees: €2950

Time Span: 1st October 2011-1st February 2013

This research is concerned providing design support in the micro domain. The demand for micro parts and products has increased rapidly recently. Some of the applications for such parts are micro sensors and actuators, micro surgery, medical implants and drug delivery systems. Processes such as micro milling, micro turning, micro injection moulding, micro EDM, micro hot embossing and laser ablation are used to fabricate such parts. A micro part may require more than one of these process. For example a micro injection moulded part shall require a mould insert which must be carried out using micro EDM; which in turn requires electrodes manufactured via micro milling. Hence when taking a decision regarding a geometrical feature of the plastic part to be moulded; the capabilities of all the processes must be taken into consideration. This gives the requirement of a multi technological perspective must be employed when providing design support. This involves the investigation of the physical principles involved during the micro processes concerned. For example the vertical and lateral forces on micro cutters during micro milling, as well as the effects of the spark gap and voltage on the electrode and metal removal rate during micro EDM. Once the processes have been fully understood, design support can be given with regards to the selection of the material and geometrical features of a micro part based on the multi technological knowledge gathered about the processes.



*Figure 1. Micro EDM fabricated parts*



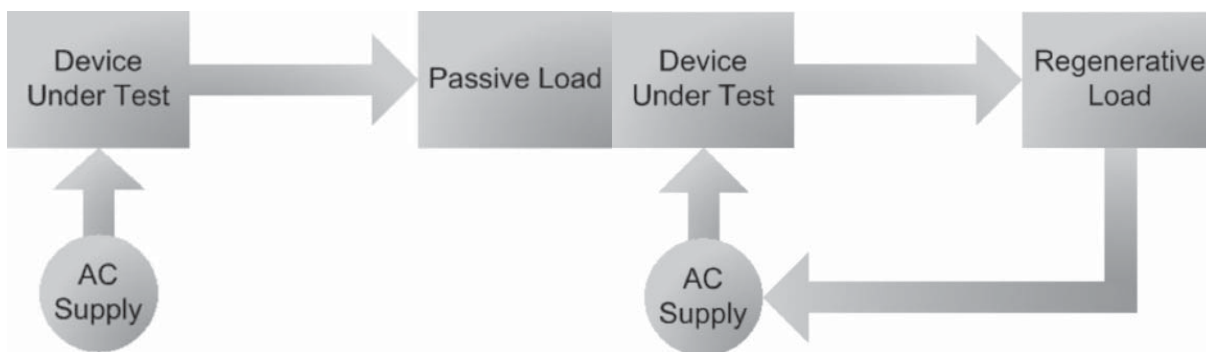
## Improving Efficiency during testing of DC equipment in Manufacturing

Researcher: Francarl Galea

Supervisor: Dr. Ing. Maurice Apap

Co-supervisors: Prof. Ing. Cyril Spiteri Staines, Prof. Joseph Cilia

This project focuses on improving efficiency figures in the testing equipment used by the manufacturing industry in order to test DC equipment. This project looked at two different types of DC equipment: DC power supplies and batteries. In both cases, the DC equipment is loaded using dissipative loads that convert the energy drawn from the DC power supplies or batteries into heat. A Regenerative load was designed to replace these dissipative loads. The regenerative load will allow testing of the DC equipment under the same conditions but instead of converting the energy absorbed during testing into heat, it redirects the energy to the grid as shown in Figure 2. The regenerative load has the potential to save up to 90% of the electrical energy that is currently being consumed during the testing of DC equipment.



*Figure 1: This project proposes to replace the dissipative loads with a Regenerative load to redirect back the energy to the grid*

The Regenerative load has been proven to save a considerable amount of energy during the testing of Power supplies, battery equipment or other DC equipment. Dissipative loads can easily be replaced by a regenerative load as long as it is operated within its operating conditions being; an input voltage range of 20V to 600V, a maximum input power of 2000W and a maximum continuous current of 50A.

The first case study has proved that the percentage energy savings obtained when testing power supplies with the regenerative load (excluding losses from the power supply itself) was from 72% to 88%. The second case study has proved that the percentage energy savings obtained when discharging the batteries with a regenerative load was 53% for Lead Acid batteries and 59% for Lithium Ion batteries (including all the losses incurred within the system during the cycling of batteries).

Acknowledgements: Research funding under the Manufacturing Research Platform project ERDF083, Operational Programme I - Cohesion Policy 2007-2013 "Investing in Competitiveness for a Better Quality of Life", project part-financed by the European Union European Regional Development Fund (ERDF).

Start date: April 2010

Duration: 2 years



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

### Objectives

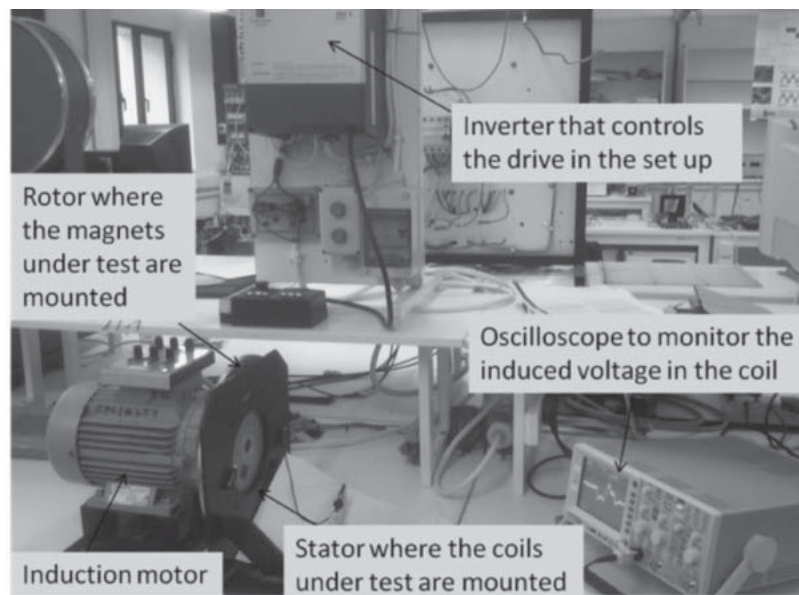
The aim of this research is to design and develop a brushless drive to be combined with a Stirling engine. In doing so, it would be possible to obtain a cost effective solution to exploit heat energy from the sun and convert it to rotational energy using a Stirling engine. In turn, this rotational energy is converted to useful electrical power, using this specifically designed brushless drive. The objectives of this research are to develop a low cogging alternator and also using the same drive to kick-start the Stirling engine and transfer the energy generated to the grid.

### Methods and technologies

It is of fundamental importance that the cogging torque of the brushless drive is negligible in order to be able to generate power with the least torque possible. Different techniques are being analysed in detail to conclude and implement the best design concepts, as discussed by several researchers in this area: dual alternator to create cogging cancellation, fractional pitch construction.

To obtain the above mentioned requirements, an axial flux alternator is being designed since it is possible to use a coreless construction and in doing so, the cogging of the drive could be significantly reduced. Rare earth magnets are being used in this implementation since these magnets offer the highest flux per volume of magnetic material. Several tests using different sizes and shapes of magnets, with several different coils are being carried out to study in depth the energy pulse induced in the coil, and its relation to the shape of the coils and magnets. This is of utmost importance to design an efficient drive.

In order to connect such a system to the grid, it is necessary to connect the above system to a rectification circuit, possibly a DC to DC converter and also an inverter. For each stage, readily available modules will be integrated into a system to obtain the maximum efficiency at all times. This study is being supervised by Prof J. Cilia and Dr. M. Apap from the Department of Industrial Electrical Power Conversion, and is also supported by an industrial partner, Sirius Systems Ltd.



*Figure 1: 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.*

Start: October 2011    Duration: 24 Months



## Sensorless Control of a Matrix Controlled Doubly-Fed Induction Machine

Research Student: Kris Scicluna

Research Supervisors: Prof. Ing. Cyril Spiteri-Staines, Dr. Ing. Maurice Apap

Department: Industrial Electrical Power Conversion

Research Sponsor: STEPS Malta

The use of wind turbines to capture wind energy has been on the rise for the past decade. Most of modern wind turbines being constructed use a Doubly-Fed Induction Machine (DFIM) to generate electricity. Hence this machine configuration is one of the most widespread machines used for wind energy.

DFIMs are typically controlled through vector control schemes, which require information about both the rotor angular position and angular frequency. Such measurements are usually provided via a speed sensor. The aim of this project is to implement sensorless algorithms, which are used in order to provide for the rotor angle and frequency through an alternative way, without using the sensor. The advantages of sensorless techniques include improved system reliability, robustness and cost reduction. The Model Reference Adaptive System (MRAS) which is a model-based sensorless technique was reviewed and implemented as part of this research. The advantage of MRAS algorithms is that they can be implemented on most vector controlled DFIM setups without the need for additional hardware.

The basic MRAS controller for the DFIM was studied along with various Stator Voltage Model implementations. The DFIM and the various sensorless algorithms were simulated using MATLAB/Simulink© and implemented on the experimental setup shown in Figure 1. The experimental setup uses a novel power converter topology known as a Matrix Converter which allows for direct ac to ac conversion without the requirement of a DC link.

This research is being conducted as part of a Master of Science in Electrical Engineering degree with the Faculty of Engineering, University of Malta.

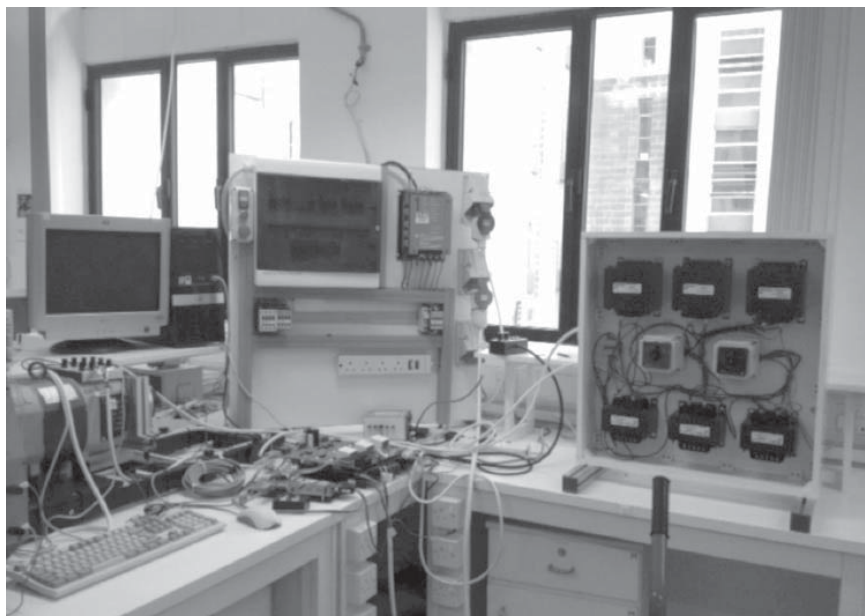


Figure 1 - Matrix Controlled DFIM Experimental Setup

Start: October 2011    Duration: 18 Months



## More Energy Efficient Electric Motor for the Manufacturing Industry.

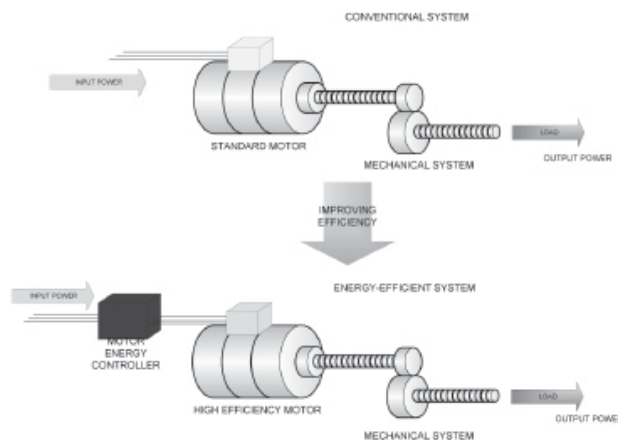
Key Expert: Prof. Ing. Cyril Spiteri Staines  
 Co-Supervisor: Dr. Cedric Caruana  
 Researcher: Mr. Peter Spiteri

Motor driven systems account for approximately 65% of the electricity consumed by EU industry. Switching to energy efficient motor driven systems can save Europe 202TWh in annual electricity consumption. This excess energy consumption represents an annual €10 billion operating cost and an unnecessary 79 million t/yr of CO<sub>2</sub>eq emissions. These figures make it very attractive to look into introducing several schemes and conducting case studies on the Maltese manufacturing industry, in order to increase the efficiency in factories of Malta.

The project carried out an extensive review and research concerning motor standards, motor energy controllers and energy efficient motors available on the market. A study of the motor population in the Maltese industry was carried out to establish the use and rating of motors in the different industries. In particular, plastic injection moulding plants and food processing plant were considered.

On-site monitoring on various motor driven systems was performed to analyse the operation of various motors. In many cases, it was found out that, apart from the fact that some of the motors were overrated, they operate most of the time at low load which means that their operation is inefficient. The efficiency of the motor driven system can be improved by installing a motor energy controller (MEC) which reduces the supply voltage of the motor and consequently the magnetising flux when it senses low load. Tests on such MECs were carried out in the lab and on-site and an average of 5% overall energy savings were observed. Another test was carried out by replacing an old standard motor with a new high efficient motor (Refer to Figure 1) and in this particular case an overall energy saving of about 25% was observed.

During the project a software application, named MEST (Motor Energy Saving Tool), was developed to guide technical persons in industry to take several measures in order to increase the efficiency in motor applications.



*Figure 1: A comparison between a conventional system and an improved efficiency system by introducing a motor energy controller and replacing the standard motor with high efficiency one*

Acknowledgements: Research funding under the Manufacturing Research Platform project ERDF083, Operational Programme I - Cohesion Policy 2007-2013 “Investing in Competitiveness for a Better Quality of Life”, project part-financed by the European Union European Regional Development Fund (ERDF).

## **Fabrication of Advanced Hybrid Composite Sandwich Panels – Testing and Simulation.**

Project financed by the Malta Council for Science & Technology through the National Research & Innovation Programme 2011 Joint partner with Buccaneer Boats Ltd, grant fund Error! Unknown document property name., 2 years, starting 12th September 2011

Main Investigator: Dr. C. De Marco

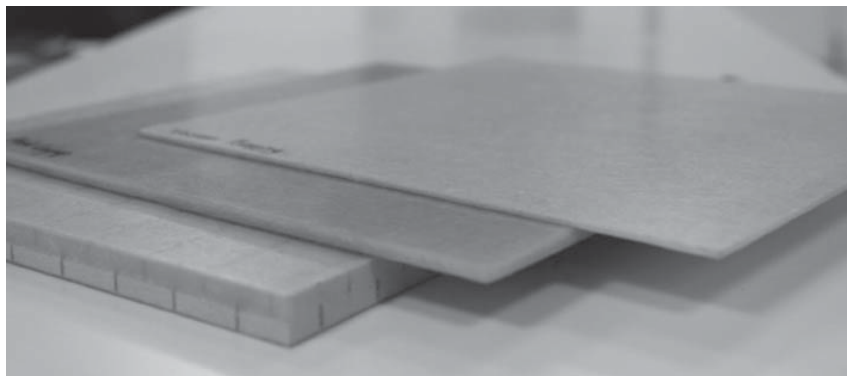
### **Description:**

Laminated composite hull panels are widely used in high speed light craft (HSLC), small pleasure craft and sailing yachts. The superior stiffness of the high-modulus fibres has resulted in an increase in use of these materials for fast marine vessels from lengths ranging a few meters long to vessels in excess of 50 m. Properties such as light weight, corrosion resistance, low maintenance costs, enhanced properties, and low magnetic characteristics have been successfully applied to marine vessels of all kinds.

Single skin composite laminate panels may lack stiffness due to their relatively low thickness, and when dealing with long ships, hull flexibility must be considered, since composite vessels have relatively low stiffness when compared to similar vessels of aluminium or steel construction, fatigue damages in the hull may result. In small craft design and in typical boat building locally, the boat builders, traditionally introduce stiffeners of wood encapsulate in additional fibre and resin, producing additional frames for strength, thereby adding to the weight of the boat and increasing the construction complexity.

A sandwich construction consisting of two high strength composite laminate skins are separated by a core material. The core material is light weight, with favourable properties of shear strength and stiffness. The panel which although may increase in thickness, does not suffer a weight penalty, and offers additional strength support, which acts as an I-beam shear web, as the global sandwich panels bend and flex during the in service loading, such as hydrostatic loads, bottom slamming loads, and impact load on the side shell.

The use of sandwich construction in boat building requires the utilization of advance construction techniques in order to gain the maximum performance from the build materials. Vacuum bagging is one such technique which lends itself not only to the primary structure of boats, but to all aspects of boat building. This fabrication process is an effective, cost-effective techniques utilising pressure difference to produce a superior high strength hybrid sandwich material.





## **Damage Analysis on Marine Vessels,**

Project financed by: UoM, grant fund € 3,000: Jan 2012 – ongoing  
Main Investigator: Dr. C. De Marco

### **Description:**

The project is to investigate the behaviour and response of ships' plating and structural frameworks on impact with either moving or stationary structures/ships and during grounding scenarios. The response and resistance of the material and structure to large scale deformation flow and possibly fracture of the plating and frames are to be investigated. Experiments on scaled bodies simulating the scoring, denting, perforation and puncturing of plating and small or large deformation of frames and sections are to be investigated. Analytical methods using proven elasto-plastic fracture mechanics for full size and scaled bodies and FEA will be used to analyse the experimental results. The objective is to be able to predict the amount of damage that can be sustained during such incidents and to possibly provide structural guidelines for such scenarios

## **Development of a Prototype Solar-Powered Stirling Engine for Domestic Electrical Power Generation**

Main Investigators: Dr. T. Sant, Dr M.Muscat, Prof. R.Ghirlando  
In collaboration with the Department of Industrial Electrical Power Conversion (Prof. Joseph Cilia)  
Stirling Engine Project - Funded by Industry (Sirus System Ltd.)

Funding: Euro45,700  
Period: Oct 2011 - Sept 2013

## **Design and Analysis of an Innovative Offshore Wind Turbine Support Structure for Deep Water Applications**

Main Investigators: Dr. T. Sant, Dr M.Muscat, Dr P. Mollicone, Dr D. Camilleri  
In collaboration with the Institute for Sustainable Energy (Ing. Robert N. Farrugia)  
DeepOffshoreWind (DOW Project) - Funded by MCST (R&I-2009-003).

Funding: Euro98,000  
Period: Oct 2010 - Nov 2012

## **FiReComp – Innovative Fibre Reinforced Composites Designed for Higher Structural Stiffness**

Main Investigator: Dr. D. Camilleri  
Funding Body: MCST – National Research & Innovation Programme 2009  
Funding: Euro 100,000  
Period: 2 years – Start date Feb 2011

## **HILDA – High Integrity Low Distortion Assembly**

Main Investigator: Dr. D. Camilleri  
Funding Body: European Commission FP7  
Funding: Euro 2,139,939  
Period: 3 years, Start date to be established



## **SATVAWT - Self Adjusting Torque Vertical Axis Wind Turbine**

Project financed by the Malta Council for Science & Technology through the National Research & Innovation Programme 2011

Main Investigators: Dr. P. Mollicone, D. T. Sant, Mr. D. Micallef

Consortium: Econetique

Department of Mechanical Engineering, Faculty of Engineering, University of Malta

Alurwind

Architectural Projects – AP

Vertical Axis Wind Turbines (VAWTs) are a class of wind turbines that, due to their intrinsic design, do not need to be oriented into the wind direction. Whilst this gives them a number of advantages over other types of wind turbines, current technology for VAWTs suffer from problems of start-up and maximum torque output.

The SATVAWT project is aimed at developing a novel design adaptation to VAWTs in order to improve their starting speed and control capability. The development will lead to an increase in efficiency and range of applications, making this type of wind turbine attractive for use in densely populated areas by integration to existing landscape. The development will also bring about knowhow on the most feasible design for future manufacture and distribution from local industry.







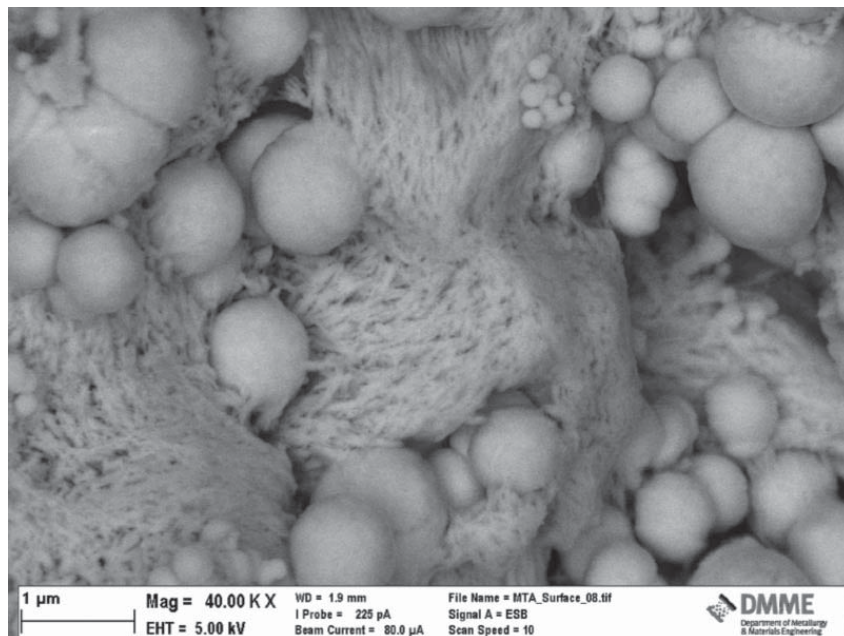
## Investigation of a novel biomaterial for use in dental applications

Mineral Trioxide Aggregate (MTA) is a dental root-end filling material comprising 80% Portland cement with 20% bismuth oxide radiopacifier to make the material distinguishable from body tissue on X-rays. The main advantage of MTA is its bioactivity – it reacts with body fluid to develop a surface layer of bone-like hydroxyapatite. This layer imparts biocompatibility and gives MTA excellent sealing ability.

MTA's disadvantages include long setting time (>3 hours) and poor resistance to “washout” (tendency of cement to disintegrate upon premature contact with liquids). My research aims at investigating novel MTA-based materials to address these shortcomings, namely MTA mixed with proprietary antiwashout gel to impart washout resistance, and MTA mixed with dental light-curing or chemically-curing resin (instead of water) to reduce the setting time.

The setting time of the novel MTA is just 20 seconds with light-curing resin and 22 minutes with chemically-curing resin. A novel method for evaluating washout resistance was developed and published in International Endodontic Journal. Testing revealed that the antiwashout gel successfully mitigated washout.

The materials have been characterized and their hydration mechanisms studied using techniques including scanning electron microscopy, X-ray diffraction and Fourier-Transform Infra-red spectroscopy. Furthermore, the materials are being tested for their suitability as root-end fillers following ISO standards for assessment of radiopacity, compressive strength, calcium ion release, pH, fluid uptake, porosity, micro- and nano-hardness and adhesion strength to extracted human teeth.



*View of MTA surface at 40,000x zoom, taken with an electron microscope at the DMME. The MTA was cured for 28 days in physiological solution prior to taking this image. The spherical particles are hydroxyapatite (refer to text).*



## **An Investigation on the Effect of Environmental Degradation on Glass Fibre Reinforced Composite Material Properties.**

### **Introduction**

Composite Materials offer significant properties over other materials such as weight and cost saving and the ability to design the material as required. This results in energy savings and opportunities for technological improvement that reduce running costs and emissions, as well as new product solutions and designs 1.

Composites are selected for various applications, including automotive, aerospace, medical and maritime which result in exposure to a variety of environments, and this can lead to synergistic degradation with property loss, associated repair costs and reduced performance 2.

### **Aim & Objectives**

The University of Malta has analyzed the qualitative changes to composites, by environmental degradation. Currently, quantitative analysis of their property changes is being investigated. Methodology includes:

- 1) Measuring properties of as-manufactured samples.
- 2) Expose samples to accelerated degradation for 500 and 1500 hours.
- 3) Mechanical testing of the exposed samples to map the property change.

The subsequent results will help designers and industry understand how the material will behave during in-field applications and provide data for engineered decisions on how to cater for this environmental effect. This gained knowledge will offer industry:

1. An understanding of how the environment changes material properties;
2. Information that can be applied to improve a design, to avoid excess or insufficient material.

The improved designs and material application from this knowledge base can make a product more competitive whilst reducing costs and introducing weight savings and technological improvements that reduce running costs and carbon footprint. Longer product life furthermore means less waste and environmental impact.

### **References**

1. Miracle, D.B. and S.L. Donaldson, Introduction to Composites, Air Force Research Laboratory.
2. Armstrong, K.B., L. Graham, and W.F.C. II, Care and Repair of Advanced Composites. 2nd Edition ed, Warrandale, Pa: SAE International.

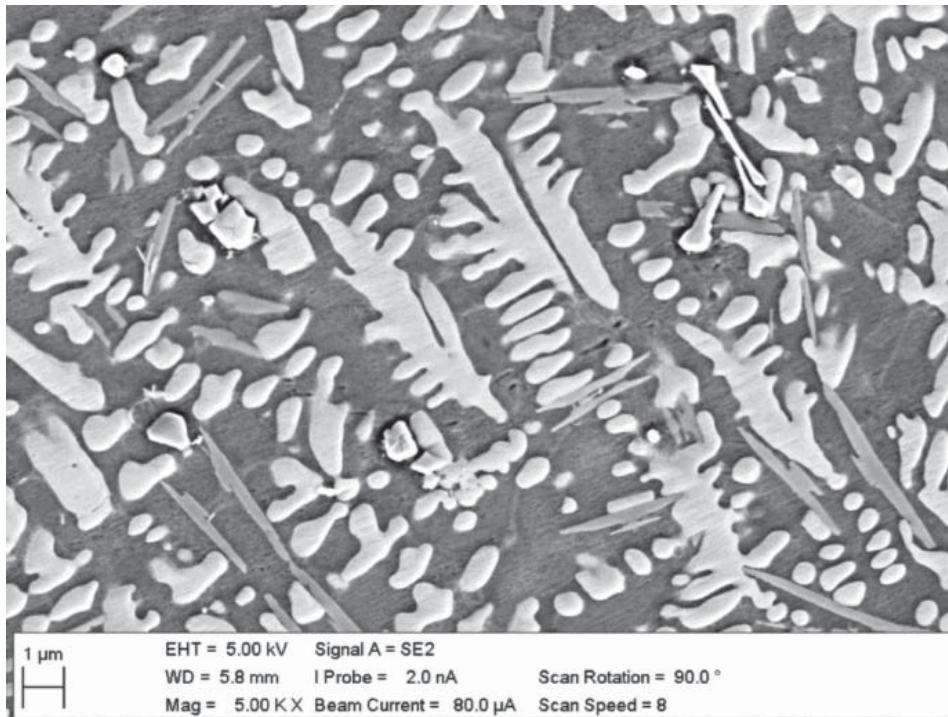


## An Investigation on Laser Surface Processing of Aluminium Alloys

### Abstract

Aluminium alloys find use in a wide range of application due to their low density and ease of fabrication, but their poor hardness and tribological characteristics limit the extent of their use. In this study laser surface processing of aluminium alloys is investigated as a means to improve the properties of the surface of such alloys. Laser remelting and alloying on an A356 aluminium alloy was carried out using a CO<sub>2</sub> laser, equipped with a coaxial powder delivery system. The parameters needed for such processing in order to create uniform and repeatable surface layers were identified and optimized.

A considerable improvement was achieved with laser alloying with nickel, where a hardness improvement of nearly 3 times that of the untreated material was reported for uniform crack-free surfaces. Microstructural, chemical and phase analysis of such surfaces showed that dendrites of Al<sub>3</sub>Ni and Al<sub>3</sub>Ni<sub>2</sub> intermetallics were formed in the microstructures; these being the cause of the high hardness achieved. Further experimentation with the introduction of ceramics in the alloyed surfaces proved to be successful since alloying with Ni-Ti-SiC and Ni-Ti-C resulted in the formation of fine TiC particles. The resulting microstructure was in fact made up of TiC particles dispersed evenly in a structure of aluminium-nickel and aluminium-silicon-titanium intermetallics within an aluminium-silicon matrix. The presence of these carbides and intermetallics could be beneficial to wear resistance, thus further experimentation is due in this respect.



*SEM image of the microstructure of a surface alloyed with Ni-Ti-C*

## In-vitro studies of cobalt chromium molybdenum biomedical alloys

The project aims to test the in-vitro biocompatibility of Cobalt-Chromium-Molybdenum alloys (Co-Cr-Mo) which have been surface treated by a process called Kolsterising®. Kolsterising® is a low temperature carburizing process that can be used on medical alloys due to the hardness it imparts to the surface, without reducing its corrosion resistance. Kolsterising® is a proprietary surface hardening treatment by Bodycote GmbH.

The objective of this research is to analyse the biocompatibility of Kolsterised® cobalt-chromium-molybdenum alloys, and to characterise the material surface in order to show the advantages gained by using the Kolsterised® material relative to the original untreated alloy, and other materials. This work will be conducted on four approaches including: (1) material characterisation, (2) in-vitro corrosion testing, (3) in-vitro corrosion-wear testing, and (4) biological testing conforming to ASTM F748-04.

From preliminary results in the first few months of the Ph.D. study, S-phase formation was observed on the Kolsterised® material. The actual thickness of the S-phase layer, 13.4µm, was confirmed by SEM analysis of the etched sample. Although thinner than the Kolsterising® layer normally created on stainless steels it is still thick enough to protect the underlying softer material. Preliminary nano-indentation tests show that the hardness of the S-phase layer on Kolsterised® Co-Cr-Mo is  $17.38 \pm 0.30$  GPa (99% confidence limits) which is 2.5 times greater than the hardness of the untreated material which has a hardness of  $6.78 \pm 0.08$  GPa (99% confidence limits).

Cell viability testing and other biocompatibility tests will also be carried out using both mouse and human osteoblast and pre-osteoblast cell lines in the laboratories of the Department of Anatomy which were recently refurbished using funds from ERDF project 081. This will then pave the way for future research to be carried out, in order to ensure that the Kolsterised® Co-Cr-Mo system is proven to be biocompatible, permitting its use as a material for hip and knee replacements as well as in other biomedical components.

Sponsored by: Bodycote GmbH.

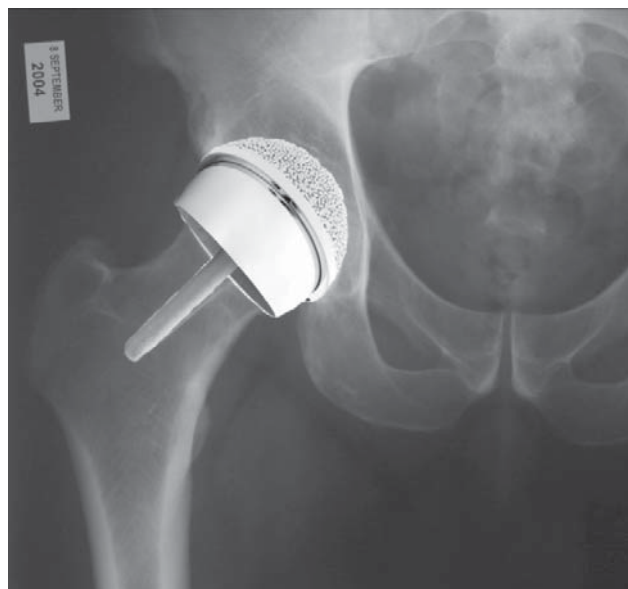
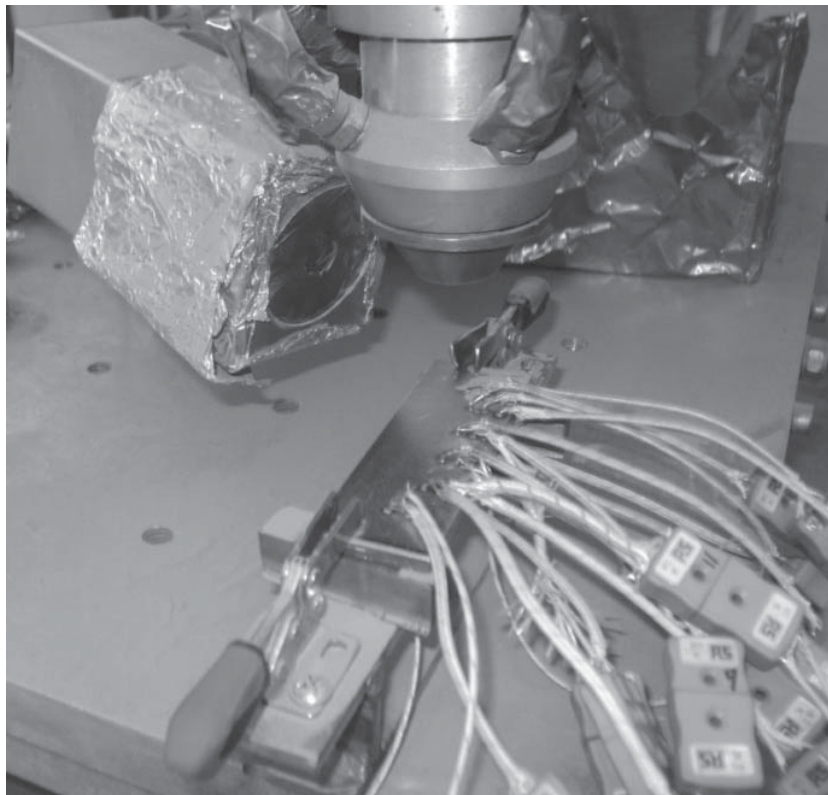


Figure: superposition of Birmingham hip replacement prosthesis onto X-ray image of pelvic area adapted from: [http://www.childrenhealthwatch.com/wp-content/uploads/2010/09/wp-id-1285631496\\_hip-resurfacing.jpg](http://www.childrenhealthwatch.com/wp-content/uploads/2010/09/wp-id-1285631496_hip-resurfacing.jpg) (viewed: 14/04/2012) and <http://www.qmtmag.com/images/BHR-device.jpg> (viewed: 14/04/2012)



## Characterization and modelling the laser deposition of 3-dimensional structures

The need for a reduction in the time between the initial concept design to the finished part led to the development of various rapid fabrication techniques such as Laser Material Deposition (LMD). This manufacturing process utilizes a laser, metallic powder, and a CNC machine to fabricate three-dimensional fully dense and fully functional components. LMD involves complex thermal, mechanical and metallurgical interactions. Due to these interactions, the optimum parameters need to be defined in order to produce models with improved thermal-mechanical properties. An experimental approach may be used to find the optimum parameters, however, this is quite a costly and time consuming method. The finite element method (FEM) may be used to accurately model this process, allowing for optimized selection of input parameters. In this study Ansys was used to model the laser material deposition process to predict thermal histories and residual stresses developed in the deposited clad walls. Thermocouples and XRD were used to measure the temperature and residual stresses respectively in order to compare the simulation results with the experimental results for validation purposes. A parametric study was performed to determine how the thermo-mechanical properties vary with these parameters. The microstructure of each clad wall produced was also evaluated in order to investigate the effects different process parameters have on the microstructure. Moreover, changes in the dimension and shape of the melt pool due to heat build up during deposition and the resulting changes in model geometry were investigated by the use of both a coaxial camera and a mounted side camera.





## Nano-particle based consolidants for Globigerina Limestone

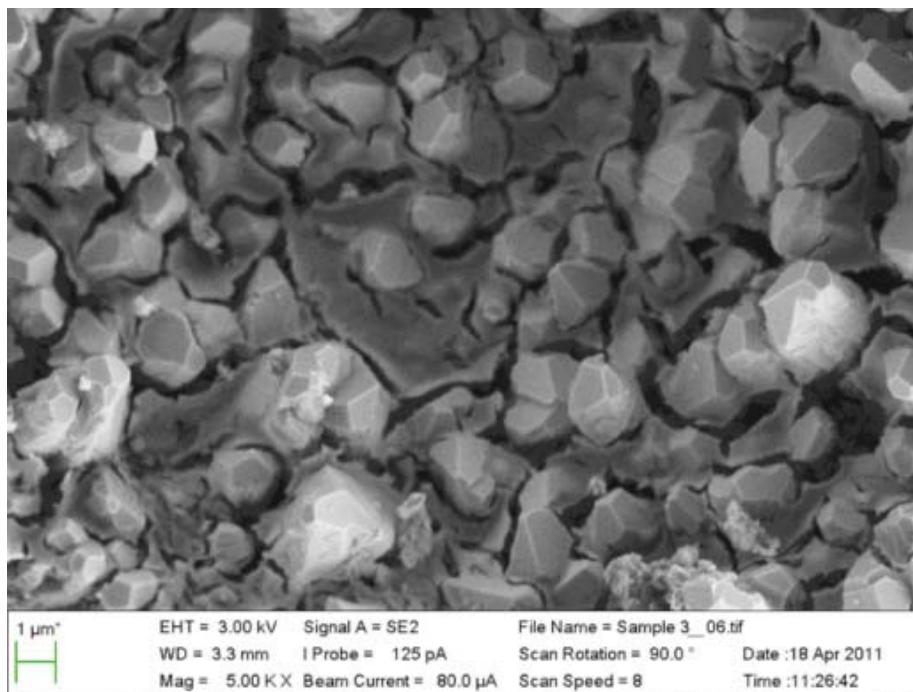
Sponsored by: STEPS

Weathering processes are continuously affecting buildings and stone monuments. Natural weathering is inevitable and the degree of deterioration depends on the type of stone. Consolidation is one way in which stone monuments can be protected. Consolidants are materials that penetrate into the stone matrix and act by gluing together the deteriorated stone material with the underlying healthy stone.

Lime-based consolidants are widely used in Malta where the main building material is a sedimentary limestone. Commercial alkoxy silane consolidants have also infiltrated the local market, yet the effects of these materials on local Globigerina Limestone are still not well documented. In this work, Globigerina Limestone test specimens are treated to the following silica hybrid consolidants:

- (i) A silica consolidant produced from tetraethylorthosilicate (TEOS);
- (ii) A silica hybrid consolidant composed of silica with epoxy-group functionalities;
- (iii) The hybrid consolidant indicated in (ii) with 2 % (wt/v) loading of 10nm particles;
- (iv) The same hybrid indicated in (ii) but with 2% (w/v) loading of 10 nm epoxy-functionalized particles.

The consolidant treatment was applied by fully immersing the test specimens in the consolidant or by brushing. A number of limestone specimens were also left untreated to serve as controls. Following application, treated specimens were left to dry and subject to accelerated weathering (wet-dry cycles with intermittent UV exposure). Following the weathering regime, consolidant – limestone systems will be characterised through colorimetry, optical and electron microscopy and infra-red spectrometry. The physical properties of the consolidated stone will be assessed through Shore hardness, micro-drilling, resistance to sodium sulphate crystallisation and a water absorption by capillarity test.





## Spatio-temporal Analysis of Pollution Data

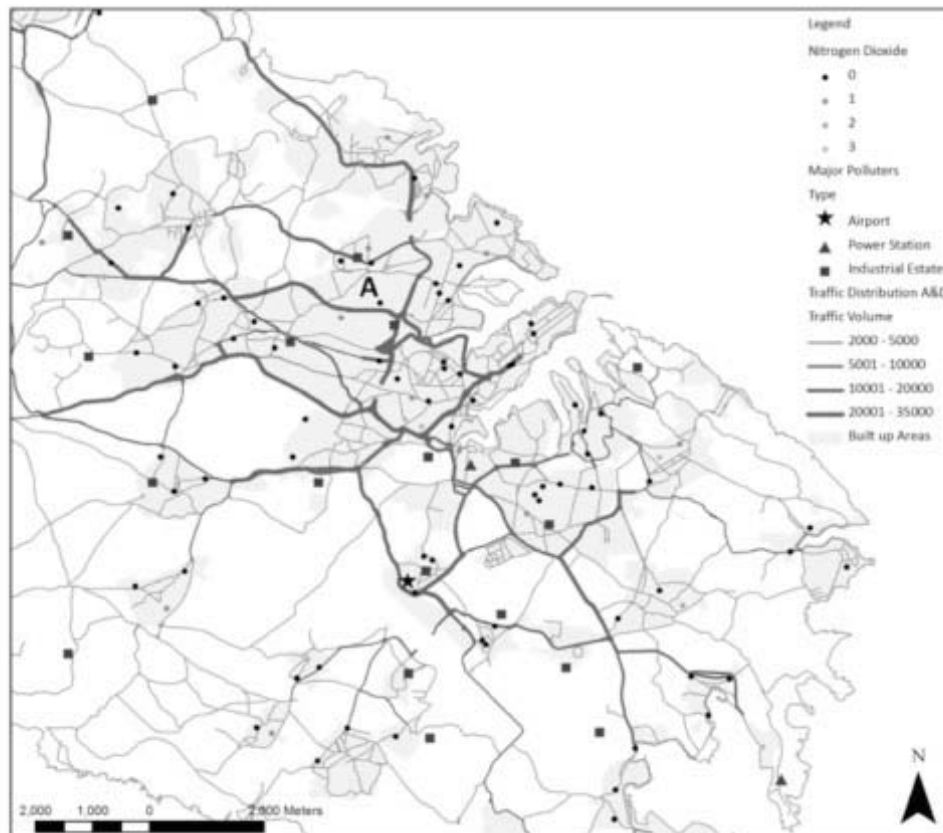
Main investigators: Dr. Kenneth Scerri and Ms. Luana Chetcuti Zammit in collaboration with Dr. Maria Attard and Ms. Therese Bajada at the Institute of Sustainable Development at the University of Malta and Mr. Mark Scerri at the Environment Protection Directorate of the Malta Environment & Planning Authority.

Funding: Malta Government Scholarship Scheme (MGSS)

Project start: October 2011

Project Duration: 3 Years

The Environment Protection Directorate of the Malta Environment & Planning Authority has been collecting pollution measurements using diffusion tube technology since 2004. Unfortunately, this data has not been extensively analyzed, mostly due to the technical challenges involved in dealing with such noise corrupted measurements. The aim of this project is to apply a systems theory approach that effectively deals with the noise introduced in the measurements for the analysis and modeling of this data. This work has shown that pollution patterns in Malta are highly uncorrelated, indicating that local sources rather than diffusion are the prominent dynamics behind these pollution measurements. Future work aims to obtain transport models describing the travel patterns in Malta and quantitatively relating these models to the pollution patterns being observed. The pollution modeling results have been recently published at an international conference and this work was chosen by the conference chairs for publication in a special journal issue covering the conference.



*Correlation analysis results*



# 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
- Avionic Application Laboratory:
  - Presagis VAPS and VAPS XT - HMI rapid prototyping tools
  - MicroNav Best - ATM simulator
  - Class A Aircraft simulation test bed
  - Model Aircraft simulation and training software
  - UAV flight control application board
  - UAV test bed

## Department of Industrial and Manufacturing Engineering

- CAD/CAM SYSTEMS LAB
- CAD Systems (2D, 3D, Animation)
- CAD/CAM Systems
- MoldFlow, 3D Studio, AutoCAD, Autodesk Inventor
- Tecnomatix - manufacturing development and simulation package

### CERU Lab

#### Concurrent Engineering Research Facilities

- Thermoplastic Design Guidelines
- Picza LPX-250 3D Laser scanner
- RIAL Facilities
- 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

### 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
- CNC LAB
- CNC Vertical Milling Machine
- CNC Vertical Machining Centre
- NON CONVENTIONAL MACHINING LAB
- CNC Electric Discharge Machining (EDM) with Micro EDM capabilities
- Rapid prototyping equipment Plastic – Dimension 1200es
- Rapid prototyping equipment Titanium - ARCAM EBM S12 (Electron Beam Machining)

**Department of Industrial Electrical Power Conversion**

- Grid Connected PV and Wind Systems
- Harmonic Voltage and Current Measurement Set-up
- High voltage and current DC supplies
- Passive/Active Filters for Power Factor Improvement
- Switching Frequency Current Sensing for Power Electronics and Control
- Electrical Drives
- 200V AC 28kVA 3-phase and 200V DC 20kW Supply for Testing Purposes
- Electrical Drives and Control Simulation Software
- High Performance Machine Control
- Medium Power DC Machine Loading Units
- Vector controller Induction Motor, Permanent Magnet Synchronous Motor and Switched Reluctance Rigs
- Electrical Mobility
- Electric Car
- Electric Boat
- Water Tank for Electric Outboard Testing
- Solar Catamaran

**Department Of Mechanical Engineering****Thermodynamics Laboratory**

- Laboratory experiments for thermodynamics and heat transfer
- Testing beds for internal combustion engines
- One electrical dynamometer, two water brake dynamometers and other smaller dynos
- Demonstration type gas turbine
- Testing beds for air conditioning setups, including variable speed (inverter) compressor
- Heat transfer in pipe testing facility
- Supersonic nozzle setup testing bench
- Labview and Keithley data acquisition systems

**Mechanics and Mechanical Testing Laboratories**

- Machine vibrations diagnostics
- Vibration monitoring equipment and software
- Run-up Run down vibration testing equipment
- Modal analysis equipment
- Dynamic balancing of machines testing bed
- Sound level monitoring equipment
- Tensile and impact testing equipment
- Strain gauging equipment and data acquisition cards

**CAE Lab - Computer Aided Engineering Laboratory**

- Computer facilities to run the following engineering software:
- FEA – Finite Element Analysis – ANSYS: academic and research licenses
- CFD – Computational Fluid Dynamics Fluent: academic licenses



- MATLAB/Simulink: academic licenses
- CAD – Computer Aided Design SOLIDWORKS
- WindPRO (EMD)
- WAVE/VALDYN (Ricardo)
- FloTHERM
- Maxsurf

#### **Fluid Mechanics Laboratory**

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

#### **Welding Laboratory**

- Semi-automated welding rig capable of measuring thermal and distortion transients developed during fusion welding

### **Department of Metallurgy and Materials Engineering**

#### **DMME Laboratory**

- 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

#### **Support Equipment:**

- Manual Surface grinder
- Manual/ automatic sample polishers
- CNC and Manual Milling
- Lathe
- Multistage Ultrasonic cleaners
- Degreasing Facility
- Sand blasting
- Power hacksaw
- Welding (GTAW, MMA)
- Oxyfuel gas brazing / welding

#### **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
- 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 Spectroscopy (LIBS) for elemental qualitative analysis

**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
- Foundry
- Heat treatment and Laser processing Laboratory
- Physical Vapour Deposition Laboratory
- Mechanical Characterization Laboratory
- Nano Analytics Laboratory



## **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
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- Matlab and Simulink Research Licences

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- 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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# Electrical Stream

# A very fast, line-following Wheeled Machine adapted to imitate Aircraft Landing Systems

**Student: Matthew Borg**  
**Supervisor: Prof. Carmel Pule'**

## Introduction

In bad weather such as in heavy fog pilots have to rely on instruments to land an aircraft since their visibility is greatly impaired. It could be very useful if there would be a system that follows visible and invisible line contours to help the pilots especially during landing.

## Project Objectives

The aim of this project is to synthesize a machine which would move horizontally on the floor following a painted curve which would simulate an aircraft closing in to the centreline of the runway. In this project only the localizer which provides lateral guidance to the aircraft was simulated.

## Project Methodologies

The project was tackled as follows:

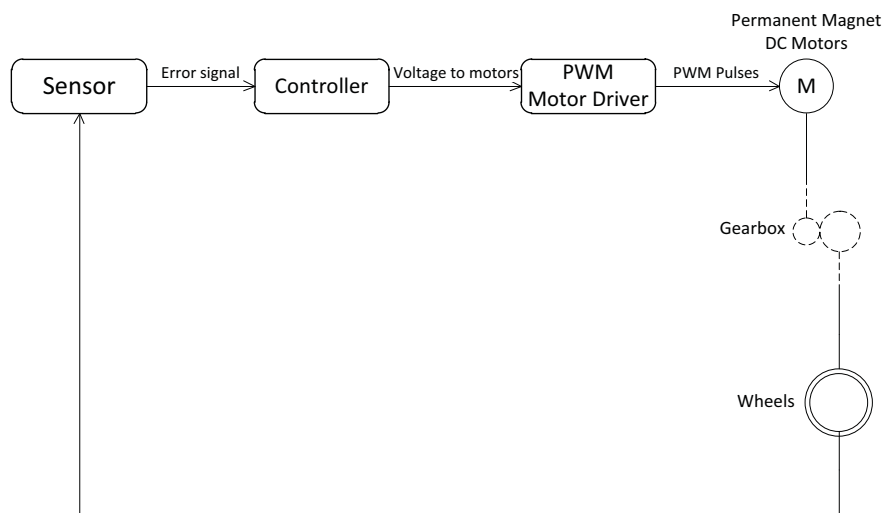
- First a literature review on Instrument Landing Systems was done along with researching ways in which this wheeled machine could be built electrically and mechanically for best performance.
- Designing the electronic circuitry required and simulating how it would perform when

built. In a nutshell, the circuit consists of a sensor comprising of 8 LDRs which indicate the position of the line. Using the sensor's output the distance from the centreline could be calculated. This is then fed to a controller which determines the best way how to drive the motors in order to improve the response and reduce oscillations as far as possible. Then the motors are driven using Pulse Width Modulation (PWM) which increases the efficiency of the system by up to 30%. The system is powered by four 3.7V 3000mAh Lithium-ion batteries which have a larger energy density compared to other batteries and are also much lighter.

- Then the circuit was built on a prototype board and tested. After successfully testing the circuits, a PCB was designed to make the circuits permanent.
- Finally the controller was tuned to give the best performance possible.

## Results and Achievements

A stable and reliable system was obtained in which the machine followed the line painted on the floor accurately and at a reasonable speed. The machine may show some difficulty in tackling sharp corners because of its speed however it follows straight lines and moderate curves very well.





# Design of an Embedded System for GPS & IMU Data Fusion

**Student: Andrew Terry Buttigieg**  
**Supervisor: Ing. Paul Zammit**  
**Co-supervisor: Dr. Ing. David Zammit Mangion**

## Introduction

Multiple Sensors often can measure the same or similar parameters, each with its own accuracy, limitations and error characteristics. What if accuracy can be improved, if these sensors could be merged? In this case two distinct navigation sensors GPS (Global Positioning System) FV-M8 and IMU (Inertial Measurement Unit) ADIS16350 are combined exactly for that purpose. The aim of the project is to develop a platform capable of fusing data from both navigation sensors to achieve better estimates of Position, Velocity and Acceleration, than possible with each individual sensor alone.

## Project Objectives

The main objective was that of building an embedded system for IMU and GPS data fusion, this main objective is subdivided in the following parts:

- Design of electronic circuitry capable of interfacing GPS and IMU to a central processor.
- Prototyping of the system, on a printed circuit board – design, manufacture and assembly
- Development of Firm-ware to operate system, and communicate to a host system such as a personal computer
- Testing and Utilizing the system to obtain data sets for the Data fusion process

## Project Methodologies

The primary step of the project involved researching and understanding the sensors utilized, and of reaching to a conceptual model of how these can be combined. (See figure 2) The secondary step was the actual electronic design of the system with rigorous printed circuit board specifications and tolerances in mind. Thirdly the manufacture of the printed circuit board was carried out via an international company called PCB-Pool®. (See figure 1)

The whole design was completed, the printed circuit board manufactured and preliminary tests carried out. Difficulties were encountered in the actual soldering of components, due to the small dimensions and these being done by hand. The voltage supplies of circuit were stabilized and the next stage was to test out the MCU (micro-controller unit), Firmware programming of the MCU and then connection of the platform to the PC (personal computer) over serial link.

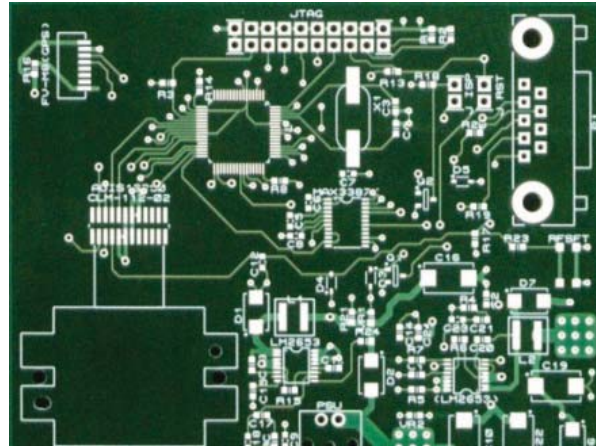


Figure 1: Printed Circuit Board for Data Fusion of INS and GPS information

Soldering of components on the PCB (Printed Circuit Board) was then carried out. Lastly firm-ware was developed, programmed and debugged. The system was made operational ready to be tested out with data fusion algorithms.<sup>2</sup>

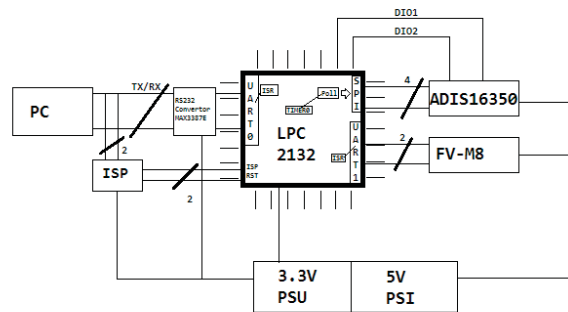


Figure 2: Conceptual Model for Data Fusion platform Results and Achievements

# Displaying 3D Transients in Inverters and Networks

**Student: Gordon Camilleri**  
**Supervisor: Profs C. Pule**

## Introduction

Inverters are an efficient and convenient sources of AC power, be it a fixed frequency application or one that requires variable frequency. Electrical signals in the inverter itself can be interpreted in a three dimensional from. These three dimensional displays of the output of the inverter, would from a transient set which would have their limit bounded by two circles of different diameter, whereby the output is assured to be a smooth sinusoidal waveform.

## Project Objectives

The final goal of this thesis is to obtain the circle boundaries as close together as possible to minimize harmonics. This will be done using different types of switching. While explaining such types, the use of both theory and software is to follow.

## Project Methodologies

This thesis is mainly organized as follows: First, a study is made on the types of switching and the effect these have on harmonics and transients. The output waveforms are to be plotted on an oscilloscope in the X-Y domain and a circular output is expected. Depending from the shape, distortion and orientation of such an output, one can determine the characteristics of such a switching type.

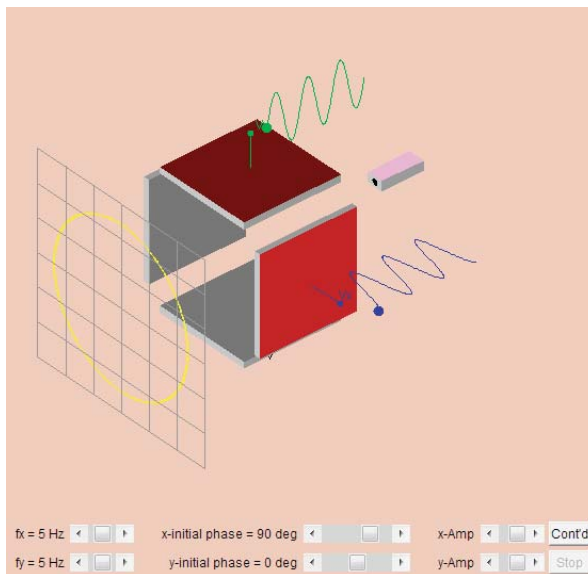


Figure 1: XY Plot Expected Output 2

An inverter uses switches in order to produce the output required. It uses a type of modulation in which the switches are switched on and off in an orderly

fashion to produce a sine wave. If turned on and off only once in each cycle, a square wave waveform results. However, if turned on several times in a cycle, an improved harmonic profile may be achieved. The types of switching and control in inverters are discussed

Secondly, BBC BASIC and MATLAB/SIMULINK models are built in the dq-axis rotor reference frame. The Stator Flux trajectory is discussed and understood

As a final goal, the proposed direct torque control of the induction motor method is developed in MATLAB/SIMULINK using the rotor reference frame with the help of inexpensive hall-effect sensors without using any DC-link voltage sensing.

## Results and Achievements

Since this thesis is mostly theoretical and research based, almost all results are produced by simulation with software. Various programs were written using two different kinds of programs: BBC Basic and Matlab/Simulink. Also, a PCB needs to be developed in order to show a mimic of the current trajectory that would be seen at the current output of a motor. The following chapter is divided into three sections, each section explaining what program was used and what was simulated.

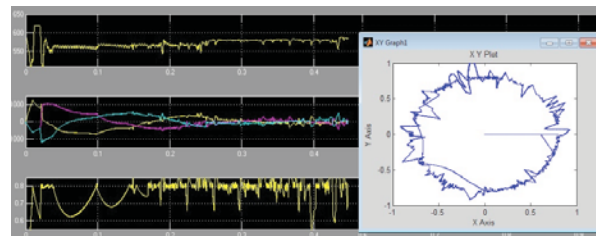


Figure 2: Matlab Output

## References

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- 2 D.Casadei, G.Serra G.Buja, "Direct Stator Flux and Torque Control of an Induction Motor: Theoretical Analysis and experimentation results," Proceedings of the IECON '98, pp. T50-T64, 1998.
- 3 D. Wang K. Zhou, "Relationship Between Space-Vector Modulation and Three-Phase Carrier-Based PWM: A Comprehensive Analysis," IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, vol. 49, no. 1, February 2002.
- 4 Microchip, "Sensorless Field Oriented Control of PMSM Motors," AN1078, 2008.



# Low Power Piezoelectricity Energy Harvesting

**Student: Jason Caruana Camenzuli**  
**Supervisor: Prof. D. Zammit Mangion**  
**Co-supervisor: Ing. Evan Dimech**

## Introduction

Harvesting small amount of energies from environmental sources to power portable or remote electronic devices which work in the mW range has been the incentive for carrying out this thesis. Even though the main materials available that are capable of energy coupling have been around for decades, their harvesting capabilities haven't been examined until recent years. Only recently have electronic devices evolved in a way so that their power requirements have gone down and the gap between energy scavenging from environmental sources and power requirements has narrowed.

## Project Objectives

Analyzing and investigating present energy harvesting solutions.

Designing and developing methods to enhance the power output of a piezoelectric energy harvesting device to power an autonomously/partially powered automotive electronic sensor.

## Project Methodologies

The thesis starts with an investigation of present power harvesting technologies available for harvesting from the different types of energy source, including solar, thermal and the various types of mechanisms to harvest from vibrations detailing power output levels found from literature.

Following this, reasons for focusing on piezoelectric conversion of vibration energy were outlined and an overview of the piezoelectric concept and materials was introduced. A view of the technological contexts with approaches to power enhancement of piezoelectric generators was given.

The thesis then progressed to studying methods of enhancing the power output of a piezoelectric energy harvesting device. Through initial investigation, the power output of a prototype device using a simple test setup was observed. A computer-based optimization algorithm was developed with Matlab to predict outputs and optimize the device.

The second part concerned the harvesting circuitry. Initial investigations were performed using the prototype harvesting device and a bridge rectifier circuit. The operation was also analysed via circuit simulation. The mechanisms that limit power from being transferred from the harvesting device to the load were observed and analyzed from the simulation. Following this, a new harvesting circuit concept was proposed. The new concept comprises: a Synchronised Switch Harvesting on Inductor (SSHI) functional block, which boosts the output voltage of the piezoelectric generator; a 'storage' functional block, and a 'DC-DC converter' block which can provide regulated DC power to an end application system. In figure A, the block diagram shows the relevant blocks and connections.

A prototype circuit that can implement the concept was designed and built, using a mixture of discrete and integrated components, and the performance of the concept was assessed through an experimental and simulation approach.

## Results and Achievements

Both the analytical model simulation and new harvesting circuit concepts provided methods of enhanced power output. The model helped in designing for the optimized parameters of the material. The new circuit concept provided an approximate of 80% more energy harvested into storage over the commonly used bridge rectifier. At the time of writing the circuit is now being compared to other techniques found in literature to verify its efficiency.

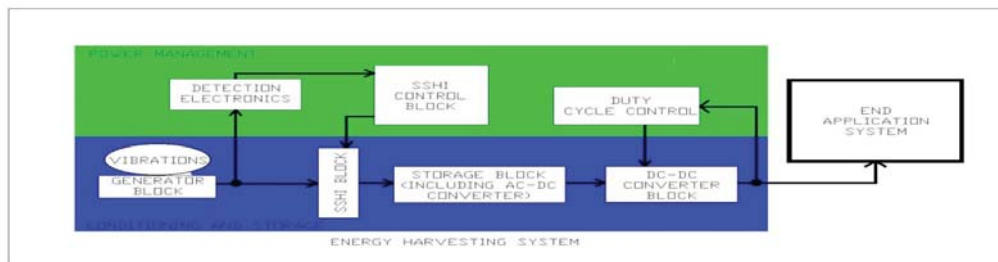


Figure A: Block Diagram of proposed harvesting circuit and envisaged power management circuitry

# An Asymmetric Data Transceiver System for a U.A.V.

**Student: André Cilia**

**Supervisor: Ing. Marc Anthony Azzopardi**

## Introduction

Long distance communication has been a challenge for humanity for millennia. Radio technology can provide long distance transmission and reception of data. However, it is difficult to give a direction to radio signals, and a lot of power is required to achieve successful reception at long distances.

Free space optical communications solve this problem by using lasers. Their narrow beam contains all the power required for long distance transmission and the signal to be transmitted.

## Project Objectives

The aim was create a highly directional network between two data terminals (a U.A.V and a ground station), through which data and commands can be transmitted and received as shown in Figure 1.

The directionality of the network ensures that the power used to transmit the required data is used as efficiently as possible by directing it only where this is required 1.

This directionality also has the added advantage of making the system practically tap-proof. In fact for an eavesdropper to successfully gather any information, he must be located across the beam. Also, such activity is easily detected, since the transmission of data is interrupted or severely hampered.

## Project Methodologies

The whole project was subdivided into the following categories:

- Conducting a Literature review of other similar works was conducted so as to find the best way to implement this system. Hence a list of subdivisions required for successful transmission and reception was created as can be seen in Figure 2.
- Creating a test to ensure that Ethernet works on a directional cable pair.
- Designing and simulating the required circuitry for the different sub-sections.
- Designing and etching the boards implementing the designed circuitry.
- Testing the individual subsections to ensure correct operation at the required frequencies.
- Connecting a network between two computers or a computer and a network webcam.

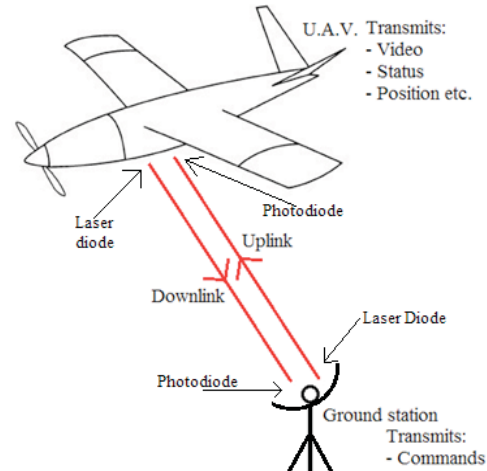


Figure 1: Description of the network configuration

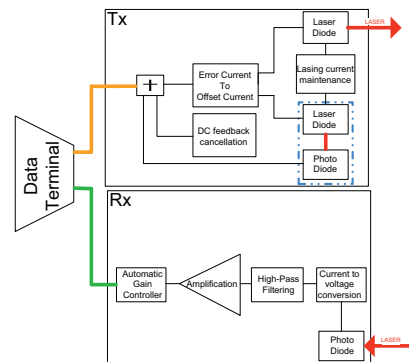


Figure 2: Simplified block diagram of the whole system

## Results and Achievements

Signals ranging from 3MHz up to 25MHz have been successfully transmitted and received. The signals transmitted and received are square-wave signals (hence confirming operation at least up to 75MHz, three times 25MHz). Hence 10Base-T frequencies and 100Base-T frequencies are covered. 100Base-T need a minimum of 31.25MHz 2

## References

- 1 Lakhra S., Sharma D. P., Singh J., "Study of Laser Based Transmission/Reception Parameters Under Fading Conditions", Instrument Society of India, Hyderabad, India, 2003.
- 2 IEEE Computer Society, "IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements Part 3: Carrier sense multiple access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications", IEEE, New York, USA, 2008.





# The use of a Rotating Vane Capacitor to detect a Target Position

**Student: Christopher Cusens**  
**Supervisor: Prof Carmel Pule'**

## Introduction

Even with the development of new technologies, such as the Global Positioning System, sonar remains one of the primary uses for detecting objects located underwater. The increase in terrorist attacks has given rise to the need for enhanced protection. A subsurface attack can have devastating results, thus the detection of any threat is of utmost importance. The use of a module that can detect the position of an enemy vessel during surveillance operations could come as a great advantage.

## Project Objectives

There are three main aims to this project. The first aim is to investigate and study the various types of capacitors and oscillators available in order to identify the most suitable setup. Following this, the development and construction of a device capable of detecting the angular position of a threat/target is to be implemented. Finally, the appropriate circuitry shall be designed and tested in order to display a positional result in a digital format to the user.

## Project Methodologies

The methodology implemented in the project is essentially divided into the below stages;

- Literature Review – This was carried out in order to obtain a better understanding of the task at hand. The literature survey provided a better understanding of the different types of transducers available. Each component to be used in the final design was thoroughly researched in order to gain optimum performance.
- Design of the Capacitor – Equations that relate Position to Capacitance and Frequency led to the appropriate shape of the capacitor to be used. A prototype was built to simulate and gather results.
- Oscillator Design – Different RC and LC oscillators were studied. The LC oscillator was chosen to produce the frequency required from the variable capacitance.
- Converter and Microcontroller Implementation – A suitable converter was chosen to change the varying frequency to a varying voltage. The voltage was then fed to a microcontroller input and with the use of an appropriate algorithm, an output that shows the angular position of the capacitor plates was given. This output is presented on a digital display.

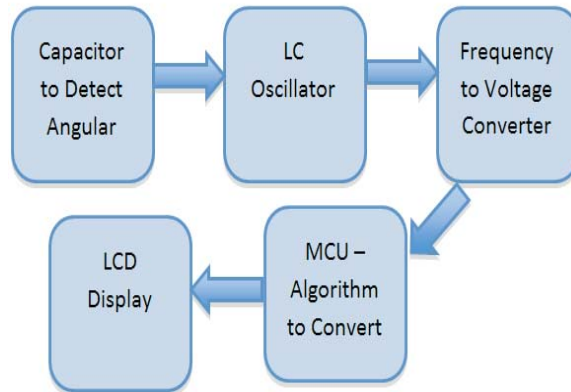


Figure 1 - Diagrammatic representation of the stages to be implemented

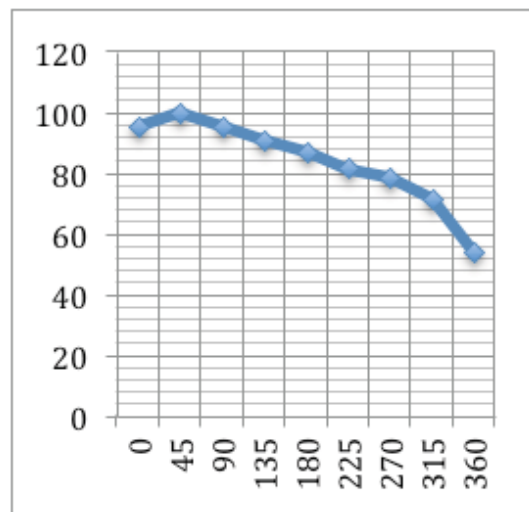


Figure 2 - Frequency (KHz) vs Angular Position (°)

## Results and Achievements

Once the construction of the capacitor was complete, the capacitance was measured for varying angular positions. The capacitor was connected to the oscillator, which in turn produced a varying frequency. Figure 2 shows how frequency varied in a linear fashion along a large portion of the 360° revolution.

Non-linearity was displayed towards the extremities due to stray capacitances. This was the main limitation of the project. However, this could be overcome by manipulating the microcontroller's algorithm. As a result, a wider range of the 360° intervals could be digitally displayed.

# Two-Axis Magnetic Levitation of a Magnetic Material

**Student: Darren DeBattista**  
**Supervisor: Dr. Kenneth Scerri**

## Introduction

The motivation behind this thesis is to gain experience in the design, construction and assemble of electronic systems to develop a magnetic levitation system. Application of this thesis include Magnetic Bearing [1] used to eliminate friction otherwise caused by using standard bearings, high precision magnetic planar levitation devices used for photolithography (IC Design) [2] and transportation were trains known as MagLev are magnetically levitated to reduce friction.

## Project Objectives

The aim of this thesis is to construct a magnetic levitation system to be used as a test bed to test different control algorithms. The construction of this system consists on the following tasks:

- Design and construct the electromagnets to be used
- Design and construct a current driver for the electromagnets
- Design and construct a sensing circuit to sense the position of the levitated object in 2D space
- Create an interface to the constructed setup to enable controllers to be used on PC
- Obtain a mathematical model describing the system dynamics
- Design, implement and test different controllers capable of stabilizing the magnetic levitation system.

## Project Methodologies

A mathematical derivation of the force produced by an electromagnet on a given object was first done. The result was seen to be too complex and hence, a simulation was done to approximate the force produced by an electromagnet with a more simple equation. Following the simulation, current drivers were designed and built which could give enough current as determined by the simulations done. The current driver is shown in figure 1.

The sensor circuit was next designed. This circuit was made by using an array of IR sensors. Measurements from these sensors with different position of the levitated object were taken and a mathematical relation between the output of the sensors and the position of the levitated object was then derived. Finally, the levitated object mathematical model was also derived. By analysing this model, suitable controllers were designed and tested to determine and compare their performance on such a system.

## Results and Achievements

Due to the nature of the system, especially due to

the lack of air friction, the system is very sensitive to modelling errors. The sensors used were also too sensitive and induced reading errors. Both issues made it very difficult for the system to work. This showed that to design such a system, there is the need of having a good and error less feedback and also to design more robust controllers which can work and give good performance even with system modelling errors.

## References

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 [2] Won-jong Kim\* and David L. Trumper†. \*SatCon Technology Corporation, Cambridge, MA and †Massachusetts Institute of Technology, Cambridge, MA, USA. Precision Engineering 22:66-77, 1998 © 1998 Elsevier Science Inc. Avenue of the Americas, New York, NY 10010

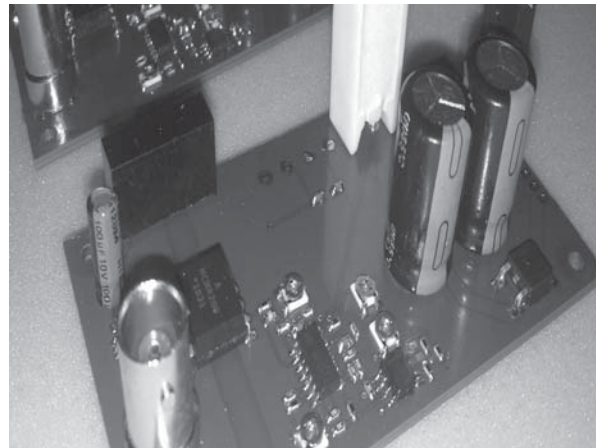


Figure 1 Current Driver

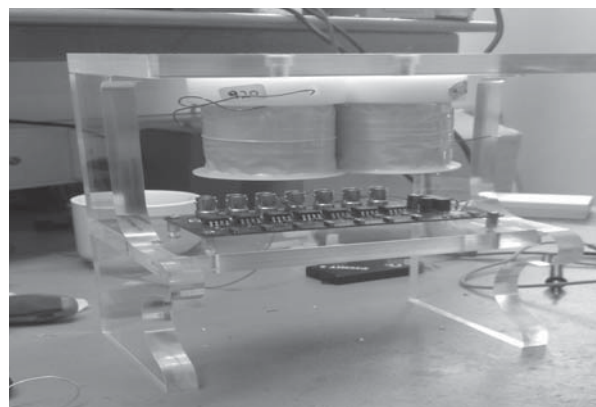


Figure 2 Physical Setup use



# Acquisition and Tracking for UAV Communications

**Student: Andre Micallef**

**Supervisor: Ing. Marc Anthony Azzopardi**

## Introduction

Nowadays UAV's have gained a lot of importance due to their efficiency and flexibility. Most of these vehicles are equipped with Radio Frequency links which are rather inefficient and slow when it comes to signal transmission. A free space optical link would be ideal for such use. However due to its high directionality this requires a system to automatically point and track the laser beam to ensure data connectivity between two points.

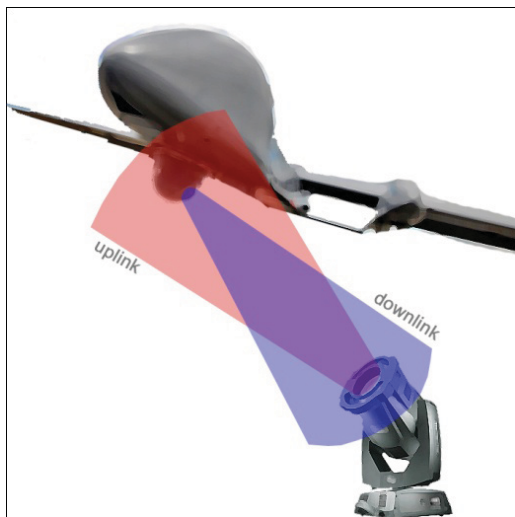


Figure 1: Simplified diagram showing application

## Project Objectives

The main targets are to gain knowledge on free space optical communication systems whilst also designing and implementing a simple hardware solution capable of maintaining an optical link between two points.

## Project Methodologies

In the initial stages a literature review was done to search and explore any previous work done in this field. This was followed by a thorough research and analysis to determine which configuration is best based on resources available. It was decided to opt for a 2 DOF gimbal while tracking was to be based on beam directionality. Moreover a project plan was drawn for the following stages of work, leading up to a finished product.

The final set-up consists of 4 main thematic areas, with each being further divided into market and feasibility search, development, and finally implementation and testing.

The first component is the sensor, which is responsible of detecting the direction of the incoming beam. This sensor ideally has to be used with an optical set-up capable of projecting the beam onto an image plane as a spot.

The second block is the processing part. Here is where the data is being processed for both tracking and acquisition in high speed so that the motors are actuated accordingly. Last on the loop are the drivers. These must be responsible for the current modulation required by the stepper motor, including any safety features required.

Another important part is the mechanical and optical section. An extensive research was done in regards to optical engineering, and specifically Gaussian laser optics. An in depth review of the theory involved was done together with utilization of optical simulation software for design purposes.

## Results and Achievements

Needless to say each section was implemented in hardware separately after thorough simulation and testing. A separate module for each component had to be designed, manufactured, assembled and tested under different conditions to ensure reliability and thus proof of concept. All different blocks have worked so far and have shown exceptional results even in extreme conditions. A final product was then designed and built incorporating every section into one holistic product. At this time of writing the product is being tested thoroughly.

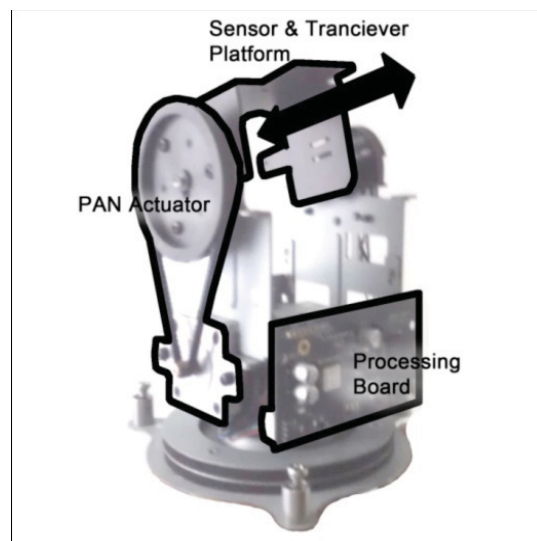


Figure 2: Gimbal with sectioned out components

# GNSS Local Area Augmentation System

**Student: Nathaniel Ebejer**  
**Supervisor: Dr. Ing. Andrew Sammut**

## Introduction

A Global Navigation Satellite System (GNSS) is a satellite based technology that provides position, velocity and timing information of a receiver. The Global Positioning System (GPS) that is used in this project consists of 24 satellites orbiting the Earth. The navigation solution of a receiver is calculated using the positions of these satellites and the ranges between them and the user. These measurements are however corrupted by a number of errors such as clock offsets, atmospheric delays and random noise, contributing to an error in the receiver's GPS derived position. One technique to compensate for these errors is a Local Area Augmentation System (LAAS). This is a Differential GPS (DGPS) technique that improves the performance of a standalone receiver by factoring out the common-mode error experienced by a fixed reference station and a roving receiver. This technique is applicable where the range between the reference station and receiver is below 100km and is therefore ideal for the Maltese scenario.

## Project Objectives

- Analysis of the basic GPS principles and Differential GPS techniques.
- The selection of two GPS receivers providing the data required to calculate a standalone navigation solution.
- The implementation of an algorithm that calculates the position for a standalone GPS receiver using Matlab.
- The setup of an internet link between the base station and rover station.
- The calculation and transmission of corrections by the base station and the application of these corrections by the rover station.
- The implementation of a Kalman filter to provide a further improvement to the differential correction.

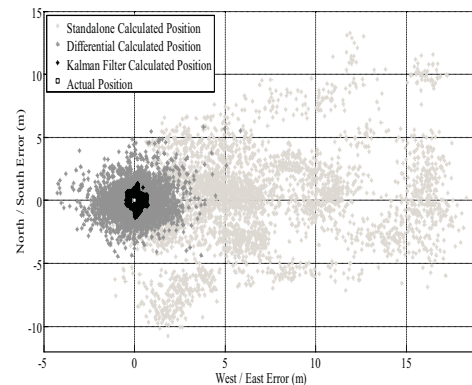
## Project Methodologies

A Ublox GPS receiver was configured in Matlab and communication was performed using the Instrument Control Toolbox (ICT). Once a GPS packet is received the satellite positions and ranges are calculated, hence obtaining a navigation solution. A residence in Attard was chosen as a fixed reference station whilst an office in Marsa was chosen to act as a rover station, separated by approximately 6km. An Internet link was setup between both stations also using the Matlab ICP and the UDP protocol. When the base station performs the standalone calculation, the satellite range corrections are calculated using a

predetermined set of equations. These corrections are transmitted to the rover station over the Internet, which once acquired by the rover are used to obtain a more accurate navigation solution. An adequately tuned Kalman Filter is then used to further improve the estimate of the rover's position.

## Results and Achievements

One can interpret the most significant results of this project as addressing two position error components which are systematic offsets and random noise. The differential algorithm reduced the offset and standard deviation whilst the Kalman filter dealt with the residual random noise. In fact, the standalone calculation resulted in a standard deviation of 5.96m and an offset of 6.91m. The differential algorithm improved this to a deviation of 1.62m and an offset of 0.11m. The Kalman filter further improved this solution to a standard deviation of 0.5m as seen in Figure 1.



*Figure 1: Rover Station Position Error for Standalone, Differential and Kalman Filter Calculations*



# Terrain Aided Navigation for TERCOM UAV/Missile Guidance using FPGA

**Student: Barnaby Portelli**

**Supervisor: Ing. Marc Anthony Azzopardi**

## Introduction

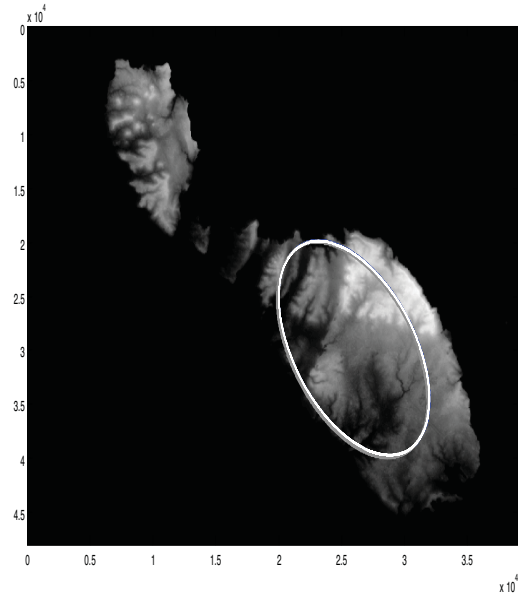
A major part of the navigation problem is obtaining an accurate position of the aircraft with respect to the surrounding environment. One way to go about this problem is Global Navigation Satellite Systems (GNSS) such as GPS. The drawback of this technology is that the satellite signals can be jammed during wartime and in some environments the signal is unavailable. Terrain Aided Navigation (TAN) is a different approach that compares the terrain with a stored digital elevation map to obtain the position. This system is not dependent on external devices and is very hard to block.

## Project Objectives

The main objective of the project is to design and simulate alternative ways for the TAN problem. These algorithms are implemented over a Digital Elevation Map (DEM) of the Maltese islands shown in Figure 1, as they are aimed for future implementation on a UAV that surveys the islands. The algorithms are to be simulated on MATLAB and later implemented on an FPGA in order to obtain the speed requirement for such system.

## Project Methodologies

The project is divided in four stages. The first stage is research on the current systems with detailed analysis of disadvantages and advantages. The second state is to analyse alternative approaches and simulate a 2D model of the system to show its effectiveness. In this part alternatives to the common iterative trilateration algorithm are implemented and tested. The algorithm is then converted to 3D space and tested over the Maltese Islands. The final step is to convert the system to VHDL and using the parallel advantages of this system to obtain a fast system response.



*Figure 1: Map area where simulations were carried out showing the path of the aircraft*

## Results and Achievements

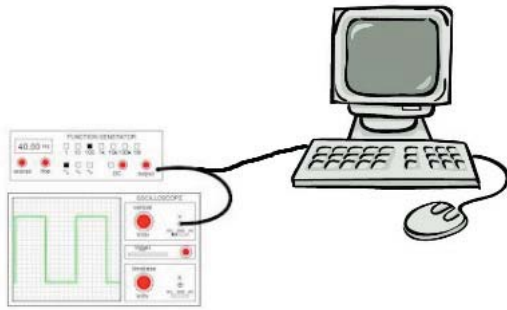
A system that utilizes system a trilateration and innovative positioning technique has been successfully implemented. The MATLAB simulation was tested over a DEM of Malta and the continuous increasing inertial error was corrected. Demanding parts of the algorithm have also been implemented on the COM1500 FPGA development board resulting in an increase time performance.



*Figure 2: Results with dead reckoning errors (narrow line) and errors after correction (bold line)*

# An FPGA based instrumentation system

**Student: Stephane Role**  
**Supervisor: Mr Kenneth Chircop**



## Introduction

Oscilloscopes and signal generators help resolve the mysteries behind electronics. The most commonly used CRT oscilloscopes are being replaced with their digital brothers. Digital oscilloscopes and instrument boast a number of advantages over fully analogue systems. The size of the equipment as well as the functionality of the instrument has greatly improved. These equipment help engineers daily test, fix and design complex circuitry. Having both of them combined on a small portable PCB can improve the quality of life for engineers. 1, 2

## Project Objectives

The aim of the project is to design and develop an instrumentation system on an FPGA board. The system should include an oscilloscope and a signal generator. The board should communicate with a PC system to display the data on a monitor. The board should also be able to change the frequency and voltage scales as well as the signal generator's type (square or sine wave).

Project Methodologies

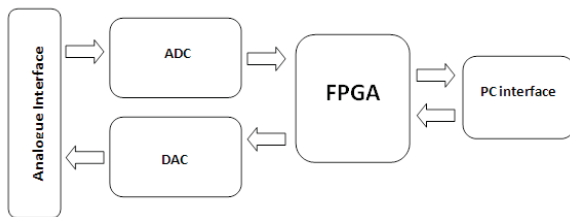


Figure 1: Basic PCB Diagram

The project was divided into six different phases:

- Literature review and research on the components needed to carry out such a system

- Development of analogue circuitry to interface signals to the analogue to digital converters and the digital to analogue converters.
- Devising the FPGA interfaces and input/output modules.
- Designing a PCB board layout.
- Research, Design, Development and test the full FPGA system.
- Development of a C++ program to display the results and provide a user interface.

Figure 1 shows the simplified PCB diagram. The ADC samples the analogue circuitry and converts the voltages to digital values. The digital values are selected by the FPGA and sent to the PC using a Serial (UART) to USB integrated circuit. The PC sends data to the board through the same interface to control the many functions which are generally found on an oscilloscope such as; the triggering voltage, oscilloscope timescale, the voltage gain, the signal generator frequency, the type of waveform (sine or square) and the signal generator amplitude.

The board has to display the oscilloscope readings on a screen of pixels. Therefore to populate the screen an ADC of at least 9-bits is needed. The ADC has to operate at least twice the frequency of the highest frequency waveform according to the Nyquist theorem.

## Results and Achievements

The analogue circuitry was simulated and tested in the lab. Also a number of FPGA modules have been hardware tested on an FPGA development board. Hardware testing involves the writing of physical modules to send the required data to the modules being tested.

## References

- 1 J.Miguel Dias Pereira, The History and Technology of Oscilloscopes, IEEE, 2006
- 2 <http://www.radio-electronics.com/articles/test-measurement/developments-in-oscilloscope-technology-an-36>



# Real Time Ground Vehicle Navigation Sensor

**Student: Kevin Theuma**

**Supervisor: Prof. Ing. David Zammit Mangion**

## Introduction

Most automotive navigation systems such as the Global Positioning System rely on satellites. Unfortunately these systems can reach inaccuracies of up to 10m due to sources of errors mainly those from satellite geometry, satellite orbits, multipath effects, atmospheric effects, relativistic effects, clock inaccuracies and rounding errors. Technologies such as Assisted GPS, Differential GPS, Wide Area Augmentation System and Local Area Augmentation System attempt to reduce these errors. However these systems struggle to provide centimetric accuracy and ones which do are expensive.

## Project Objectives

The aim of this project was to find a cheaper solution with which a vehicle can be controlled. An image retrieved from a CCD camera had to be analysed in real-time by an FPGA in order to identify the road line and calculate its angle and off track error. This information had to be used to control the vehicle so that it followed the road line.

## Project Methodologies

The project was organised in the following manner. First, research on different algorithms and mathematical procedures relevant to the project was done. The advantages and disadvantages of these algorithms and procedures were compared to each other. Most attention was given to the results they produce and their execution time. The best solutions for the project were chosen and they were combined together to construct a prototype on Matlab. This prototype was tested using different images together with additional effects such as change in contrast, change in brightness and blurring. Figure 1 shows the curve fitting for one of the input images. From the results it was possible to identify the strengths and weaknesses of the program and hence improve it. After applying changes, it was tested once again in order to know its limitations when using it in practice. Once the prototype was fully finished, the Matlab code was ported to the Spartan 3E 1600E development kit which can be seen in Figure 2. The FPGA design was programmed in VHDL using Xilinx ISE. The project was simulated using the inbuilt simulator. The results of simulation were compared to those of Matlab and it was made sure that they were identical. Then the project was synthesized and tested on the actual hardware using Chipscope in case of any differences due to timing.

## Results and Achievements

In this project different algorithms and mathematical

procedures were combined together to produce a real-time system. These components can be used as low cost solutions for other real-time applications because they can be integrated into devices like FPGAs and microcontrollers.

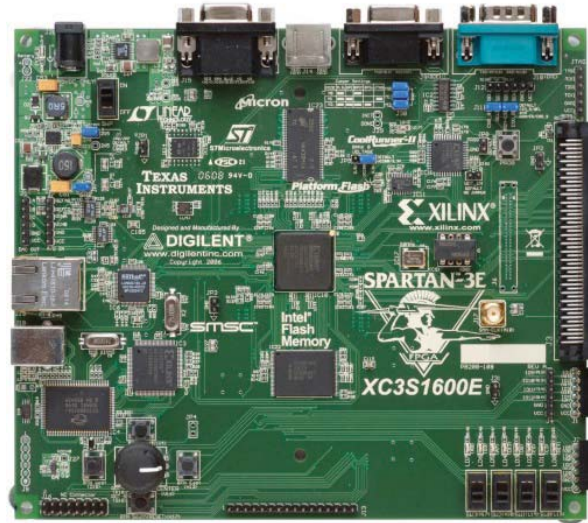


Figure 1 – Curve fitting of a road line

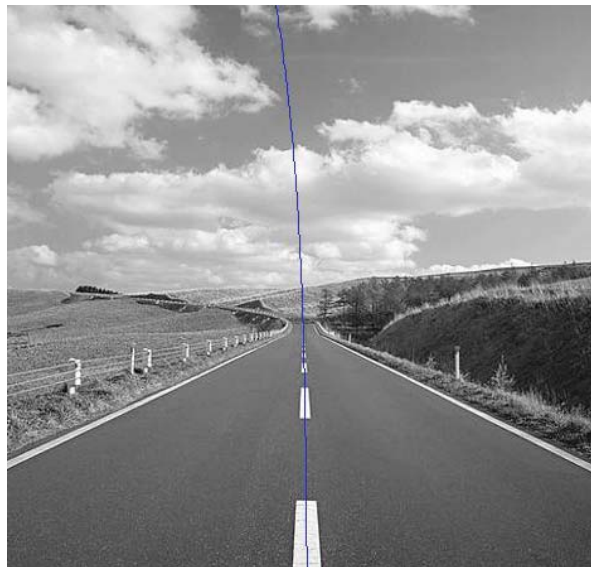


Figure 2 – Spartan-3E 1600E Development Kit

# Obstacle Avoidance of an Unmanned Vehicle

**Student: Joseph Vella Wallbank**  
**Supervisor: Dr Ing. Andrew Sammut**

## Introduction

This work deals with the problem of autonomous control of a ground vehicle, specifically the issue of path planning. Solutions have been considered with an emphasis put on the technique known as Artificial Potential Fields (APF) for navigation of autonomous vehicles. The mathematical formulation of the APF has been explored and an implementation of a navigation controller has been programmed on a PC.

This work continues with the design of a real world test setup and describes the issues considered when implementing navigation of unmanned vehicles. The setup consists of a simple obstacle course to be run by a radio controlled ground vehicle. An overhead camera allows the controller to monitor the progress of the vehicle and issue commands over a wireless link to guide the vehicle around the course.

## Project Objectives

To test the viability of APF in a real world scenario the following objectives had to be achieved:

- Building a ground vehicle that can be controlled over wireless link.
- A program capable of extracting the location of the vehicle, the end point and any obstacles within an image.
- Implementing the APF algorithm as a program able to issue commands to the vehicle so as to complete an obstacle course.

Building an obstacle course for the vehicle to traverse with a camera above the setup providing images for the program.

## Project Methodologies

Due to the specifications required it was decided to construct the vehicle using discrete electronics connected on a PCB. The PCB was attached to a piece of acrylic plastic and two motors were mounted underneath, the motors were equipped with encoders so that the speed could be monitored and adjusted accordingly. A controller program was coded in C++ which monitored the test setup using an overhead camera. From the camera the locations of the objects were found, and using an APF algorithm 1 directions could be passed to the vehicle over the wireless module allowing it to complete the obstacle course.

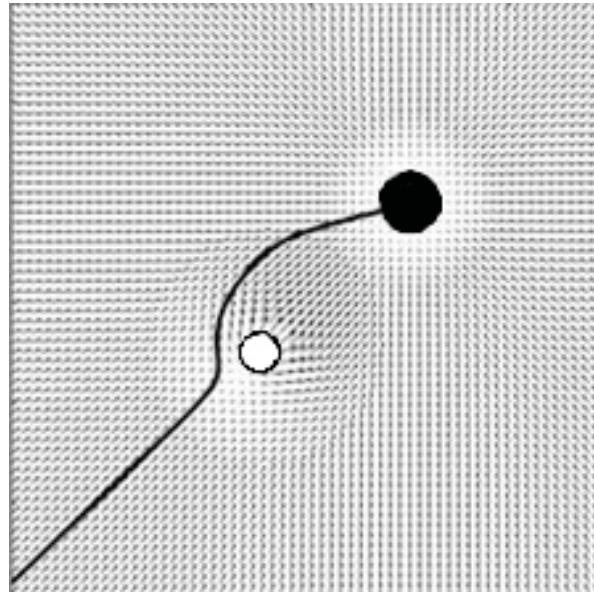
## Results and Achievements

The results from this project show that the controller program is able to extract objects from an image, establish the location for each of the objects and pass this data onto an APF algorithm. The APF indicates in which direction a ground vehicle should travel to

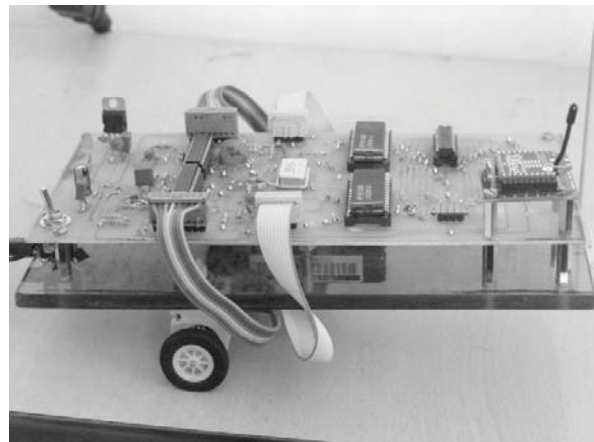
reach the destination. Full control over the vehicle was achieved with the ability of driving each motor at any speed and altering it on the fly.

## References

M.A. Goodrich Potential Fields Tutorial online PDF Available: [http://borg.cc.gatech.edu/ipr/files/goodrich\\_potential\\_fields.pdf](http://borg.cc.gatech.edu/ipr/files/goodrich_potential_fields.pdf)



*Figure 1 - Virtual representation of a typical Artificial Potential Field. Obstacle shown in white and target shown in black. The line indicates the path a vehicle would take.*



*Figure 2 - A picture of the constructed vehicle.*





# Energy Efficiency in Domestic Electrical Appliances

**Student: Matthew Agius**  
**Supervisor: Dr Ing. Maurice Apap**

## Introduction

The Electricity tariffs in Malta, as in many other countries around Europe, are constantly on the rise and hence Energy Efficiency has become today a major concern for both engineers and the general public. This is also reflected in the policies which both local and European governments have been issuing. The Maltese government for example has issued an Energy Policy Proposal which deals amongst other issues with energy end-use efficiency (energy usage in domestic premises and how this can be more sustainable). This project basically deals with implementing an experimental setup for domestic electrical energy efficiency measurements. The setup is then used to perform relevant investigations into energy efficiency of domestic appliances that are available which mainly include two different air-conditioning units and a water heater.

## Project Objectives

The main objectives of this project are the implementation of an experimental setup for domestic appliances' energy efficiency measurements. This setup is used to study the electrical consumption of electrical units and how they can be more efficient. The setup designed allows the user to plug any appliance and

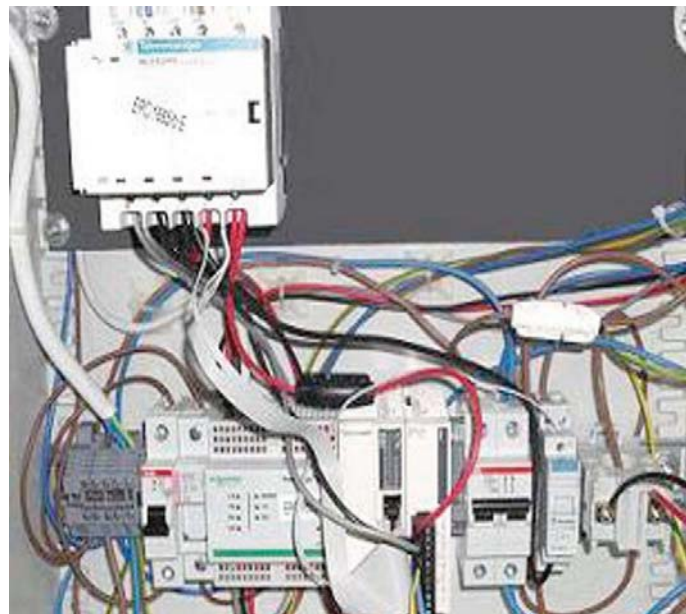
monitor the electrical consumption, which can also be logged in a computer through an available port for further analysis and waveform plotting.

## Project Methodologies

The approach taken towards this task was to implement a power monitoring 'box' which is totally closed to the user with only a display, a computer connection and plug outlets on the outside. The internal structure of the system is shown in figure 1 which basically employs a power supply for the components, protective MCBs and fuses, a power meter, a current transformer, an Ethernet Gateway, a PLC and its temperature analogue module with a PT100 sensor and a relay.

## Results and Achievements

Using the above setup it was possible to achieve a series of results related to the electrical consumption and efficiency of the mentioned appliances. Graphical representations of the results were used for the ease of discussion and in order to compare the outcomes of the different air-conditioning units, so as to show which unit is more feasible and for what application. Interesting results which came out and their relevant discussion are summarised in the dissertation for this project which gives a good insight towards being more energy efficient in our homes which is of benefit for us all.



*Figure1 – Power Monitoring Apparatus*

# Setting up of an Active Filter for Non-Linear Load Harmonics Filtering

**Student: Karl Saviour Ascik**  
**Supervisor: Prof.Ing. Cyril Spiteri Staines**

## Introduction

The use of non-linear loads in industry is increasing rapidly with the advancement of power electronic converters. This is leading to several harmonic problems and loss in power quality. The voltage supply waveform is a pure sine wave. Non-linear loads draw non-sinusoidal currents from the supply, which are added to the sine wave, leading to losses and greater thermal overload. Certain measures are therefore taken to reduce harmonics produced by a load. This can be done by means of a filter, which may be either passive or active.

## Project Objectives

An active filter system will be set up in this project to measure the harmonic currents present in the system and hence generate currents equal and opposite in phase to them.

Two induction motors are coupled together, with one acting as the driving motor (prime mover) to drive the motor acting as a load. The driving motor would be controlled by two motor drive systems, namely an inverter and a soft-starter, which are both non-linear loads, generating harmonics. The load motor would be connected to a regenerative inverter, capable of sending energy back to the power grid by means of regenerative braking.

The system will also be interfaced to a PC to monitor the performance of the active filter and a Programmable Logical Controller (PLC) which enables automatic running of the setup.

## Project Methodologies

- The necessary hardware equipment, including protective and control circuitry, was assembled and wired
- A sequential PLC program was designed to enable the setup to work automatically
- Tests were performed to confirm functionality of the equipment
- Waveforms were measured using a Power Quality Analyser

## Results and Achievements

Current and Voltages at the inverter and soft-starter terminals were measured to obtain their respective waveforms and the harmonic content present. A high amount of distortion was visible, especially when the motor was operated through the inverter. The final step is to determine whether the active filter is

attenuating the current harmonics produced by the non-linear loads.



Figure 1: Active Filter Setup



Figure 2: Programmable Logic Controller



# Investigating the Effect on Power Quality due to Renewable Energy Systems

**Student: Joseph Azzopardi**  
**Supervisor: Prof. Ing. Cyril Spiteri Staines**

## Introduction

Following sharp increases in the cost of fossil fuels and the increasing awareness of the greenhouse effects, sustainable living has become very important in today's world. In fact following schemes such as the ERDF scheme managed by the MRA, there has been a steep increase in the number of grid connected renewable energy systems being used, in particular photovoltaic systems. Such systems may cause the voltage to increase, and elevate the harmonics in the utility grid. These negative effects might create problems regarding the power quality of the grid as the penetration of such grid connected systems increases.

## Project Objectives

The main aim of this project is to perform a series of monitoring exercises on grid connected renewable energy systems situated in various premises. The data acquired from these studies is then compared to the Enemalta network code and other relevant standards. Where power quality issues are detected these shall be pointed out and analysed. Grid connected systems shall be simulated using PSCAD@/EMTDC™. The results obtained from the simulations shall then be compared to the actual data obtained from the monitoring exercises.

## Project Methodologies

In order to tackle the power quality problem that might arise following a significant increase in the penetration of grid connected renewable energy system, monitoring of such systems was carried out as shown in figure 1. From the data obtained, parameters such as voltage, current, power, power quality and harmonics present in the voltage and current profile were analysed. Using the local network code and other relevant standards as a bonus, any anomalies were pointed out. Similar systems were then simulated and the results compared to the actual data.

## Results and Achievements

By following the above procedure, it was noted that problems such as overvoltage at the point of common coupling are already present in the grid although the causes vary from one site to the other. The grid connected inverters have also been observed to inject a current waveform with high harmonic content when operating with an input power much less than rated. It has also been observed in some sites that overvoltage at the point of common coupling has

interrupted the operation of the inverter leading to a sudden loss of power. Following a significant increase in the penetration of grid connected renewable energy systems, such effects create problems regarding frequency and voltage variations in the grid such that they may not comply with the requirements specified in the network code. An elevated level of harmonics will increase losses in the grid and reduce the lifetime of components, however harmonics were injected when the inverter was operating at a power much less than rated implying that the harmonics were of a relatively small power.

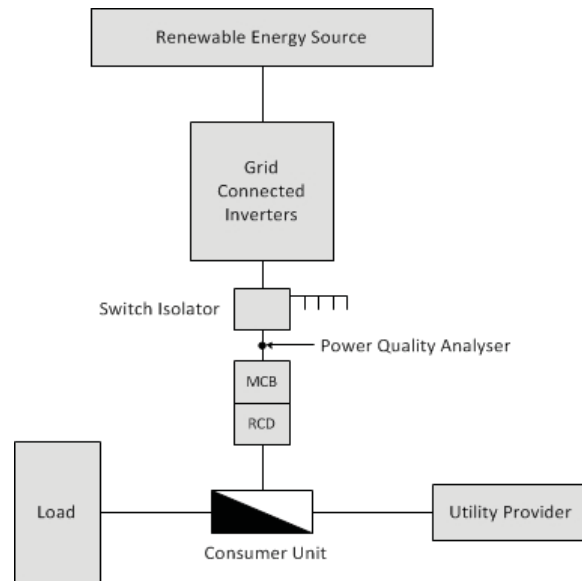


Figure 1 - Schematic diagram showing setup used

# Advanced Phase Angle Control of Induction Motors Soft Starters

**Student: Terence Moses Bartolo**  
**Supervisor: Mr. Alexander Micallef**  
**Co-supervisor: Dr. Ing. Reiko Raute**

## Introduction

A three-phase induction motor typically draws 6 - 8 times the full load current when it is started direct-on-line. This starting current reduces the life-time of the motor windings due to thermal effects, causes mechanical stresses on the rotor shaft and also causes voltage dips on the supply lines. To reduce the starting current, conventional starting techniques such as star-delta starting are still being used. However, for applications requiring a smooth start-up, such as conveyor belt systems, escalators and compressors, power-electronic starting devices such as soft starters are generally employed. In soft starters, discrete-time control algorithms executed by a microcontroller unit apply a reduced voltage to the motor by controlling the firing angle of thyristors so as to control the starting current. This project was based on optimising the control algorithms implemented in soft starter units produced by Carlo Gavazzi Malta, used for controlling the starting current of three-phase scroll compressors.

## Project Objectives

- Investigate the present four discrete-time control loops and analyse the stability of the starting current control loop (control loop 1) and the initial starting current control loop (control loop 2).
- Select and design a new control algorithm which provides a higher degree of stability for these two control loops.
- Use simulation models implemented in Simulink to verify the expected results.
- Implement control algorithms in the soft starter units provided and perform functional tests on three-phase motor and compressor setups.

## Project Methodologies

Initially, stability analysis of control loop1 (controls starting current during start-up) and control loop 2 (controls initial starting current from start to start) of the present system were carried out. Afterwards, a new control algorithm with a higher degree of stability was designed for these two control loops. The algorithm was then tested using simulation models and finally it was implemented in an actual soft starter unit. Hardware testing consisted of two stages. In the first stage, tests were performed on an unloaded three-phase induction motor, while in the second stage tests were performed on a three-phase scroll compressor induction motor.

## Results and Achievements

The results achieved during testing confirmed that the new control algorithm yields a higher degree of stability than the present controller. This is due to the higher gain margin that was achieved by compromising the rise time of the r.m.s starting current. Figure 1 and Figure 2 show results obtained using the present and the new control algorithms.

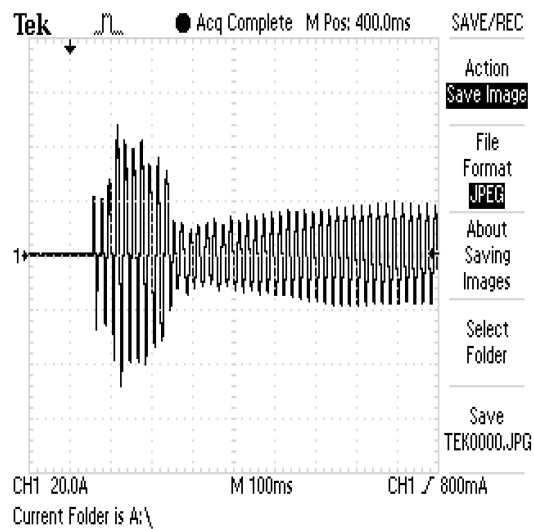


Figure 1: First start of 16A three-phase scroll compressor using present control algorithm

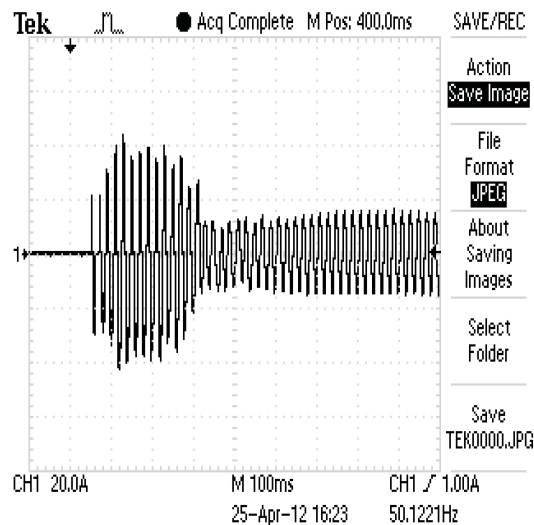


Figure 2: First start of 16 A three-phase scroll compressor using new control algorithm



# Solar Irradiance and PV Plant Generation Analysis

**Student: Jurgen Bonavia**  
**Supervisor: Dr. Maurice Apap**

## Introduction

On average the sun's power is , the earth's atmosphere receives a constant supply of of which only reaches the earth surface.

Photovoltaic panels convert light energy into electrical energy, however only a small part of the available energy is converted into electrical energy due to the efficiencies of the modules. For this reason, this project involves the setting up of a weather station and the necessary software tools to compare the generated energy with the expected generated energy for the available solar irradiance at any time.

## Project Objectives

- Setting up of the automatic weather station.
- Setting up of the data logging equipment for the PV Plant output
- Record sufficient measurements of solar irradiance and PV output to provide adequate data for analysis
- Analyse and assess the performance of PV plant from data recorded on the basis of available solar power at any time.

## Project Methodology

A solar tracker was installed together with two pyranometer sensors and a pyr heliometer sensor. One of the pyranometer was installed with a shading ball assembly for diffuse solar irradiance measurement while the other was set up to measure the global irradiance. The pyr heliometer was needed to measure the direct solar irradiance.

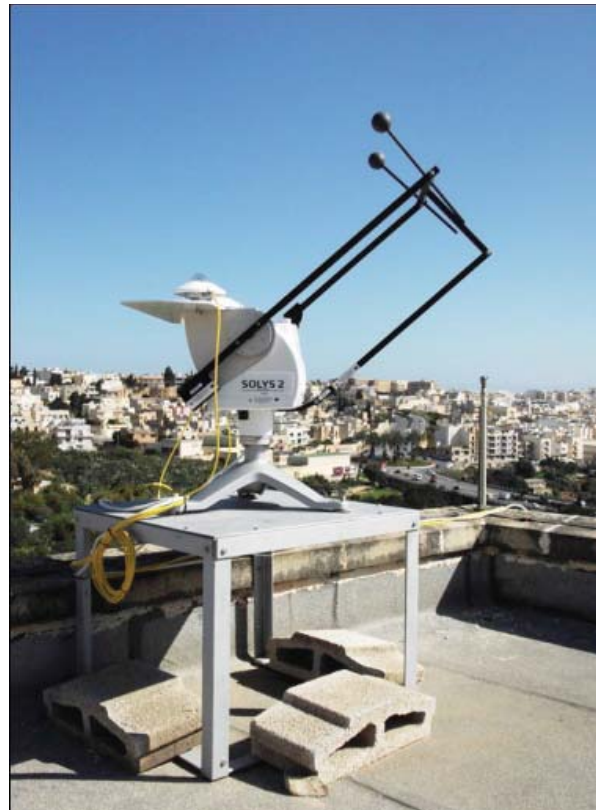
An anemometer, wind vane, barometer, temperature and humidity sensor were installed in place and connected to the data logger. Each sensor was configured separately depending on the type of signals generated. The data logger provides enough space for 145 days of data at intervals of 1 minute.

Two software programs were written using Matlab to create a Graphical User Interface. The first one calculates all relevant information on the solar position being able to generate 24 hour data and storing it into a spreadsheet.

The second program collects the required data for the analysis and stores it into one spreadsheet. The user is also able to enter the photovoltaic plant characteristics according to the specific installation, thus making it possible to be used on different systems. The entered data is then used together with the solar irradiance data to work out the expected AC power generated by the system. This data is

then available to the user through graphs. The same program also gives the user the ability of choosing which variables to plot.

The current data was obtained from the solar panels when they were dirty, and another sample was taken after cleaning. The collected data was then used in the Matlab GUI to produce the necessary results for the data analysis.



*Figure 1: Solys 2 solar tracker fixed with pyranometer and pyr heliometer sensors*

## Results and Achievements

Both the data obtained from the weather station and the data obtained from the PV panels were plotted onto each other. One could note that most of the peaks and glitches coincide on both graphs showing that both systems experienced the same weather conditions. Predictions for the expected power output for the available solar irradiance were also performed.

## References

1 Hersch P. and Zweibel K., 'Basic Photovoltaic Principles and methods' Solar Energy Research Institute, Colorado, 1982.

# Set-up of Stand-Alone RES System & On-line Parameter Display

**Student: Matthew Bonello**  
**Supervisor: Prof. C. Spiteri Staines**

## Introduction

This project will help the market monitor their renewable energy sources via the internet without having to read the parameters from the inverter itself. It shall also provide a backup means of electricity when the supply grid is interrupted.

## Project Objectives

The project's objective is to install a system which can still operate a load when the grid is interrupted. It also includes the online display of renewable energy data so that it may be viewed remotely.

## Project Methodologies

The first part of this project was concerned with setting up an island system which can isolate the system from the grid and thus keeping all internal loads online. An automatic switch box senses whether the grid is on. When the grid is uninterrupted the load is supplied from the grid, and any energy produced from renewable energy sources is fed to the grid. Yet, when the automatic control box senses that there is no grid, it isolates the internal system from any grid connections while at the same time creates a stand-alone system with typical grid parameters. Thus, the load will still be energised. The load power is now either supplied directly from the renewable energy inverter or from the battery pack which comes as part of the Backup system.

The second part of this thesis concerns the gathering of data and its display on a website which can be viewed remotely. For this part, a wind inverter and a solar inverter were used. The wind inverter saves data directly to a predetermined file while the solar inverter needs a data logger which logs the inverter's data. This data may then be accessed manually and saved according to the date it was acquired. This data is then published graphically on a website.

## Results and Achievements

The Sunny Backup system is up and running and all tests have been successfully performed. Data is also being constantly gathered, which will be displayed on the website.



Figure 1: Solar Data Logger: Sunny Boy Control Plus



Figure 2: Sunny Backup System S



# Permanent Magnet Pancake Wind Generator

**Student: Robert Caruana**  
**Supervisor: Prof. Joseph Cilia**

## Introduction

Permanent Magnet Motors (PMMs) are quickly becoming popular for use as generators or alternators in micro wind turbines. This is due to the fact that the permanent magnets provide the excitation of the coils, instead of requiring a current through wound coils, to generate the magnetic field. The type of alternator being studied here is an axial flux alternator, meaning that the magnetic lines of flux are parallel to the alternator shaft. This allows the rotor to be placed as close to the stator as possible, giving the alternator its flat, pancake shape. For this application two rotors can also be used, mounted on the same shaft. This will increase the magnetic flux density at the stator.

## Project Objectives

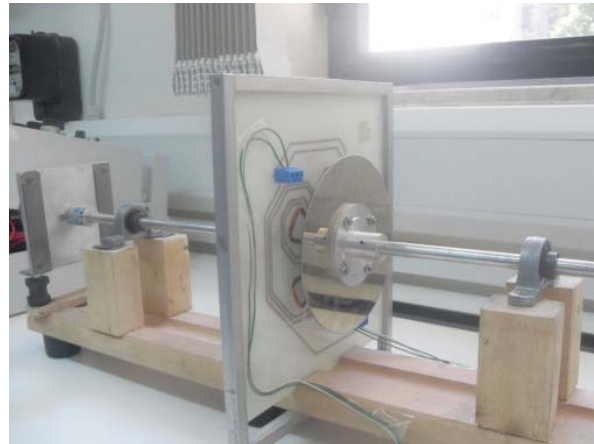
- Design, development and implementation of a permanent magnet axial flux alternator for a micro wind turbine.
- Maximizing the power output and cost efficiency of the alternator by testing for different numbers of magnets, coils and wire thickness.

## Project Methodology

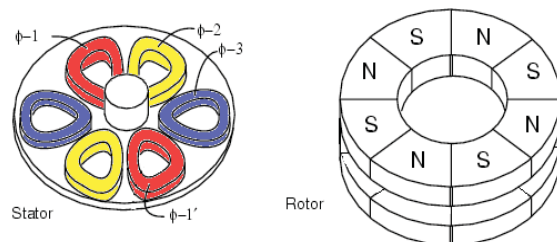
The project consisted first of a literature review examining wind turbine types, different motor drives, and most significantly the different types of motors available for the wind generation application, and why a PMM was chosen. A short study on the magnetic flux equations and what magnet shapes to use for the highest flux density was also performed. The construction of the rotor and stator was first mounted on a testing rig. This testing rig was used to test different configurations of magnets, distances of these magnets from the coils and speed of rotation of the shaft. Tests were also performed on the wind turbine itself, examining its rotational speed at different wind speeds to be able to design the alternator accordingly.

## Results and Achievements

Results have shown that an increased number of magnets on the rotor, decreased distance between the magnets, a faster turbine speed, and a larger number of coils all contribute to generating a higher output power. Thus it is important to balance out these factors to keep the construction cost as low as possible while generating as much power as possible.



*Figure 1: Stator and rotor construction of the alternator*



*Figure 2: Testing Rig Set up*

# The design and implementation of a Lithium Phosphate (LiFePO<sub>4</sub>) energy pack for EV applications.

**Student : Alistair Ciantar**  
**Supervisor: Prof. Joe Cilia**

## Introduction

As the awareness towards a cleaner environment continues to raise discussions worldwide, one of the main sources of pollution is transportation. The introduction of electric vehicles would be the first step in reducing carbon content and particulate matter from the atmosphere.

Several manufacturers have set their prototypes but the use of lead acid technology has failed to deliver the distances the market demanded. This is the major reason why electric vehicle prospective buyers were always sceptic about.

The discovery of Lithium gave electric vehicles a new dimension. Several lithium technologies have been implemented where Lithium phosphate resulted to be the most promising technology for ZEV (zero emission vehicle). LiFePO<sub>4</sub> technology achieves a high energy density, up to 140 Wh/kg and is intrinsically safe when overcharged or operated at high temperatures. Lithium phosphate can be charged randomly to full capacity, since it does not suffer from memory effect. This was a problem when using Ni-Cd and Ni-MH technologies. This would give the owner the benefit of plugging in the vehicle near the closest charging point, keeping the cells at maximum charge.

## Project Objectives

The aim of the project was that of setting up a LiFePO<sub>4</sub> energy pack. The battery pack proposed was to include all necessary circuitry to maintain all cells within the string, healthy and balanced.

After developing the necessary hardware the LiFePO<sub>4</sub> energy pack was to be tested on a motor load rig for transient performance and testing the behaviour of the output current.

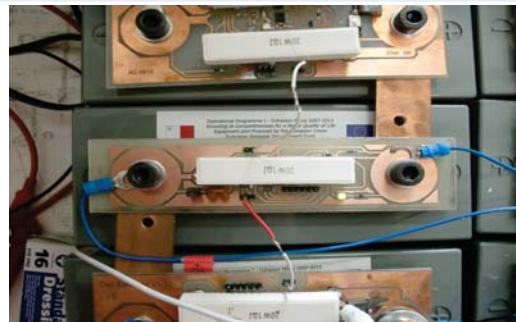
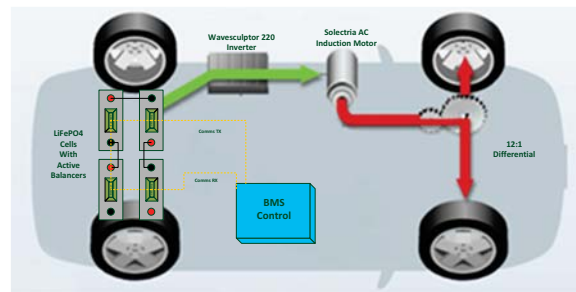
Another objective was to install and tune a new 165KVA vector controlled 3 phase inverter. This included the interfacing of the quadrature encoder, extraction of motor data including stator and rotor inductances and the voltage and current operating limits.

## Project Methodologies

Prior to the complete assembly of the energy pack, several tests were performed on the batteries in order to analyse their behaviour. This included the charging and discharging profiles, problems when charging and discharging unbalanced cells within a series array, and the behaviour of parallel lithium

battery banks.

A significant problem with LiFePO<sub>4</sub> was that of cell balancing. This required the use of balancing circuits. After analysing several techniques the charge shunting method was prototyped and tested. The circuit was tested for performance and for the percentage of power being dissipated in the resistor during a balanced and an unbalanced charge. A communication system using a single wire daisy



chain communication protocol was also developed where the complete battery pack was monitored through a remote terminal. Several functions embedded on the cell balancer were also controlled from the main terminal including the selection of the discharge profile.

## Results and achievements

Testing showed that when unbalanced cells within a battery pack are present, the output power of the pack will be significantly decreased.

By the use of balancing circuits the cells were restored to a balanced state by a single charge. From both prototypes, the active balancer had significantly shorter balancing times. The integration of embedded communication made the balancer more versatile.

As regards to the LiFePO<sub>4</sub> technology, discharge tests had a very flat characteristic and an average charge factor of 1.06 making the technology ideal for Electric Vehicles.





# Modelling, Control and Analysis of a 90MW Wind Farm connected to the Local Power Network using IPSA

**Student:** Ernest Ciantar  
**Supervisor:** Prof C Spiteri Staines  
**Co-supervisor:** Ing. A Cassar

## Introduction

Lately, a set of strict targets have been issued by the European Union in order to use renewable energy sources. Since Malta is a member of the European Union, it is following such targets, mainly by embarking on two large projects in the near future. The first one is the introduction of the 200MW interconnector which electrically connects Malta to Sicily. This makes it possible for Malta to buy electricity from less polluting power stations. The second project consists of the introduction of a 90MW wind farm. Before integrating such wind farm with the Maltese electrical grid, a study of the operation of such farm and its effects on the grid has to be studied.

## Project Objectives

The main objectives of the project are to model the Doubly Fed Induction Generator (DFIG) which is the generator mostly used in wind turbines. After modelling the DFIG, the design of the required control loops used for the control of the wind farm have to be considered. Moreover, the analyses of the wind farm when integrated with the Maltese electrical grid are studied by various simulations.

## Project Methodologies

Initially, research on various European wind power grid code requirements was done. Following this, the modelling and control of the DFIG was carried out and the control loops were designed and implemented in the Interactive Power System Analysis software, IPSA. This was used to carry out simulations of a number of worst case scenarios so as to study and analyse the transient response of the designed controllers whilst verifying whether the operation of the wind farm is in compliance with the European Standards.

## Results and Achievements

The simulation results showed that when using the designed control loops, the operation of the wind turbine forming the wind farm are in compliance with the European Standards. Moreover, when comparing the results obtained when using the controllers designed in this thesis to the results obtained when using other readily available controllers, the controllers designed gave the best performance in all cases.

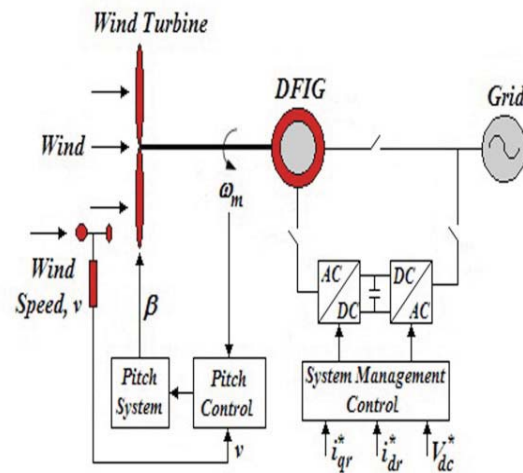


Figure 1: Wind Turbine Control System



# The Design, Building and Testing of a Solar Water Heater Circulation Pump Controller

**Student: Michael George Cini**  
**Supervisor: Prof. Joseph Cilia**

## Introduction

The aim of this thesis is to design, build and test a controller for a solar water heating system. Components related to the structure include the solar collector (Schott Solar Collector Tubes), the heat exchanger (Zilmet Heat Exchanger), an indoor insulated hot water storage tank, a primary circulation, a secondary circulation pump (water), temperature sensors (used for monitoring and feedback analysis), an expansion tank and actuators.

It was clear that the system had various margins of error that needed continuous automated control to maintain qualitative results. This was instrumental to have the project directed to a focus point in order to establish the characteristics of an efficient solar water heating system. This led to the research for the selection of the equipment required, bearing in mind the environmental factors surrounding the location of the system. Thus, the idea for a closed loop monitored feedback system was sustained.

## Project Objectives

The objective of the solar water heater was to control the circulation of the water and the transfer of heat between the heat exchanger and storage tank located close to the bathroom (or kitchen etc). This was done by the introduction of a circulation pump. The system used is called a re-circulation system because the inlet and the return to the heat exchanger are in a closed loop.

The head of the closed loop re-circulation system can vary from one to several stories high. The larger the separation between the heat exchanger and the storage tank, the less the system is effective; resulting in a longer time required to reach the temperature set by the user in the storage tank. Several tests were performed in order to demonstrate this.

## Project Methodologies:

The system performance was investigated through the following three methods:

- The complete setup, without plumbing between the Heat Exchanger and the Storage Tank
- The system with lagged plumbing between the Heat Exchanger and Storage Tank
- The system with non-lagged plumbing between the Heat Exchanger and Storage Tank

These methods were applied to a system which is also commonly found in households. Hence the results obtained can be easily applied in practice.

## Results and Achievements:

The system with no plumbing operates satisfactory; hence with such a choice of equipment one can achieve the required temperature set by the user in the storage tank.

The lagged system performance is superior to that of the non-lagged system in terms of heat transfer and efficiency of the complete system.

To optimize the performance of the system the following implementations are to be done:

- Microcontroller

The sun concentration peaks only for a short period of time. This results in warmer oil in the heat exchanger than in the storage tank but the heat transfer is very low in such a way that it acts like a radiator. The scope of heating the water present in the storage tank by passing it through the heat exchanger, in reality, during that time it is being cooled. The microcontroller is required such that it senses the difference in temperature between the two and switches the pump ON and OFF accordingly in order to balance the temperatures.

In order to improve the system further the heat collector (solar tube panel) could be mounted on a revolving structure such that it would align itself to find the best position to collect solar heat. The alignment process would be within a closed loop which is controlled by the microcontroller.

- Heat Exchanger

The heat exchanger could be of a larger capacity in order to ensure better heat transfer with lower solar activity. The one utilized in the system does not have enough capacity to ensure optimum heat transfer throughout the day. In fact from the analysis performed on the data acquired, the system works satisfactorily for 4 to 5 hrs daily. This time window is approximately from 10 am to 3 pm. This period is too short considering the solar potential in Malta.

- Plumbing

The circulation of water and the temperature are affected by several factors such as the type of insulation, route selected and the ambient temperature. Hence the planning of the installation is critical in order to improve the efficiency in delivering and circulating water at the desired temperatures.



# Power Management Control System for Boats and Super Yachts in the 25 – 70 Meter Range

**Student: Simon Duca**

**Supervisor: Dr. Ing. Maurice Apap**

## Introduction

The increase in the electrical demand on board super yachts, leisure boats and fishing vessels has made power management control a necessity onboard most vessels. Trained personnel have to constantly monitor electrical parameters, and manually synchronize the generators in the event of an increase in the load demand using a synchroscope or the dark lamp test and manually close the circuit breaker when the generators are synchronized.

## Project Objectives

Recognizing an opportunity for improvement, this dissertation project aimed to experimentally develop an intelligent power management control system. The main objective was to develop a modular prototype switchboard that enabled full control over the generators and automated the synchronization process. Additionally, it was important to implement a system that included the added function of monitoring load variations, as well as implement load sharing and load depending generator start and stop. With the intention of developing a fully automated system, the project was designed to incorporate an immediate reaction response in a controlled manner to reduce the risk of total ship blackout. An important objective was the implementation of a modular design approach for the purpose of marketing the product as a plug and play system. This was an important feature to implement as it facilitates future installations of additional generators by the simple addition of another generator switchboard panel thus avoiding the complete redesign of the PMS.

## Project Methodologies

- Design of electrical schematics including the interface between the generators, synchronizing and load sharing units, PLCs, motorized circuit breakers, pushbuttons, selector switches, meters and indicator lights, compliant with Lloyd's Register standards which is a marine classification society
- Software development for control of PLCs, synchronizing and load sharing modules
- Modular design approach
- Wiring of the complete system as per the electrical designs
- Interfacing of the power management control system to the generators and shore power
- Software debugging and synchronization testing
- Documentation and finalization of dissertation



*Figure 1: Modular Power Management Control System Panels*



*Figure 2: Generator Under Test*

## Results and Achievements

Although the circuit was designed and implemented to carry out load-sharing between the generators, this functionality could not be tested due to unforeseen circumstances regarding the lack of availability of generators having an electronic governor in Malta. Nevertheless, the building, wiring and testing of panels was successful and both generator panels were effectively synchronized with the grid. Moreover, excellent control over the synchronization process was achieved. Hence the objective of this project was reached and the intelligent power management control system was fully operational.

## References

- 1 N. T. Stringer, "Voltage Considerations During Generator Synchronizing," IEEE Transactions On Industry Applications, pp. 526-529, May/June 1999.
- 2 M. J. Thompson, "Fundamentals and Advancements in Generator Synchronizing Systems," Schweitzer Engineering Laboratories, Pullman, USA, 2010.

# Three phase high power factor rectifier using HF inductors

**Student: Paul Salnitro**

**Supervisor: Dr. Maurice Apap**

## Introduction

Given the proliferation of non-linear loads in the global market there has been an international effort by utility companies as well as governing bodies regarding the permissible amount of harmonic pollution these loads are allowed to emit. A common non-linear load found through grids worldwide is the three phase rectifier. Considering the harmonic pollution limits are being tightened as more of these loads are connected to the grid it has become of importance to offer reliable and economically sound alternatives to the uncontrolled six-pulse rectifier. A better implementation is to include supply side inductances but such inductors are bulky and do not solve the problem. The PWM rectifier offers high power factor rectification at all inputs and with bi-directional power flow however this comes at a high price and complex controller design.

## Project Objectives

The aim of the project is to design a novel approach for a high power factor three phase rectifier based on the boost topology; the design will make use of hysteresis current control. Project deliverables include simulations based on MATLAB of single and three phase boost rectifier designs as well as the practical implementation of a the single phase circuit.

## Project Methodologies

The main aspect of the project is to design the appropriate current control mechanism required for high power factor operation. To this end the hysteresis current control algorithm was selected due to its relative ease and reliability. To implement the control algorithm it was decided to use the DSPIC4011 microcontroller; this was used to design a digital phase locked loop based on measured phase voltages and to output the desired current templates. The hardware for the implementation of the above mentioned work is displayed in figure 1. A hysteresis comparator was also designed and consists of a comparator circuit with external hysteresis set using discrete resistances and can be seen working in figure 2, in this example one can see how the output voltage (square wave) becomes fully positive when the triangular waveform is larger than +1V and goes negative when its lower then -1V. In conjunction simulations were run for the single phase and three phase topologies as well as a model of the digital PLL inside the microcontroller.

## Results and Achievements

The implementation of the control algorithm has been completed with the voltage sensing network and microcontroller unit successfully outputting the desired current templates. Verification of the hysteresis comparator was also conducted and the aim is to have the single phase version complete in hardware. Simulation results have also been obtained with total harmonic distortion results as well as confirmation of high power factor operation for both single phase and three phase systems.

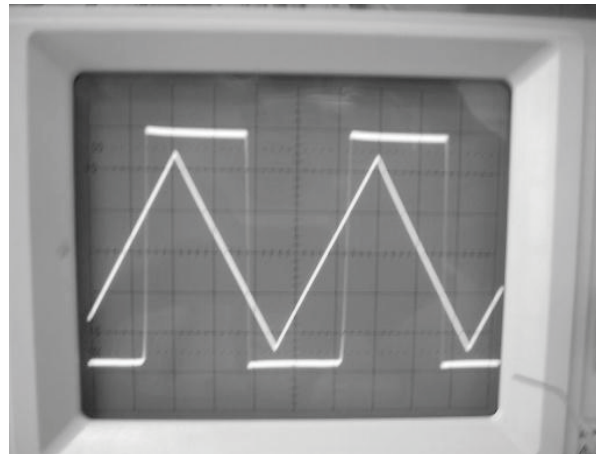


Figure 1 Hardware for current template construction

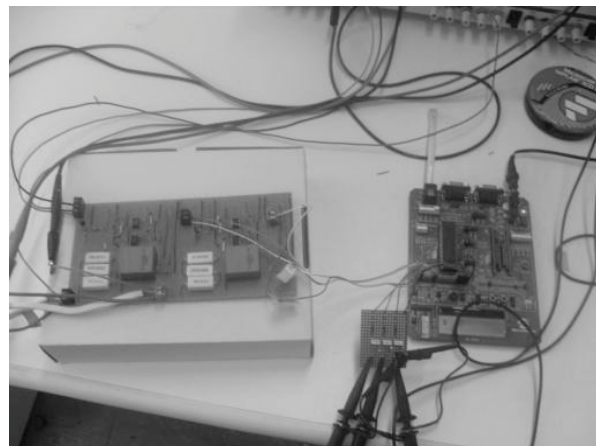


Figure 2 Hysteresis comparator output (square wave) against triangular waveform input. Note how the output changes about the +1 and -1V hysteresis band



# Pump control and monitoring using a PLC

**Student: Matthew Schembri**  
**Supervisor: Prof. Joseph Cilia**

## Introduction

For my final year project I proposed to the faculty a project in conjunction with the national water utility company, Water Services Corporation. The project involved the control of a large water pump in Fiddien that supplies potable water to Rabat, Mdina and Dingli.

A reservoir in Rabat is connected to the water main from the pump in Fiddien, the reservoir is used to hold excess water that is pumped from Fiddien but not used by the consumers. During the day, the consumption is higher than the supply so water is taken from the reservoir to meet the demand.

The task was to automate the system, making it more efficient and accessible to authorised personnel. This was achieved by using a Programmable Logic Controller (PLC) which is used to automatically control industrial systems by following the program held in its memory, the device allows communication over the network so employees can control the station from the central control room.

## Project Objectives

The main problem with the system was that if it is left uncontrolled, the reservoir eventually is emptied or overflows. This happens since water consumption is not constant especially during the weekend or public holidays when people use more water, it is known as an unstable system and should be best controlled using closed loop control.

The aim of the project was to successfully control the level of the reservoir so that it follows a certain cycle which never overflows or empties. Apart from that, the station had to be wirelessly connected to the WSC network so that employees could monitor and control the pumps using SCADA (Supervisory control and data acquisition).

## Project Methodologies

A study of the system's variables was carried out using previous logs of pressure, water flow and water level. A mathematical model was then produced to extract key values from the water network.

Testing and experimentation was not allowed to be done on the real network so no inconvenience is caused to the consumers, a simulation rig was built in the laboratory on which the PLC program is written and tested. Furthermore, modifications to the wiring at Fiddien Booster were carried out to make the system compatible with PLC control. After the program was finished and tested, it was downloaded

onto the PLC at Fiddien.

## Results and Achievements

Control of the reservoir's water level was obtained successfully using a control system called cascade control. This ensured that, not only the water level is controlled but also the pressure in the water mains is kept within an allowable band.

Water level in the reservoir was allowed to cycle in the course of a day, this made sure that the water in the reservoir is constantly moving. A clear and simple mimic was created for controlling the system remotely through the network as shown in Figure 1.

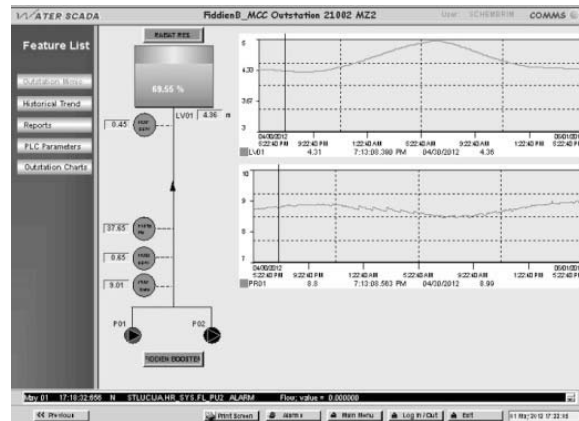


Figure 1 - SCADA mimic of the system

# Hand Pose Replication using a Robotic Arm

**Student: Kirsty Aquilina**

**Supervisor: Dr. Kenneth Scerri**

## Introduction

Even though the advances in computational intelligence of autonomous robots are remarkable, this is not always enough to cope with certain situations. In such cases when human intelligence is needed, more so when the environment of the robot is not suitable for humans, teleoperation systems must be implemented. Teleoperation of a robot means that the human controls the robot at a distance; this can be regarded as the main application of this project.

## Project Objectives

The aim of this project is to actuate a robotic arm according to the user's hand pose (position and orientation of the palm) in real time measured using only one camera, hence providing a good starting point to develop a user friendly teleoperated system.

## Project Methodologies

A coloured square marker is attached to the user's hand as seen in Figure 1. A USB CCD colour camera is fitted at about 2m height facing downwards so as to capture the images of the user's hand. The colour of the square marker is used to make it stand out from the rest of the background. Subsequently, the corners of the coloured marker are detected by fitting lines to the square's edges and consequently finding the points of intersection. These are then used to estimate the position and orientation of the user's hand using a pose estimation algorithm. This algorithm manages to obtain x, y, z, roll, pitch and yaw of the user's hand by using the known dimensions of the square marker. This data is then filtered using a Kalman filter which smoothes the signal whilst tracking it.

The data is then sent to the robot controller. Using the robot's inverse kinematics derived from Figure 2, the position and orientation of the user's hand are converted to the required joint angles of the 5 degree of freedom (DOF) robotic arm which is being used for this project. The values of these angles are subsequently fed to a proportional derivative controller which controls the position of each joint. This leads to the end effector (gripper) of the robotic arm to replicate the user's hand pose.

## Results and Achievements

The coloured marker was successfully tracked and the required corners detected. From these corners, an estimate of the 3D position and orientation of the user's hand was obtained. These were successfully tracked by the Kalman filter and sent to the robotic arm which managed to replicate the position and

pitch and roll of the user's hand in real time. The working system can also be seen at: <http://bit.ly/IF43Xy>.



Figure 1: The coloured marker

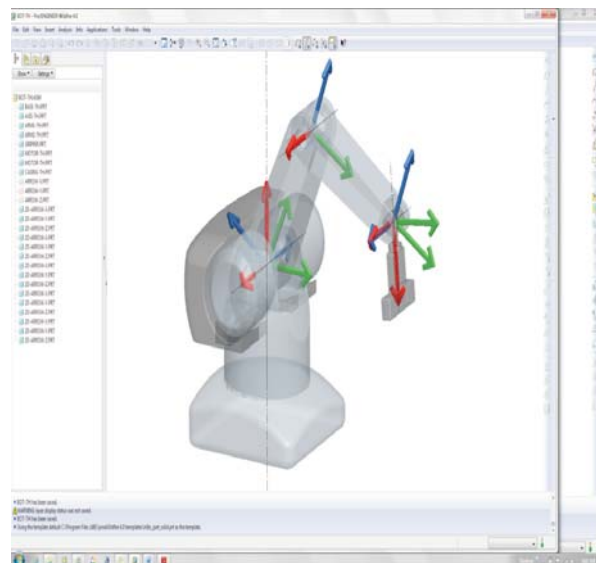


Figure 2: The 5 DOF robot showing all the 5 joints and the end effector.



# Anti-sway Control of a Gantry Crane System

**Student: Mario Borg Jr.**

**Supervisor: Dr. Ing. Marvin K. Bugeja**

## Introduction

A gantry crane consists of a trolley, capable of moving on its rail, to which a load is connected via a hoist cable. Hence, the load can be taken from its initial stationary position to the final desired one. The load can then be lowered and released. However, since the gantry crane is a flexible system, any movements of the trolley would result in swaying in the load. The operator may try to dampen these oscillations before lowering the load by moving the trolley to and fro intelligently. Also, due to this swaying other equipment or personnel can be hit. Moreover, the process of handling loads would be very time consuming.

## Project Objectives

The main objective of this project is to investigate anti-sway techniques which would assist an operator in controlling the crane. This is because the swaying in the load during the transfer and any oscillations in the load when the trolley has come to a halt would be reduced. Therefore, the load could be released as soon as it arrives at the desired location. This would speed up the work. In fact, much research is being made in this area of control engineering [1, 2].

## Project Methodologies

First and foremost, research was done to see how this problem was actually solved by other engineers. The first approach taken to deal with the swaying was to use a state-feedback controller. A reference input is then given which specifies the desired final position of the cart. Although as soon as the cart reaches this position the angular displacement of the load would be 0, significant swaying is present during the transfer. The concept of input shaping was then investigated. It is based on the fact that if an impulse is given to a system, the response of the system to this impulse can be cancelled out by giving the system another impulse. This technique involves shaping the input force acting on the trolley in such a way that the shaped input would cancel its own induced vibration in the load. In other words, the input is given in steps. These two types of controllers were then implemented on the setup (previously used as an inverted pendulum) in the Control Systems Laboratory.

## Results and Achievements

It was concluded that in the case of state-feedback controllers direct control on sway reduction is minimal. On the other hand, an input shaper is designed specifically for this purpose. Hence, this second method gave very promising results.

## References

- 1 Ahmad M. A., Nasir A. N. K., Raja Ismail R. M. T., and Ramli M. S., "Control Schemes for Input Tracking and Anti-sway Control of a Gantry Crane", in Australian Journal of Basic and Applied Sciences, 2010, 4(8): 2280-2291.
- 2 Kim Y., Hong K., and Sul S., "Anti-Sway Control of Container Cranes: Inclinometer, Observer, and State Feedback", in International Journal of Control, Automation and Systems, 2004, Vol. 2, No. 4, pp. 435-449.



Figure 1: The Gantry Crane

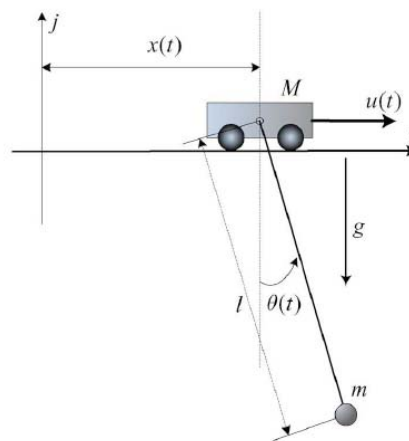


Figure 2: 2D Gantry Crane Diagram  
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# Path Planing and Control of a Mobile Robot Team

Student: Jean Paul Callus

Supervisor: Dr. Kenneth Scerri

## Introduction

Autonomous mobile robots have been developed to be used in environments such as urban (house vacuuming robots), agricultural (pesticide spreading helicopters) and underwater (AUVs used for shoal finding) amongst others. This project aims to improve on the path planning algorithms for these robots and to investigate different methods to control the robots.

## Project Objectives

The aim of this project is to find a path planning algorithm and control two robots such that a given surface is completely scanned in the most efficient way possible.

## Project Methodologies

Different path planning algorithms were investigate and an algorithm known as the Chinese Postman Problem (CPP) was implemented. The aim of the CPP is that in a given map every edge must be visited once and only once. Therefore for the robots to cover the entire area, nodes are spaced out such that if the robots traverse every edge once, the entire area would be covered exactly once. The map is set out as shown in Figure 1. That gives the path for 1 robot. The multiple agent problem was then studied to expand this to two robots and a modification was suggested to make the algorithm better suited for this scenario.

The robots used in this project are the Khepera III Robots developed by K-Team® (shown in Figure 2). The Khepera III is a differentially driven mobile robot which has a diameter of 130mm and a height of 70mm. It has 8 infra-red proximity and ambient light sensors with up to 30cm range, 2 infra-red ground proximity sensors mainly used for line following applications and 5 ultrasonic sensors with a range of 20cm-4meters. It can reach a maximum speed of 0.5m/s. Although the Khepera III has a DaFIC 30F5011 processor included in it clocked at 600MHz (used for sensor interface purposes), a Korebot II microcontroller also developed by K-Team® is included, having a 600MHz processor, 128MB RAM and 32MB FLASH. This second microcontroller is used for higher level control algorithms. Communication between the Korebot II and the computer is done via bluetooth.

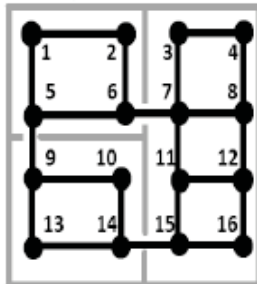


Figure 1: Map with nodes numbered



Figure 2: The Khepera III Robot with Korebot II Microcontroller

Different controllers were studied to control the robots in question (known as differentially driven robots). The discontinuous controller was implemented and a modification not found in literature was suggested to make the paths obtained smoother.

## Results and Achievements

In this project an algorithm was successfully implemented to find the optimal route to cover the entire area of a given map using both one and two robots. A controller was also implemented to have the robots follow their respective paths. An interface was also constructed for communication between a central computer and the robots. Therefore the final result is two robots which can, given a map of the area, go around the entire area in the shortest possible route. A test map (shown in Figure 1) was implemented and the resultant paths obtained were found to be the ideal solution.





# Programming of Virtual Haptic Environments

**Student: Matthias Cassar**  
**Supervisor: Dr. Ing. Simon G. Fabri**

## Introduction

This dissertation deals with the use of haptic systems and their application in today's world. A haptic system is a human controlled system in which the human receives force feedback through a haptic device, and would therefore respond accordingly. This project was taken up due to an interest in engineering systems that aid people that are unfamiliar to the engineering field. In this dissertation, a commercial haptic device is used to aid stroke patients that have lost ability of their wrist.

## Project Objectives

The aim of this project is to program a library of haptic environments around a commercial 3D haptic device, the PHANToM® Desktop™ (Figure 1) from SensAble Technologies.

## Project Methodologies

A background review about haptic systems and their application was achieved, as well as an understanding of the PHANToM® Desktop™ and its programming software to be used. To practice and learn the coding used by the toolkit, two demonstration exercises were created. The first is a simple push button, in which the user can feel the spring force that a button such as that of a keyboard would exhibit. The second is a small physiotherapy exercise where the user tries to move the cursor from one point to another in a specified amount of time, after which the device generates forces to pull the user to the destination. Finally, the main project was created. (Figure 2) This project teaches stroke patients that have lost ability of their wrist to draw simple shapes and letters. The aim of the device is to generate small forces at the patient's hand such that s/he would remain on track when drawing, as if there is a second person holding the patient's hand to guide him/her. The program opens with a simple user interface where the patient's ID is entered, and an exercise and difficulty are selected. The exercise is set up as a game, displaying scores, accuracy and time, to keep the patient entertained and encouraged. The program can then record the patient's data, recording his/her position in the environment at every time step. This data is useful for the physiotherapist to assess the patient's progress.

## Results and Achievements

This project has been a success. Sample control patients were asked to use the system to test it out, and to acquire some control data. Such systems are already in use in other countries. A further development would be to make this system portable,

such that the device is in place at the patient's home, and data on his/her progress is sent to a hospital server via Internet.

## References

1 Image taken from: <http://www.sensable.com/haptic-phantom-desktop.htm>



Figure 1 – PHANToM® Desktop™ 1

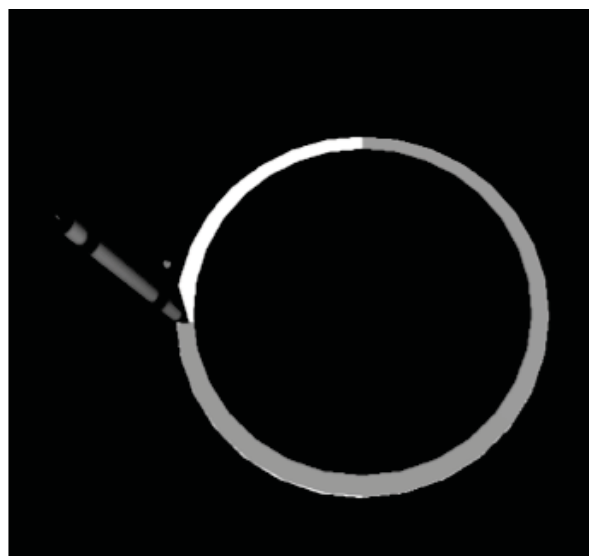


Figure 2 – Handwriting Rehabilitation Program

# Two-Axis Magnetic Levitation of a Magnetic Material

**Student: Darren DeBattista**  
**Supervisor: Dr. Kenneth Scerri**

## Introduction

The motivation behind this thesis is to gain experience in the design, construction and assemble of electronic systems to develop a magnetic levitation system. Application of this thesis include Magnetic Bearing 1 used to eliminate friction otherwise caused by using standard bearings, high precision magnetic planar levitation devices used for photolithography (IC Design) 2 and transportation were trains known as MagLev are magnetically levitated to reduce friction.

## Project Objectives

The aim of this thesis is to construct a magnetic levitation system to be used as a test bed to test different control algorithms. The construction of this system consists on the following tasks:

- Design and construct the electromagnets to be used
- Design and construct a current driver for the electromagnets
- Design and construct a sensing circuit to sense the position of the levitated object in 2D space
- Create an interface to the constructed set-up to enable controllers to be used on PC
- Obtain a mathematical model describing the system dynamics
- Design, implement and test different controllers capable of stabilizing the magnetic levitation system.

## Project Methodologies

A mathematical derivation of the force produced by an electromagnet on a given object was first done. The result was seen to be too complex and hence, a simulation was done to approximate the force produced by an electromagnet with a more simple equation. Following the simulation, current drivers were designed and built which could give enough current as determined by the simulations done. The current driver is shown in figure 1.

The sensor circuit was next designed. This circuit was made by using an array of IR sensors. Measurements from these sensors with different position of the levitated object were taken and a mathematical relation between the output of the sensors and the position of the levitated object was then derived. Finally, the levitated object mathematical model was also derived. By analysing this model, suitable controllers were designed and tested to determine and compare their performance on such a system.

## Results and Achievements

Due to the nature of the system, especially due to the lack of air friction, the system is very sensitive to modelling errors. The sensors used were also too sensitive and induced reading errors. Both issues made it very difficult for the system to work. This showed that to design such a system, there is the need of having a good and error less feedback and also to design more robust controllers which can work and give good performance even with system modelling errors.

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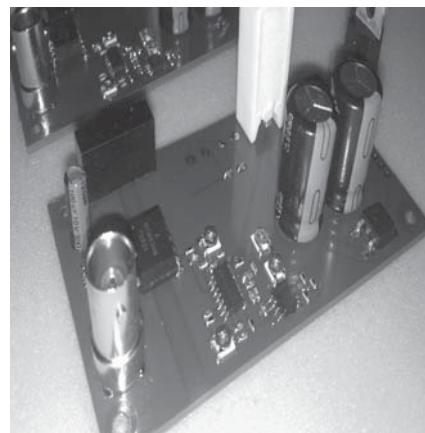


Figure 1 Current Driver

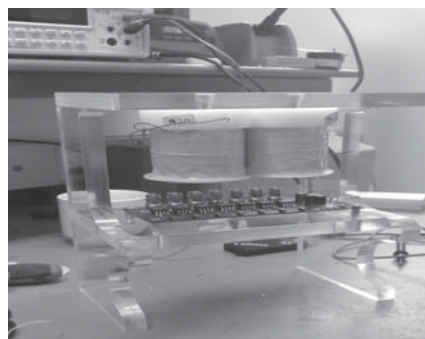


Figure 2 Physical Setup use



# Title – Self-tuning PID Controllers

**Student: David Debono**

**Supervisor: Dr. Ing. Marvin K. Bugeja**

## Introduction

Adaptive Control theory deals with the design of controllers that modify their parameters with respect to changes in the dynamic process. One kind of adaptive controllers are self-tuning regulators, which learn and track parameter changes in the plant with respect to time. The regulator changes its own parameters online to maintain the specified performance at all times. This type of control is useful in practical situation where the plant's dynamics and its disturbances are not known beforehand.

## Project Objectives

The aim of the project is to design and implement an indirect self-tuning PID controller that learns its own dynamics and adjusts its own parameters online. The PID Controller, after initial tuning, should continue to adapt to any changes in the plant to maintain the specified performance at all times. Thus the controller design can be divided into two different sections, as shown in Figure 1. These are the:

- Estimator which learns the actual plant parameters in real time
- PID Controller Design which designs the PID parameters from the parameters estimated by the estimator at every sampling interval, by pole placement.

The designed algorithm was simulated and physically tested on a dc servo motor experimental setup.

## Project Methodologies

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

- Literature review about different self-tuning controllers
- Development of a suitable estimation algorithm that learns the system parameters
- Design a digital PID controller that constantly updates it's parameters with the estimated parameters
- Simulations of the designed algorithms, under different testing conditions, were carried out
- Implementation the self-tuning PID controller on a dc servo motor setup
- Analysis of the results obtained

## Results and Achievements

The self-tuning PID managed to learn the dc motor parameters and managed to track the reference input with the required specifications. Figure 2 shows the initial tuning up of the self-tuning controller, which had no prior information about the motor dynamics. The figure clearly shows how quickly the system adapts to the unknown dynamics and stabilizes to

the unknown performance. The self-tuning controller also successfully managed to adapt to changes in the motor parameters.

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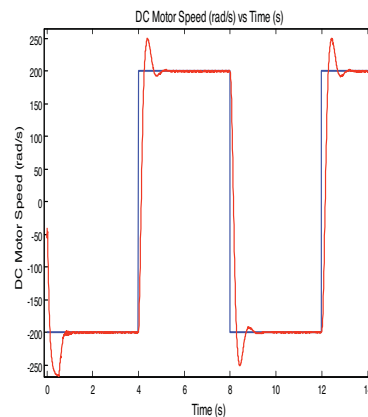
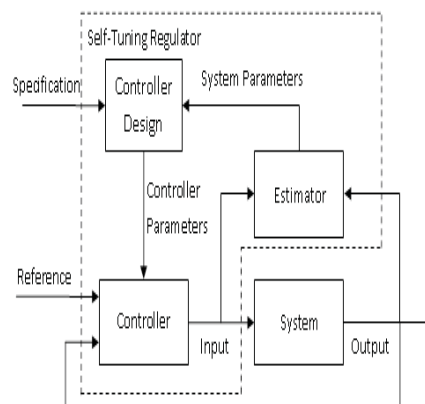


Figure 1: Indirect Self-Tuning Controller Structure

Figure 2: Output response of the Motor



with self-tuning PID



# Simultaneous Localisation and Mapping in Mobile Robotics

**Student: Mark Debono**  
**Supervisor: Prof. Ing. Simon G. Fabri**

## Introduction

Mobile robots have been experiencing an increased use in applications such as mine exploration, oil pipeline inspection, ocean and cave surveying and military applications amongst others. The problem of Simultaneous Localisation and Mapping (SLAM) deals with uncertainty in the robot's sensors and is a set of algorithms designed to estimate the robot's pose whilst simultaneously building a map of its environment.

## Project Objectives

This project has two main objectives. After the mobile robot is driven around some environment, an Extended Kalman Filter (EKF) based SLAM algorithm uses data from the robot's odometry and Laser-Range-finder (LIDAR) to produce an estimated path of the robot. After the path is produced, a human-readable map is created using an Occupancy Grid Mapping Technique.

## Project Methodologies

A kinematic model of the mobile robot, together with its odometer and laser rangefinder were built using Simulink. A feature extraction algorithm was first developed in MATLAB to extract features such as walls from laser scans. A SLAM algorithm together with data association using the Nearest Neighbour rule was then coded in MATLAB. These were tested on the Simulink model before moving on to experimental data gathered from the robot. Finally, a stochastic mapping technique known as Occupancy Grid Mapping was developed and tested on both the simulated and experimental data.

## Results and Achievements

Shown in Figure 1 is the occupancy grid map produced of the Systems and Control Laboratory. This was created using the estimated path from the SLAM algorithm and raw laser scans.

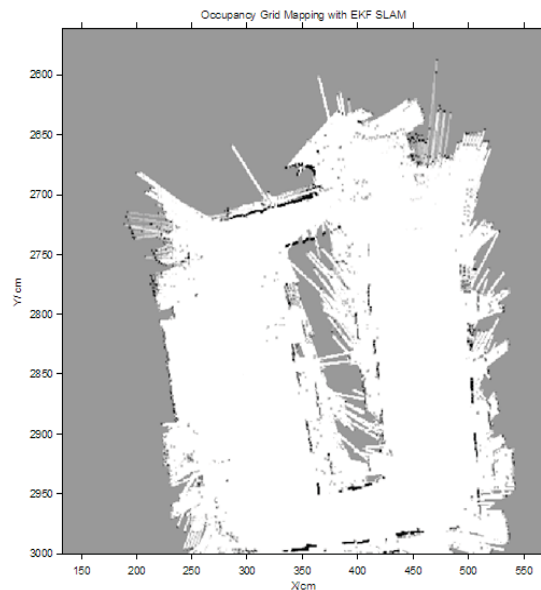


Figure 1: Occupancy Grid mapping using the EKF SLAM path and raw laser scans



# Dynamic Modelling of an Industrial Robotic Manipulator

**Student: Luke Farrugia**  
**Supervisor: Prof. Ing. Simon G. Fabri**

## Introduction

The availability of an accurate dynamic model is essential for system analysis and control design of a robotic manipulator. Robotic manipulators tend to exhibit highly nonlinear dynamics and hence mathematical modelling of such a system is difficult to derive since the underlying process is very complex. Moreover dynamic systems depend on past outputs, together with past and present inputs in order to determine the output at a certain time instant. One approach to modelling of systems, referred to as black-box modelling, is based upon the input-output collection of data and hence eliminates the need for a priori information about the system. This process is known as system identification.

## Project Objectives

The main aims of this project are to (a) set up the basic robotic system for standard operation as delivered by the manufacturers and (b) apply nonlinear system identification techniques so as to derive a set of black-box dynamic models for the 5 degrees-of-freedom CRS Catalyst-5 robotic manipulator shown in Figure 1. The developed models will be tested and compared using both simulation and practical results to correctly evaluate their performance.

## Project Methodologies

Using a mathematical modelling approach, a simulated model of the arm was implemented using Simulink® to collect the necessary input-output data. System identification was achieved using artificial neural networks which try to harness the learning process of the human brain. The idea is to train the neural network in such a way that it behaves as an accurate model of the system. The inputs considered from simulation were the torques developed by the motors of the joints while for the physical arm the currents to the motors were used. The outputs were the joint angles and their angular velocities. These were then used to train the neural network to approximate the non-linear dynamics of the manipulator and eventually to test its performance. To aid the system identification process, a noise signal of a small variance was superimposed on the current values to make the inputs more persistently exciting. The models generated by the artificial neural network were compared analytically using model validation tests.

## Results and Achievements

One of the most important result analyzed was the error between the outputs generated by the models and the corresponding outputs obtained from the physical arm. In general, the error values were relatively small such that the obtained models could be considered accurate enough while the noise signal superimposed to the inputs improved the results as well when compared to having no added noise. Currently, repeated tests are being applied using data generated from the robot manipulator when operated at different speeds and accelerations and using different variance values for the persistently exciting inputs. The aim is to deduce whether there exists any noticeable trend correlating these factors.



*Figure 1: The CRS Catalyst-5 robotic arm*

# Modelling and Analysis of the Interactions between Air Pollution and Traffic Flow

**Student: Nicolette Formosa**  
**Supervisor: Dr. Kenneth Scerri**

## Introduction

Automobile transport is now an inherent part of our civilization and its negative aspects are becoming more and more pronounced. Vehicular emissions continue to be a threat to the environment and need to be monitored in order to ensure acceptable air quality. The Malta Environment and Planning Authority (MEPA) collects average monthly concentrations of various air pollutants from a network of diffusion tubes across Malta while Transport Malta (TM) executes traffic flow counts for the main arterial roads. This data can be used to infer models describing the interaction between traffic levels and pollutant concentrations.

## Project Objectives

The main aim of this project is to use spatial analysis techniques and statistical modelling to capture the key characteristics of the relationship between air pollution and traffic count. Unfortunately, transport and pollution data are not measured at the same sites, so the main work focuses on interpolation techniques to obtain accurate pollution values at each traffic measurement site. These estimated pollution values and traffic counts can then be used to quantify the traffic effect of certain air pollutants.

## Project Methodologies

A spatial model is a mathematical description required to realistically represent the spatial dynamics of the attribute being modelled. The most widely used statistical model is given by:  $\text{Data} = \text{Structure} + \text{Residue}$ . The structure consists of the mean and/or weighting of its dominant neighbours together with a nonlinear covariance structure for the residue. The covariance structure depicts how the data measured to sites in close proximity tends to be more directly related than data from far away sites. The process of obtaining a mathematical model thus boils down to estimating the linear parameters in the structural part by least squares and fitting a nonlinear covariance model to the residues by a global search. The estimated model can then be used to interpolate for the required pollution values. This is done by Kriging. Simple Kriging (SK) is used for missing data values while Universal Kriging (UK) is used for interpolation at unobserved sites.

## Results and Achievements

When tested, the models which gave optimum results for both SK and UK are made up of the mean

and parametric covariance residue. The correlation coefficient between traffic volumes and pollution concentration was found to be 0.5901 for weekdays, 0.5466 for Saturdays and 0.42180 for Sundays showing positive correlation for each day tested. Dividing Malta in four zones, the highest correlation coefficient was obtained for the Grand Harbour area. The central part of Malta was noticed to have high correlation coefficient for week days with this decreasing for Saturday and further decreases on a Sunday. The north and south parts of Malta experienced practically similar values for weekends (lower than for the central part). However, the northern part has a relatively higher correlation coefficient for week days than the southern part.

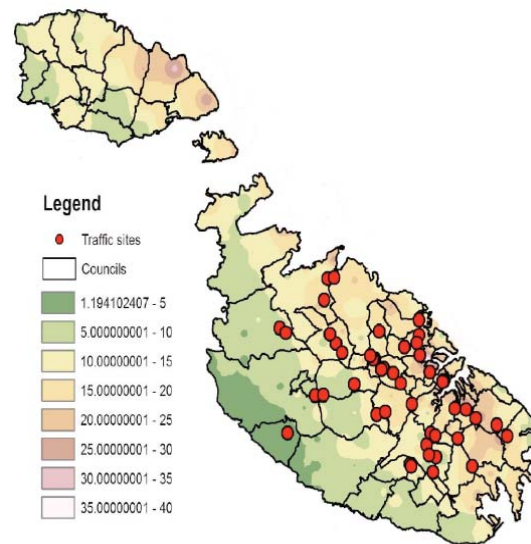


Figure 1 – Interpolated pollution surface and traffic measurement sites



# Remote Control of a Lego Mindstorms Robot over the Internet

**Student: Darryl Schembri**

**Supervisor: Prof. Ing. Simon G. Fabri**

## Introduction

The aim of the project was to study and implement network control system architectures which allowed an operator to control a Lego Mindstorms mobile robot 1 over the Internet.

## Project Objectives

Research, study and present the possible architectures for Internet based networked control systems.

- Design and develop an experimental networked control system.
- Test and implement various loop topologies for controlling the Lego Mindstorms mobile robot over an Internet connection.
- Evaluate performance of these topologies and list potential advantages and disadvantages of each architecture.
- Describe potential areas for improvements which may be adopted in the implementation of Internet tele-robotic systems in industry.
- Project Methodologies
- Study of present implementations of Internet robotic systems
- Design, development and implementation of a test bed for the Internet control system. This included client, server and Lego Mindstorms mobile robot systems.
- Implementation & simulation of point stabilization control techniques including the presence of network delays.
- Implementation of the aforementioned control algorithms on an experimental setup.
- Analysis of results obtained and list of future improvements.

## Results and Achievements

Two types of control architectures are possible for network control systems. A hierarchical structure uses a network to send a command to a remote closed loop system. A direct structure includes the network inside the closed loop system. This latter structure introduces significant time delays which will degrade system performance and may cause the system to go unstable.

A kinematic controller 2 for the Lego Mindstorms differential mobile robot shown in Figure 1 was implemented which stabilized the robot to a target position and orientation. The mobile robot was controlled using Bluetooth wireless technology.



*Figure 1 - Lego Mindstorms Mobile Robot*

Time delays were caused by the Internet and Bluetooth communication networks. These time delays led to degradation of system performance. A networked state feedback controller 3 was implemented which maintained a good level of performance in the presence of time delays in the closed loop system. A web page was designed which allowed an operator to control and monitor the robot from a remote location. The operator could operate the robot using both the hierarchical and direct structures. Visual feedback was also provided in the form of a video feed from a web camera placed at the local site.

Bibliography

# Autonomous Control of a Car-like Mobile Robot

**Student: Diandra Simiana**  
**Supervisor: Dr. Ing. Marvin Bugeja**

## Introduction

Autonomous control of vehicles is a popular field in research. This is mainly due to their practical use in our everyday life and also because they present theoretically challenging and interesting control problems. In this project the car-like mobile robot will be studied. It is a vehicle whose kinematic model approximates the mobility of a car <sup>1</sup>. The car-like mobile robot is a nonlinear system, under actuated, driftless meaning that no motion will take place under zero input and nonholonomic. The nonholonomic constraints are velocity constraints which limit the instantaneous motion of the car. The configuration of the car-like mobile robot, which is shown in Figure 1, is described by its position, orientation with respect to the x-axis and the steering angle of the wheels. The two control inputs are the driving velocity and the steering velocity.

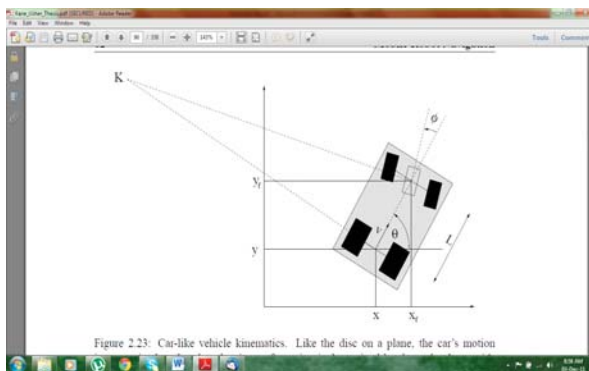


Figure 1: The Car-like mobile robot 2

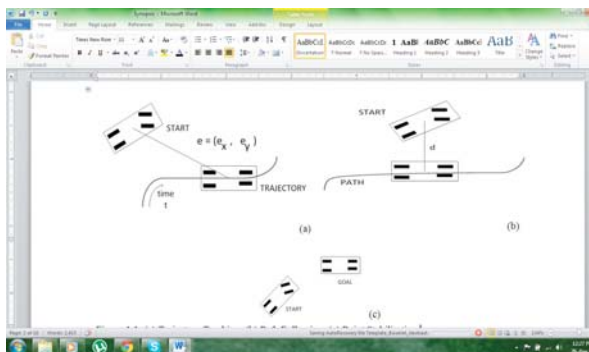


Figure 2: (a) Trajectory tracking, (b) Path following, (c) Point stabilization

The three motion control tasks associated with autonomous vehicles are shown in Figure 2.

These are:

- Trajectory tracking – where the robot must follow a desired trajectory by also taking into consideration a timing law.
- Path following – the robot must follow a given path irrespective of the timing law.
- Point stabilization – the robot must arrive at a desired position from any arbitrary initial position.

## Project Objectives

The objectives of this project are:

- Understand the kinematics of a car-like mobile robot.
- Design, implementation and simulation of controllers for specific motion control tasks.

## Project Methodologies

The objectives of this project were achieved by carrying out the following steps:

- Review of existing work on motion control of a car-like mobile robot.
- Derivation of the mathematical model of the car-like mobile robot.
- Control analysis on trajectory tracking and point stabilization.
- Simulation of a number of controllers using MATLAB/SIMULINK.

## Results and Achievements

The trajectory controller was successfully implemented on SIMULINK and the mobile robot stabilized about the desired trajectory after less than two seconds. The gain values for the controller were changed to ensure the reliability of the controller. The robot still stabilized about the desired trajectory but the stabilization time differed depending on gain values. For point stabilization two fuzzy controllers were used. These were also implemented using SIMULINK. The mobile robot stabilized at a point with a desired orientation on a circular trajectory.

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# Motion Tracking for Artistic Expression in Theatre and Dance

**Student: Michaela Spiteri**  
**Supervisor: Ms.Alexandra Bonnici M.Phil,**  
**B.Eng(Hons.), L.L.C.M.(TD)**



Figure 1: Result of Skeletonization

## Introduction

The interest in the area of human motion tracking is fuelled by its numerous applications, namely biomedical 1,2, security<sup>3</sup> and even the entertainment industry 4 as applied in this project. The main aim of the project is to capture movement on stage and produce visual effects corresponding to the performer's movements. These visual effects will be projected on a screen adjacent to the performer.

## Project Objectives

The main objective of this project is to identify and track the different body parts of a performer. It is required to detect the performer's movements, locate and identify different parts of the body and track these body parts throughout the video sequence.

## Project Methodologies

The project was split into three main areas; background subtraction, pose estimation and motion tracking.

Background subtraction was implemented using a Gaussian distributed background model<sup>5</sup>. If any pixel, of each incoming frame, does not fit the distribution then it will classify as part of the foreground. The silhouette of the moving dancer is thus obtained.

The silhouette is thinned such as to obtain a skeletal shape of the silhouette<sup>6</sup>. Salient body parts, namely the head, hands, feet, mid-chest and pelvis are

located in each silhouette. The location of these salient points indicates the pose being performed by the dancer.

These body parts are tracked using a Kalman Filter<sup>7,8</sup>. This filter works in two stages namely the time update and the measurement update stages. The time update stage predicts the next position of each salient point, whilst the measurement update stage updates this position such as to improve the next prediction.

## Results and Achievements

The background subtraction, pose estimation and tracking have been implemented and tested individually. Once the tracking system is applied to real-time data, the graphics may be generated.

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# Fuzzy Control of a Pendubot

**Student: Dwayne Vella**

**Supervisor: Dr. Ing. Marvin K. Bugeja**

The Pendubot, short for Pendulum-Robot, is an electro-mechanical system intended for the testing of novel as well as classical control algorithms. The Pendubot is a two-link planar system having an actuator at the first link and a passive revolute joint as the second link. The first link is known as the arm link while the second link is better known as the pendulum link. The actuator at the first link is in the form of a DC Motor. The dynamic coupling between the two links and its possession of multiple configurations and equilibrium points make it an interesting control problem. The Pendubot is open-loop stable in the downward position, known as the pendant position. On the other hand the position with maximum potential energy is known as the inverted upright position. The control problem investigated in this project involves the swing-up of the two links from the downward pendant position to the inverted upright position. The inverted upright position is an inherently unstable equilibrium point. Any minimal perturbations drives the system out of this equilibrium point until then stabilizing in the downward pendant position making it inherently stable.

The objective of this project is to design a fuzzy digital controller that is able to swing-up the Pendubot from the downward pendant stable position to the inverted upright position. This is to be achieved through the development of a fuzzy closed-loop controller. Two fuzzy swing-up controllers were developed in this dissertation, one being based on Two-Rules and another utilizing a fuzzy Proportional Derivative Controller. Consequently, stability about the upper equilibrium point is guaranteed by a fuzzy stabilizing controller. A fuzzy stabilization controller tuned by Linear Quadratic Regulator and a Fuzzy Proportional Derivative and Proportional Integral stabilization controller were implemented for this aim. Two novel fuzzy switching controllers were developed to combine the swing-up and stabilization controllers.

## Introduction

The name Pendubot arises from the terms 'Pendulum-Robot'. The system is mainly composed of two interconnected links joined together by means of a passive revolute joint. The dynamic coupling of both links makes it a nonlinear system. The system is only actuated at the first link, making it belong to a family of under-actuated systems having two outputs and only one control input. The system possesses multiple configurations. Such attributes make the system a benchmark in the development of novel control techniques such as fuzzy control.

## Project Objectives

The aim of this project is to deal with the control problem of the under-actuated Pendubot using fuzzy logic. The fuzzy controllers have to be designed and implemented

on the physical hardware setup which is situated in the Control Systems Laboratory. The control problem will be divided into three tasks. A fuzzy swing-up controller is required to swing-up the two links. A fuzzy stabilization is used to guarantee stability about the upper equilibrium point while the fuzzy switching controller is used to combine the two controllers.

## Project Methodologies

- Gain understanding of Fuzzy Logic and Fuzzy Controllers.
- Literature review focusing on the Pendubot configuration through Fuzzy Control
- Mathematical modelling of the Pendubot.
- Design and implementation of the fuzzy swing-up and stabilization controllers
- Implementing the designed fuzzy swing-up and stabilization controllers in MATLAB and SIMULINK and tuning the fuzzy controller parameters.
- Develop a novel soft-switching Fuzzy Transitional Controller that switches between controllers based on one set of conditions that are to be defined in the fuzzy rule-base.
- Develop a novel soft-switching Fuzzy State Switching Controller that switches between controllers based on two sets of conditions that are to be defined in the fuzzy rule-base.
- Combine the swing-up and stabilization controllers using the developed Fuzzy Transitional Controller and the Fuzzy State Switching Controller.
- Implement the designed controllers on the DS1104 board and retune the fuzzy controllers

## Results and Achievements

The designed control algorithms were implemented on the experimental setup. The fuzzy controllers proved successful in the swing-up and stabilization control problems. Furthermore, the robustness of these algorithms was verified by varying the initial conditions. Moreover the novel fuzzy soft-switching controllers produced the expected performance.

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# Real-time implementation of a motor imagery EEG based BCI

**Student: Rosanne Zerafa**  
**Supervisor: Ms. Tracey Camilleri**

## Introduction

A brain-computer interface (BCI) system creates a new communication channel between the human brain and a computer. BCI technology ultimately aims to improve the life of patients suffering from severe motor impairments by developing applications that do not depend on the brain's normal output pathways of peripheral nerves and muscles. Electrical brain activity can be recorded non-invasively through an electroencephalogram (EEG) by use of electrodes placed on the scalp.

It is observed that the actual execution of a movement of a particular limb, such as hands and feet, as well as their imagination, generate similar oscillatory patterns of cortical activation and inhibition. These event-related potentials are generally localized on relevant regions of the sensorimotor cortex and can be used as features to identify the different motor imagery tasks. These features are translated into a particular control signal to communicate with an external device, such as a wheelchair or software application.

## Project Objectives

The aim of this project is to design and implement a real-time BCI that provides the user with direct communication. EEG signals of a person performing specific motor imagery tasks are to be recorded, processed and classified in real-time to give continuous feedback.

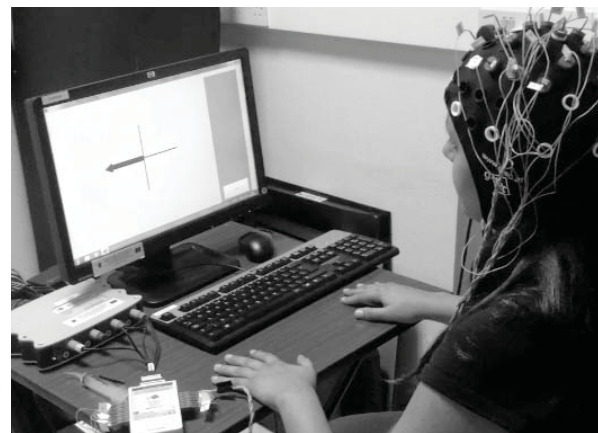
## Project Methodologies

The project was primarily focused on finding the most effective, accurate and computationally fast signal processing techniques used in current real-time EEG based BCI systems. These techniques were evaluated using data from an international BCI competition.

The designed real-time BCI system is a cue-based system using motor imagery, specifically the imagination of left and right hand movements. Amplitude modulations of sensorimotor rhythms are observed by extracting logarithmic band power features from the on-going filtered EEG data and the optimal subject-specific features are selected using Fisher ratio. A linear discriminant analysis classifier is then applied in order to distinguish between the two motor imagery tasks. The classification output is used to give continuous feedback to the user in the form of a bar varying in both direction and length.

## Results and Achievements

The implemented real-time system proved to be successful when simulated with EEG data of subjects from the BCI competition. These subjects had clear event-related patterns that could be used to distinguish between the two motor imagery tasks. EEG data of four other subjects was also recorded in the lab using the g.tec amplifier. The setup was as shown in Figure 1.



*Figure 1: Recording of EEG data*

Processing of data recorded from these subjects was not as straight forward as that of the BCI competition. This was a result of subjects generating similar brain patterns for the two mental tasks, making it difficult for the system to distinguish between them. Further training sessions in a more noise-controlled environment must be performed to help subjects gain the ability to control their sensorimotor rhythms and thus be able to control the BCI system.



# Mechanical Stream



# Design and Manufacturing of Micro Inserts for Injection Moulding of Micro Testing Specimens

**Student: Miguel Camilleri**  
**Supervisor: Dr Arif Rochman**

## Introduction

Micro injection moulding of polymer parts is a relatively new area in engineering. The effect of surface roughness of the mould on the polymer micro part is investigated.

## Project Objectives

The project consists of multiple objectives. The main objectives for the project were:

- Conduct EDM testing to determine three conditions to be used for the inserts
- Design suitable micro inserts
- Design of electrodes and ejector
- Manufacture the micro inserts with different roughness
- Injection and testing of moulds

## Project Methodologies

The project was divided in stages; design, testing, manufacture and injection moulding.

The design was initiated by determining the micro tensile specimen that is going to be injected. The basic dimensions of the mould insert were then determined due to knowing the size of the part to be produced. The insert would have two cavities; therefore a runner system was needed. The design of the runner system included the path, cold slug wells and the cross section shape.

A gate is needed between the runner and the cavity. The shape of the gate was of a ramp to provide smooth flow inside the cavity. The ejector and copper electrodes were also designed in a way to simplify the manufacturing process as possible.

Testing of electro discharge machining (EDM) parameters was done. Three conditions were chosen to machine the insert with.

The manufacture of the insert was done using the CNC milling machine and the Sodick  $\mu$ EDM. The runners, ejector holes and ejector cavity were machined by milling machine. The ejector was machined from aluminium and the electrodes from copper. The gates, vents and micro tensile specimen cavities were machined using  $\mu$ EDM.

## Results and Achievements

The three cavities have a surface roughness of 0.24Ra, 2Ra and 3Ra. The depth of the cavities is 0.43mm. The manufactured inserts will be tested using micro injection moulding at Aalen University in

Germany. Furthermore, the influence of the surface roughness of the moulded micro tensile specimens will also be investigated there.



Figure 1: Micro tensile specimen copper electrode



Figure 2: A finished mould insert

# Flexible automation for a packaging manufacturing process

**Student: Louis Attard**

**Supervisor: Mr. Sandro Azzopardi**

## Introduction

This study investigates the conceptual development of an automated packaging process used for the production of tiles by Halmann Vella, a local manufacturing company. The current system relies significantly on the human operator for inspection and palletizing of the tiles. Following this, several concepts for automatic packaging were generated with a focus on flexibility concepts to cater for the variations present in the range of tiles manufactured.

## Project Objectives

The primary objectives of this study can be summarized by the following points:

- The understanding of the complete current process focusing on the final packaging process,
- The identification of possible wastes in the current process, and
- The investigation of potential technological systems and process engineering methods available to automate this process.

## Project Methodologies

Flexibility in production could be gained by the use of reconfigurable systems and products together with the option for flexible systems. These in turn should result in a shorter change over and lead times acting as an answer to the changing market situation being faced nowadays. In a production environment it is of utmost importance that the end effectors are designed well since most of the difficulties arise from them and not from the robot itself 1. A gripper concept was generated for the required application, which is to be used for the stacking of each batch of strapped tiles, as well as for the application of expanded polystyrene sheets between these batches.

To automate the current packaging process, four steps were developed as shown in Figure X1. These are:

- Transfer from Grinding Machine to Inspection Area
- Inspection and sorting the tiles into three categories. (First-class, Seconds or Rejects)
- Strapping
- Palletizing

Different concepts were generated for each of the above process steps. These concepts were weighted primarily on economic cost, technical

feasibility, changeovers to accommodate product variables, reliability and cycle time so as to determine the most appropriate concept for each stage.

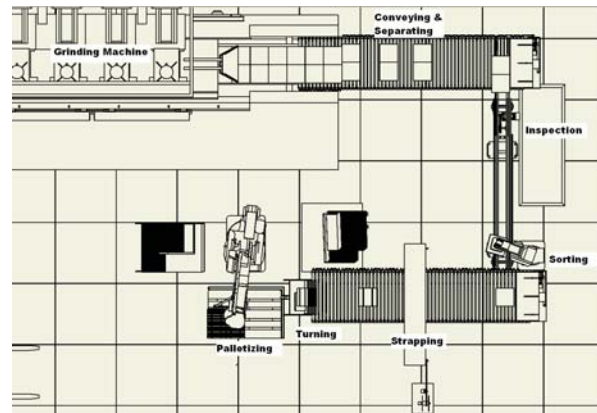


Figure X1

## Results and Achievements

The final proposed concept would require two less operators, with these being reduced from the most tiresome and hazardous process step and would give the possibility for these operators to be deployed to other more satisfying jobs within the company. Figure X2 shows a conceptual three dimensional representation of the whole proposed system. This is an extension replacing the manual packaging system to one using a flexible approach.



Figure X2

## References

- 1 Y. Yamauchi, Application and evaluation of robots in Nissan. Automotive Manufacturing International, 1993, pp. 73-81.



# Post-Processing of Electron Beam Melting (EBM) Parts

**Student: Matthew Azzopardi**  
**Supervisor: Dr. Arif Rochman**

## Introduction

EBM is a relatively new technology which allows the user to build parts out of a variety of materials. It is classified as Additive Manufacturing where parts are built up from powders which are selectively melted together using a high power electron beam. The Arcam S12 EBM machine recently acquired by the University which was used to build the parts used in the experiments uses Ti6Al4V ELI as a building material. The problem with this kind of technology is the rough surface texture which results as a side-effect of the intense heat generated while building. This is most often undesirable and hence needs to be removed for the parts to be functional. The idea is to use EBM as a near net shape process, and then use other processes to either remove the semi-sintered surface layer or coat it. This can be seen in Figure 1. Hence one ends up with a combination of processes which are both: fast, efficient, and low cost.

## Project Objectives

The aim of the project was to: perform a literature review on EBM and a selection of post-processing methods, perform an in depth analysis of the part surface as produced by EBM, and build sample parts to attempt post-processing using a variety of methods. The methods were then qualitatively compared and ranked.

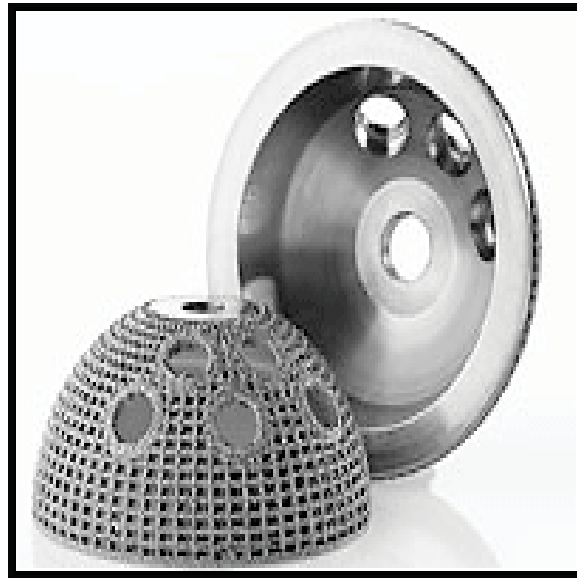
## Project Methodologies

An investigation of the depth of the semi-sintered surface layer was the first experiment performed. Sample parts were built and by testing, a value for the surface thickness was extracted. Parts were then built with different thicknesses and different build angles to see whether this varied the surface roughness. The second experiment consisted in building 5 identical sample parts and attempting different methods of post processing, one for each part. The processes investigated were Milling, Turning, Grinding, Electric Discharge Machining (EDM), and Surface Coating. The methods were then ranked by 3 parameters: duration of processing, surface roughness produced, and tool expense. As a final experiment, the information obtained was used in a case study to machine a part with many different geometric features to a specified set of dimensions.

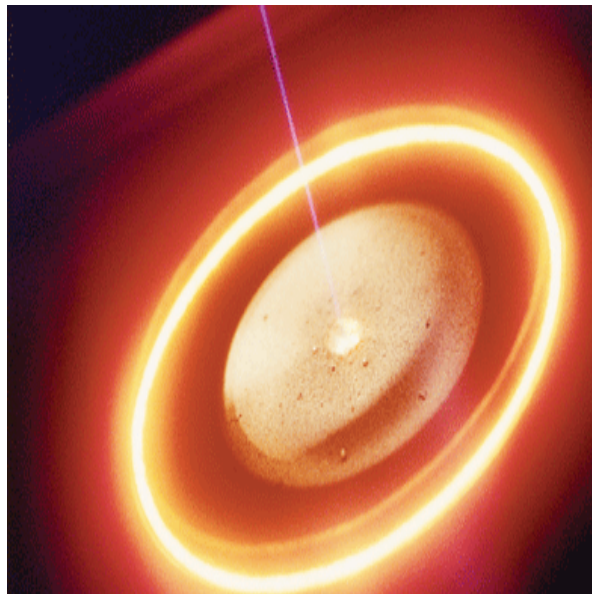
## Results and Achievements

The depth of the semi-sintered surface layer was checked via 3 different methods and resulted to be 500 $\mu$ m.

The different processes were ranked with EDM attaining the largest overall score and Milling and Turning achieving second place. EDM produced the best surface finish but Turning took the least time to accomplish and had the lowest tool cost.



*Figure 1 – Parts made by EBM which have been post-processed.*



*Figure 2 – Electron beam used by EBM*

# Development of Novel 'Hermetic Cosmetic Cases' Opening and Closing Devices

**Student: Marija Bartolo**

**Supervisor: Prof. Jonathan C. Borg**

## Introduction

Hermeticity, commonly defined as a condition of being fluid-tight, was brought about by the system failures of military electronic equipment caused by the ingress of moisture. From such applications, hermeticity also found its place in the cosmetics industry. The need for hermetic cosmetic cases arose due to the complex cosmetic formulations based on water, silicon and sun protection factors (SPFs). When such formulations are exposed to atmosphere or heat for a prolonged time, some ingredients, especially water, tend to evaporate. Eventually, the cosmetic becomes brittle and cracks. At this point the product is said to have failed, since it can no longer meet its desired function, that of easy application to the skin.

## Project Objectives

It is required to design and test a number of adequate hermetic case solutions, and design alternative opening and closing devices. The design should be one which can be easily, efficiently and economically manufactured, having good quality, thus requires adequate dimensional tolerances, an aesthetically pleasing appearance and finally, straight forward opening and closing devices, making it easy to manufacture and simple for the customer to use. Hence, the design should focus mainly on manufacturability, aesthetics and ergonomics.

## Project Methodologies

To achieve the above objectives, it was concluded that the design process structure that was going to be applied in the thesis, was the basic design cycle. So first, a problem analysis was carried out, such that a number of problems could be outlined and understood. Then a Product Design Specification list was set up to ensure that the concept proposed in the design phase satisfies the desired functions. Next, in the solution synthesis, a number of methods used to develop provisional designs, such as the SCAMPER, were applied. From these techniques, a number of hermetic solution concepts and various opening and closing device concepts, were obtained and analysed to be able to identify the best solutions. Therefore, prototypes were designed, constructed and tested. To be able to test for hermeticity, a weight loss test was performed on each prototype by filling the prototypes with water soaked sponges and then sealed, to be placed in a heating chamber at 50°C for 14 days. During this period, weight readings were recorded and tabulated. From the results, it was

concluded that mainly two of the three prototypes, performed correctly. Once testing was completed, an evaluation from various aspects, especially manufacturability, aesthetics and ergonomics was performed to be able to design the final hermetic case design solution including the latch type opening and closing device. Several improvements, especially from the aesthetics point of view, were made to the final working design principle shown in Figure 1. Other latch designs were provided to improve the aesthetics of the opening and closing device shown.



*Figure 1: Final Working Design Principle*

## Results and Achievements

From the work carried out, a hermetic cosmetic case solution with a prolonged shelf-life, between 12 to 18 months, was achieved. The design can be considered as being successful in terms of hermeticity, manufacturability, aesthetics and also ergonomics, making it a successful even from the marketability point of view.

## References





# A Concurrent Engineering Approach to Product Development

**Case Study: Methode Electronics Malta Ltd.**  
**Student: Mark Borg**  
**Supervisor: Prof. Ing. Jonathan C. Borg**

## Introduction

Concurrent Engineering (CE) emphasises on the systematic work structuring and parallel execution of decomposed development tasks, based on the premise that the overall product development time is condensed 1

However, successful accomplishment of CE is made possible through the exploitation of multi-disciplinary teams through which expert capabilities are combined to achieve results greater than any individual team-member effort. The capability of communicating instantaneously with each other and access and share knowledgeable information in a free-flow manner, unimpeded by organisational barriers or incompatible technology is imperative to this philosophy.

Satisfactorily accomplishing the implementation of a CE approach requires a clear understanding of the existing practices for product development within the organization from a CE perspective 1. The focus of this thesis is on the need for an assessment that can aid management for such a transformation.

## Project Objectives

Being an industry based project, this thesis embraces two principal objectives.

The Academic Objective: To develop, and verify an amalgamated methodology to assess the maturity and readiness of industry for a Concurrent Engineering approach within the boundaries of the product development process.

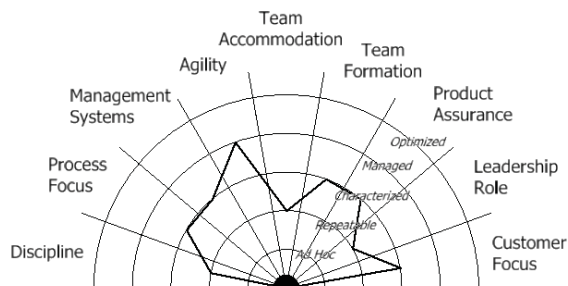


Figure 1 - The MRACE Model

The Industrial Objective: To determine practicable recommendations to support the implementation of

Concurrent Engineering by means of application of the developed assessment tool.

## Project Methodologies

The author has developed an assessment tool - the Modified Readiness Assessment for Concurrent Engineering (MRACE) - to assist CE implementers in identifying the barriers and prioritizing recommended implementation actions. Furthermore, MRACE is applied at Methode Electronics Malta Ltd. (MEM Ltd.), a local manufacturing firm, in an effort to validate the tool. Successful CE implementation requires the commitment of the managerial and technical staff. Indeed, the word "readiness" conveys both willingness as well as capability 2.

## Results and Achievements

After completing the application of MRACE at MEM Ltd., the author derived a series of identified bottlenecks confronted within current procedures from a CE standpoint. These are qualitatively presented on the MRACE model, as shown in Fig 1, which illustrates nine CE dimensions and five respective levels representing the degree to which each dimension is satisfied.

Through this model a number of recommended actions were drawn and presented to top management at MEM Ltd., as suggested means of overcoming the identified barriers to CE implementation. Validity of the suggested recommendations was obtained through theoretical and methodical sustenance based on previous works. Additionally, the perceived appropriateness and impact of each recommendation by product development top management was documented. The objectives of this thesis were thus fulfilled. MRACE provides industry with a means to gain detailed insight into current procedures and identify suitable improvement areas to assist CE implementation.

## References

- 1 Ganapathy K. et al., "A Hierarchical System of Performance Measures for Concurrent Engineering," *Concurrent Engineering: Research and Applications*, January 1997, vol. 5, pp. 137-143.
- 2 Prasad B., 'Concurrent Engineering Fundamentals: Integrated Product and Process Organization', Prentice-Hall PTR, New Jersey, USA, 1996.

# Machining of Dies and Moulds by Electrical Discharge Machining

**Student: Luke Camenzuli**  
**Supervisor: Ing. Pierre Vella**

## Introduction

There is continuous research in today's industry leading to the quickest possible processes, whilst obtaining the best quality finish. Electrical Discharge Machining (EDM) is one such important type of machinery in industry. A number of research works have already been carried out, with the aim of increasing the efficiency of the spark, as well as experimenting on ideas, to further improve the process. Nowadays, CNC EDMs reduce the time for programming as well as increase the amount of variable parameters and settings that can be carried out. This further improves the output results, including a better finished surface on the work pieces, an increase in the material removal rate and a decrease in the electrode wear. 1

## Project Objectives

The aim of this project was to research and investigate the effect of the peak current, on-time, off-time, polarity, and a number of machine circuit settings (HP/PP/C), of the Sodick AP3L EDM machine found at the University of Malta, and their effect, especially in connection to Sverker21 (AISI D2) and Orvar Supreme (AISI H13) which are used as moulds and dies. A number of output data was then used to study a number of aspects, including the material removal rate, the surface integrity, and dimensional inaccuracies.

## Project Methodologies

A total of 4 roughening and 8 finishing trials were formulated for both materials, by making use of the Taguchi approach. This approach in the design of experiments helps in reducing the number of experiments to be carried out, and in the same time still obtaining the required information, therefore eliminating the need of a full factorial approach. The experiments were carried out with a 25x25mm oxygen free copper electrode to form a 26x26x2mm cavity.

## Results and Achievements

The data gathered was then evaluated or used to calculate further results. To help analyse better certain results obtained, the statistical software Qualitek-4 was used to calculate the S/N ratio and generate graphs to investigate which factors mostly affect certain output parameters. Figures 1 and 2 represent images of the surface for roughening and finishing processes respectively.

Some of the main conclusions, as from the results

obtained, are as follows:

- The increase in peak current leads to an increase in the material removal rate, the white layer thickness and amount of surface cracks, while a decrease in the amount of surface roughness.
- The increase in On-time and Off-time results in a decrease in material removal rate, and an increase in surface roughness and white layer, during the finishing process.
- HP/PP/C and electrode polarity had a low effect on the output parameters except for the surface roughness, which was highly effected by the HP/PP/C.

Although a number of important parameters have been investigated during this project, there are other parameters, which may also affect such output parameters, like for example mode of electrode orbiting.

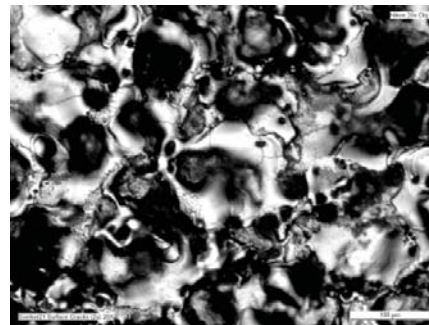


Figure 1: 20X Sverker21 surface obtained with high peak current, on-time and off-time

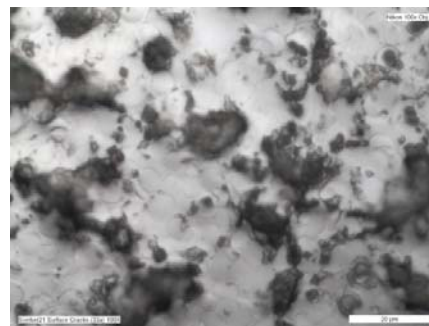


Figure 2: 100X Sverker21 surface obtained with low peak current, on-time and off-time

## References

M. S. Popa, G. Contiu, D. Preja, G. Pop and A. Trila, "Electric Discharge Machining Process Control," Annals of DAAAM for 2009 & Proceedings of the 20th International DAAAM Symposium, vol. 20, no. 1, pp. 381-382, 2009.



# Towards An Emotion-based CAD Tool Supporting Product Branding

**Student: Christopher Cassar**

**Supervisor: Dr. Ing. Philip J. Farrugia B.Eng (Hons.), Ph.D. MIED**

## Introduction

Presently companies can no longer compete simply on technology, mainly because many are facing competitors that are equal in technical expertise. It is no longer sufficient for a product to function properly, be usable and efficient or have aesthetic appeal, but it also has to provide positive emotional responses such as pleasure, inspiration, desire, positive surprise, etc. Design for emotions (DFe) is being seen as a determining factor in the success of a product and pleasurable products as a key contributor to the competitive advantage of a firm.

## Project Objectives

The main aim was to develop a database which relates emotions to product features with the introduction of branding which backs a framework to enhance emotional value of a product at the primary stages of design. Other objectives included the development of another database which relates emotions to product features to the French population.

## Project Methodologies

A literature review was carried out on the state-of-the-art Design for Emotion support. Various means of measuring emotions were found and a non-verbal instrument – Emocards was used in this project as shown in Figure 1.

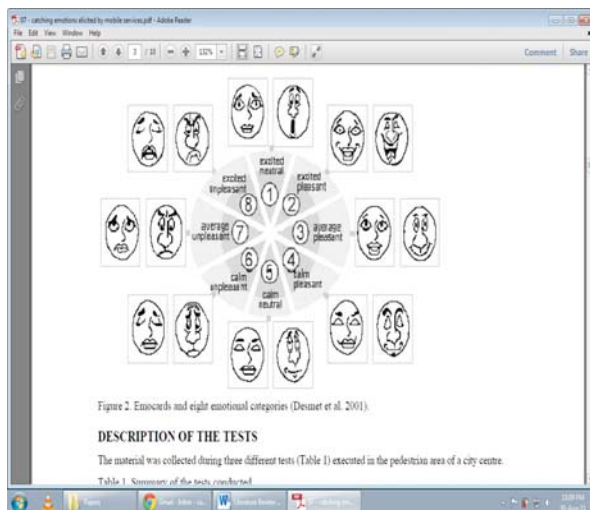


Figure 1: Emocards and eight emotion categories, reproduced from 1

Emocards were used in the questionnaire to develop the emotional knowledge database. The aim of the questionnaire was to analyse the emotions that are elicited towards product features and to analyse whether there is an association between branded products and non-branded products with emotions. All this was part of a framework development to support real-time guidance to designers to enhance the emotional content of a product. The same questionnaire was distributed in France to analyse cross-cultures between the Maltese population and the French. Based on the framework developed a proof-of-concept tool – DFe Assistant was developed using Visual Basic for Applications – VBA and implemented so that designers can produce emotional value added products at the early stages of the design process. The tool was evaluated by typical end-users in industry and also by future end-users.

## Results and Achievements

Results have shown that the emotional database required small updates. The statistical analysis have shown that for no curvatures in the product negative emotions are elicited for stakeholders that are younger than 35 years old and positive emotions to stakeholders aged over 35. The analysis of branding in this project has led to the conclusion that there is a strong association between branding and emotions; hence this was implemented in the DFe Assistant so that designers can take branding into consideration whilst designing. The DFe Assistant presented in the dissertation gives the opportunity for designers to innovate products having emotional value added. DFe Assistants' intuitive graphical user interface makes the tool for designers easy to understand and easy to use. The evaluation of the tool was very satisfactory, and the evaluators were pleased with DFe Assistant whilst highlighting various improvements for the tool and the branding section to increase its potential in the future.

## References

1 P. M. A. Desmet, "Measuring emotions; development and application of an instrument to measure emotional responses to products," in *Funology: from usability to enjoyment*, M. A. Blythe, et al., Eds., ed Dordrecht: Kluwer Academic Publishers, 2003, pp. 111 - 123.



# Title – Manufacturing Cell Improvements At Trelleborg Sealing Solutions (Malta)

**Student: Elaine Schembri**

**Supervisor: Dr Arif Rochman**

## Introduction

This project, in collaboration with a local manufacturing company, Trelleborg Sealing Solution Malta, analyses issues related to the material and process flow of the production of V-rings which was recently relocated from Sweden to Malta. 'Trelleborg is a global engineering group whose leading positions are based on advanced polymer technology and in-depth applications know-how. They develop high-performance solutions that seal, damp and protect in demanding industrial environments.'<sup>1</sup>

## Project Objectives

Just like any other manufacturing plant, the goal of Trelleborg is to produce zero defects products and provide its customers with cost-effective sealing solutions to compete with other competitors. To do so, all waste and non-value adding activities have to be eliminated while increasing the quality.

The aims of the project are;

- To analyse the current production flow from a lean perspective
- To see where waste is being generated
- Come up with necessary improvements to make the process more lean and produce zero defect quality
- Analyse and evaluate the proposed improvements
- Identify areas which require further study.

## Project Methodologies

This project identifies wasteful activities in the production V-rings at Trelleborg Sealing Solutions Malta and proposes various options to reduce this waste. The following steps were carried out during the implementation of the project:

- Literature review in order to develop a deep understanding of relevant World Class Competitive Manufacturing methodologies
- The recently transferred manufacturing unit and its current state were analysed
- The generation of waste was identified
- A set of necessary improvements required to make the manufacturing system more competitive in terms of quality, cost and delivery performance by eliminating waste were identified
- The improvements were implemented and the proposed future state was achieved
- A comparison between the current and future state was done



## Results and Achievements

Several lean tools such as 5S, TPM and Value Stream Mapping were used to improve the production process of V-rings. On doing so product quality and delivery time were improved. The implementation of a new cryogenic machine was proposed in order to reduce the processing lead time.

## References

<sup>1</sup> Trelleborg AB. (2012, May), Trelleborg, on-line. Available: <http://www.trelleborg.com/en/The-Group/About-Our-Group/>



# Artificial Rib replacement using additive manufacturing

**Student: Quinton Calleja**  
**Supervisor: Dr. Ing. Philip Farrugia**  
**Co-supervisor: Mr. Aaron Casha**

## Introduction

During this project an artificial rib implant was designed to accommodate patients that require chest wall reconstruction surgery due to rib removal. Rib removal is usually associated with either cancer at the ribs or chest wall invasion as a result of lung cancer.

## Project Objectives

The aim of this project was to construct a revolutionary artificial rib implant, which could be easily used and manufactured. Moreover, this prosthetic rib should also offer an excellent fixation to the native bone and should be easily shaped to mimic the chest contour.

## Project Methodologies

This project follows the basic design cycle methodology. In the initial stages of the project a meeting was set up with two senior cardiothoracic surgeons at Mater Dei hospital as to evaluate what is the current procedure at Mater Dei hospital. Following this stage was an exploration research which was carried out by means of a questionnaire in which the surgeons highlighted the most important properties that an artificial rib implant should possess. The information gathered from this questionnaire proved to be of outmost importance in order to better understand what the requirements of the product are. Several design tools were used in order to try and capture as much different ideas as possible. In total 7 innovative conceptual designs were created. All the design concepts were presented during a meeting with the cardiac surgeons at Mater Dei hospital, during this session the concepts were meticulously evaluated. The best concept was chosen from this session and an ABS prototype of this concept was created by means of a rapid prototyping machine. After that the model was created another meeting was setup to re-evaluate the model before an actual titanium prototype was built.

During this evaluation some suggestions were given to further enhance the design. After some slight changes were done to the CAD model a titanium prototype was created by means of an EBM machine. Following the creation of the titanium prototype a final meeting was setup to evaluate the end product but this time all the cardiac surgeons were present. During the evaluation the prototype was fit to a full size skeleton model to assess the end result.

## Results and Achievements

All the senior cardiothoracic surgeons were satisfied with the end result, and surprised with the ease by which the device was attached to the skeleton. This being said it would have been better practice if the device was made from a titanium sheet since this will promote malleability and crimping the device would have been easier.

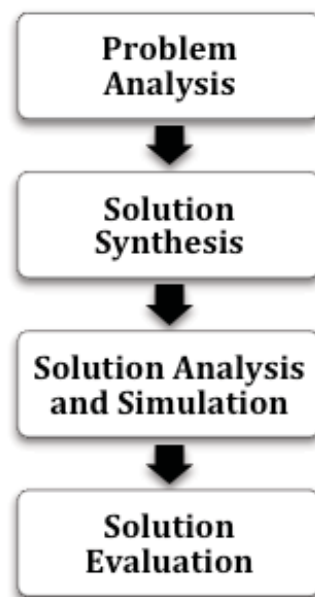


Figure 1: Basic Design Cycle

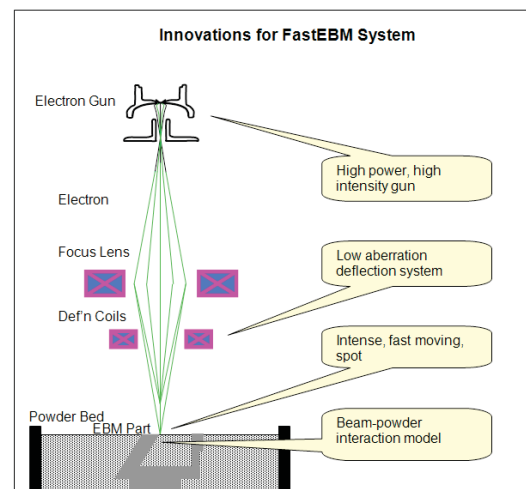


Figure 2: EBM Process <http://www.fastebm.eu/>



# Towards an Improved Methodology for the FMEA Implementation at Methode Electronics Malta Ltd.

**Student: Roderick Gatt**  
**Supervisor: Dr Ing. Philip J. Farrugia**

## Introduction

“Failure mode and effects analysis (FMEA) is an engineering technique used to define, identify, and eliminate known and/or potential problems, errors, and so forth from the system, design, process, and/or service before they reach the customer” 1. ISO/TS 16949, the automotive quality management system standard, mandates the use of five core quality tools, including the FMEA. While some organisations have embraced these tools and exploited the benefits they can offer, many fail to make use of its full potential.

## Project Objectives

From an Industrial perspective the objective was to study the existing FMEA procedures being implemented at Methode Electronics Malta Ltd., identify any shortcomings and to develop an improved implementation methodology to enhance the usability and efficiency of the process.

From an academic perspective, the goals were to follow an engineering problem-solving framework for investigating and improving current FMEA procedures and to apply established engineering principles and tools to help identify the root causes for any shortcomings and come up with solutions.

## Project Methodologies

The DMAIC (Define, Measure, Analyse, Improve and Control) framework, illustrated in Figure 1, was followed to investigate the implementation of the FMEA methodology.

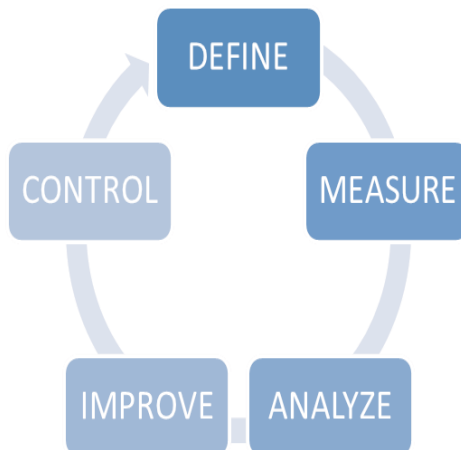


Figure 1: The DMAIC phases

Methodological triangulation was used to integrate the findings from three distinct research methodologies: survey questionnaires, observations and interviews. The data was used to construct the ‘AS-IS’ IDEF model which was analysed by means of a Current Reality Tree. This helped distinguish the main root causes which were tackled in a new implementation methodology and documented in a ‘TO-BE’ IDEF model. A control framework was introduced to safeguard all potential benefits

## Results and Achievements

The root causes were identified as the lack of a multi-interdisciplinary team while developing the FMEA and that the current Excel-based system, as opposed to a dedicated supporting software, was limiting potential benefits.

From an industrial point of view the company attained a better understanding of the condition of its FMEAs. From an academic perspective the author acquired a better understanding of established engineering methodologies that should serve useful for future endeavours.

## References

1 T.P. Omdahl, Reliability, availability, and maintainability (RAM) dictionary. ASQC Quality Press, Milwaukee, U.S., 1988.



# Automation Consideration in a Product Testing Process

**Student: Martha Micallef Anastasi**  
**Supervisor: Dr. Ing. Conrad Pace**

## Introduction

This project consists of the consideration for automation in a product testing process. Following the production process to build and assemble pH sensors at ProMinent Fluid Controls Ltd., the sensors are then tested on a testing machine. The current testing process is time consuming, operator dependant and has a lot of individual probe handling by the operator. Therefore the testing process may be improved by considering automation in certain areas to ultimately increase its functionality.

## Project Objectives

The industrial objectives of this project are; to analyse the nature of the tests carried out on the sensors and the material flow on the line, to develop a framework for the automaton of the testing process and to evaluate the development of the measurement process during the testing by applying standard hardware and software for data collection.

In line with the industrial objectives, the project also has to address the academic objectives which are; to address the problem by applying specific design process methodologies and tools, and to evaluate their appropriateness within the context of the project.

## Project Methodologies

In this project the problem at hand was tackled in a systematic manner by following the Design Process described by Ertas and Jones [1]. Through the use of the design process, the testing process was deconstructed. This simplified the analysis and the process was then solved in the deconstructed segments and finally integrated back together.

Part of the design process focuses entirely on determining the requirements of the system. Once these requirements were set, they were carried through the rest of the subsequent design phases to ensure that the new testing process follows the requirements set by the customer.

Another part of the design process was dedicated entirely to deciding the order of events in the testing process which was a critical step as it determined the flow of material and information within the testing area.

## Results and Achievements

Thus in this project a framework for the automation

of the testing process is developed using a higher level of programming language rather than that which is currently used, as well as using standard components. Instead of using a low level programming language which is difficult to update and alter, a higher level programming language is used. Standard components are used instead of using special components as they give room for future development, they are easily set up and they are not difficult to replace or repair.

In the current testing process the sensors are handled by the operator in 60% of the process steps required to complete the testing process. In the new testing process however, the operator only handles the material in batches around 35% of the processing steps.

Through the course of this project the testing time was also reduced by approximately 60% which improved the testing process throughput.

## References

[1] Ertas, A. & Jones, J. The Engineering Design Process. 2nd ed. New York, N.Y., John Wiley & Sons, Inc., 1996.

# Design of Simulated Experiments for a Manufacturing System. An Injection Moulding Department Case Study.

**Student: Daniel Saliba**

**Supervisor: Ing. Emmanuel Francalanza**

## Introduction

It is unquestionable that manufacturing is vitally important for the EU and Maltese economy. In Malta, there is a strong manufacturing base for high value-added products like electronics and pharmaceuticals. Malta is motivated to amplify the competitiveness of manufacturing.

Methode Electronics Inc. is a leading developer of custom-engineered and application specific products. This project investigated the Injection Moulding Department (IMD) of Methode Electronics Malta Ltd. (MEM). The department produces plastic parts which are then fed to assembly departments. The IMD operates with Just-In-Time (JIT) principles namely the Kanban Pull System. Apart from producing quality products, MEM needs to constantly reduce its cost base to remain competitive and sustain business in the long term.

This project applies Design of Experiments (DOE) along with Discrete Event Simulation to improve the performance of the IMD. The methodology developed yielded an experimental design which was executed with Plant Simulation by Siemens.

## Project Objectives

### Academic Goals

- To conduct a review of literature on JIT systems, Kanban systems, simulation methodologies and the Design of Experiments (DOE).
- To construct a Design of Simulated Experiments methodology.
- To apply simulation as a tool to solve the problem.
- To apply DOE as the statistical framework and analyse the results to identify the most significant system factors.

### Industrial Goal

To propose a set of recommendations aimed at increasing the performance of the IMD.

### Project Methodologies

A methodology was devised by the author in consultation with literature for an integrated DOE-Simulation approach. The system to be simulated was defined. This consisted of a sub-system of the IMD composed of 5 machines. Next, data of the failure patterns and the changeover times of each machine

were collected together with data on which parts each machine processes and with what processing time and the lot size (kanban size) for each part. This stage was conducted in concurrence with the development of the conceptual model using the IDEF0 technique. This model was then translated to a computer model using Plant Simulation. The programming of complex logic necessitated the use of SimTalk Programming Language. The model was verified and validated accordingly obtaining an overall accuracy of 84.3%

Next a DOE was conducted. The design chosen was the Classical Method with a full factorial of 5 factors (MTTR, overtime, cycle time, kanban size and setup time) and 2 responses (throughput and machine utilisation rate). This meant the responses for several “what-if” scenarios were tested in a structured manner.

## Results and Achievements

A sensitivity analysis carried out with Minitab showed that the system is highly dependent on the cycle time of the parts and that overtime significantly increases the throughput. Contrastingly, MTTR emerged as an insignificant factor.

This led to the formulation of 4 concrete strategic recommendations to the IMD which included the encouragement to invest in exercises which reduce the cycle times of parts since the early product life cycle stages and encouragement to adopt Single Minute Exchange of Dies methodologies to reduce setup times.

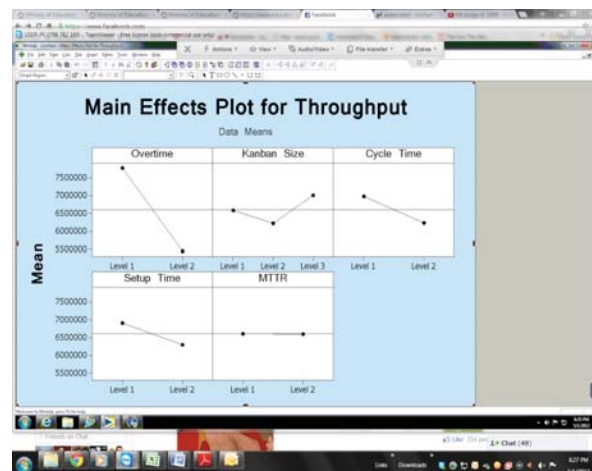


Figure 1 Main Effects Plot for Throughput





# The Development of Environmentally Conscious Cosmetic Packaging through Eco-Design and Design for Manufacture

**Student: Mark Anthony Bonnici**  
**Supervisor: Dr. Ariff Rochman**

## Introduction

Companies specializing in packaging design accompanied with many others, are in the throes of change that is manifesting itself rapidly and without any defined control. Indeed, the increasingly witnessed awareness on the use of environmental friendly products amongst the general public has invariably increased the demand not only for buying value for more products, but also for searching products that have the least possible environmental impact along their life cycle phases. Within this scenario, any possible disdain of subtle change on behalf of companies might inherently threaten their current market share [1].

## Project Objectives

This dissertation aims to analyse a case study of a product that has been designed and manufactured by Toly Products Ltd. This analysis shall be made from an environmental impact perspective whereby all environmental impacts throughout the reference product's life cycle phases shall be benchmarked. A new proposed primary packaging shall then be designed from an environmental conscious perspective and through eco-design strategies. The design proposed should also prove the design effectiveness from a manufacturability point of view.

## Project Methodologies

These objectives were satisfied with the best possible solutions adopted throughout the dissertation. Primarily, the analysis of a reference case study illustrated in Figure 1 took place on a qualitative analysis whereby environmental impacting design practices were highlighted in the Problem Analysis phase. The initial qualitative analysis was then refined by first undertaking a Spider Diagram analysis within the Solution Synthesis phase, followed by Eco-Indicator 99 within the Solution Evaluation phase.

Once a benchmark had been set for the reference product, conceptual models were generated through eco-design strategies which were then directly compared with one another together with the reference product by means of the Spider Diagram. The success of the eco-design strategies became visible and appreciated only once all conceptualised models generated, proved to be more environmental friendly than the reference product, with concept 3 illustrated in Figure 2, being the less environmental impacting throughout its life cycle phases.

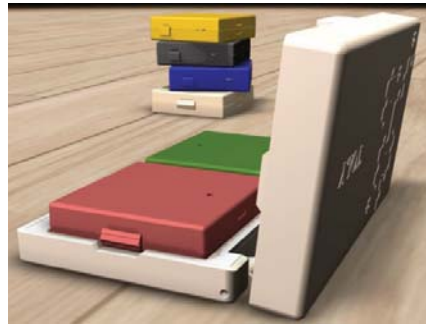


Figure 1 - Case Study [2]



Figure 2 - Design Concept 3

## Results and Achievements

Once the best concept from an environmental point of view was identified, it was then analysed from a design for manufacturing perspective in order to make sure that the presented concept does abide with design guidelines for manufacturing by means of injection moulding. Moreover, the bill of materials for both concept 3 and the reference product was conducted to prove the fact that apart from producing a less environmental impact product whilst opening new marketing paradigms to the company, there is also a higher chance of making a profit from the product due to its lower cost from a material consumption perspective.

## References

- [1] Scott Boylston, Designing Sustainable Packaging. London, UK: Laurence King Publishing Ltd, 2009.
- [2] BERGDORFGOODMAN. (2012, May) BERGDORFGOODMAN. [Online]. <http://www.bergdorfgoodman.com/store/catalog/prod.jhtml?itemId=prod53800002&parentId=cat243457&masterId=cat243411&index=13&isEditorial=false&cmCat=cat000000cat000005cat243403cat243411cat243457&ecid=BGALRJ84DHJLQkR4>



# Automation Consideration in a Product Testing Process

**Student: Martha Micallef Anastasi**  
**Supervisor: Dr. Ing. Conrad Pace**

## Introduction

This project consists of the consideration for automation in a product testing process. Following the production process to build and assemble pH sensors at ProMinent Fluid Controls Ltd., the sensors are then tested on a testing machine. The current testing process is time consuming, operator dependant and has a lot of individual probe handling by the operator. Therefore the testing process may be improved by considering automation in certain areas to ultimately increase its functionality.

## Project Objectives

The industrial objectives of this project are; to analyse the nature of the tests carried out on the sensors and the material flow on the line, to develop a framework for the automaton of the testing process and to evaluate the development of the measurement process during the testing by applying standard hardware and software for data collection.

In line with the industrial objectives, the project also has to address the academic objectives which are; to address the problem by applying specific design process methodologies and tools, and to evaluate their appropriateness within the context of the project.

## Project Methodologies

In this project the problem at hand was tackled in a systematic manner by following the Design Process described by Ertas and Jones [1]. Through the use of the design process, the testing process was deconstructed. This simplified the analysis and the process was then solved in the deconstructed segments and finally integrated back together.

Part of the design process focuses entirely on determining the requirements of the system. Once these requirements were set, they were carried through the rest of the subsequent design phases to ensure that the new testing process follows the requirements set by the customer.

Another part of the design process was dedicated entirely to deciding the order of events in the testing process which was a critical step as it determined the flow of material and information within the testing area.

## Results and Achievements

Thus in this project a framework for the automation

of the testing process is developed using a higher level of programming language rather than that which is currently used, as well as using standard components. Instead of using a low level programming language which is difficult to update and alter, a higher level programming language is used. Standard components are used instead of using special components as they give room for future development, they are easily set up and they are not difficult to replace or repair.

In the current testing process the sensors are handled by the operator in 60% of the process steps required to complete the testing process. In the new testing process however, the operator only handles the material in batches around 35% of the processing steps.

Through the course of this project the testing time was also reduced by approximately 60% which improved the testing processes throughput.

## References

[1] Ertas, A. & Jones, J. The Engineering Design Process. 2nd ed. New York, N.Y., John Wiley & Sons, Inc., 1996.



# Design and construction of a Stirling engine for cooling applications

**Student: Christopher Abela**  
**Supervisor: Prof. Robert Ghirlando**

## Introduction

The Stirling cooler works on the principle of a reversed Stirling cycle, making it possible to achieve temperatures lower than those attainable with a Rankine cycle system 1.

## Project Objectives

The aims of the project are the following:

- Design, build and test a Stirling cooler capable of reaching temperatures comparable with those of a Rankine cycle system.
- Develop a mathematical model for the designed engine using programming techniques to predict the cooling temperature and cooling capacity.
- Compare the experimental with the theoretical results.

## Project Methodologies

A second order mathematical model was employed for the theoretical analysis of the engine's performance. Such model starts with a simplified cycle analysis which would predict a certain cooling temperature and cooling capacity 2. The model is then improved by accounting for losses: pressure drop, conduction heat losses, pumping heat losses, shuttle heat losses, and reheat losses inside the regenerative annulus. Applying this ideal cycle in the first place would incur knowledge of the cooling temperature, and since this is the unknown the student made use of the coefficient of performance of a similar engine taken from a journal 3. The various losses were then expressed in terms of the unknown temperature and an iterative solution was applied using MATLAB until the coefficient of performance obtained matched the one taken from the journal. Thus the temperature, cooling capacity and magnitude of the mentioned losses were evaluated. After the model was ready, the engine was built according to the designed specifications.

## Results and Achievements

The temperatures obtained from the experiments were in range of 4.4 to -10.60C, which are in the range attainable by the Rankine cycle. However, comparison with theoretical results showed some discrepancies. Part of these discrepancies may be due to improvements required in the engine, such as the need of a formal cooling jacket to absorb the heat at the compression space area and the addition of piston rings to improve compression of the piston.

Moreover, an increase in the length of the cylinder and the displacer would reduce the amount of heat flowing by conduction from the compressor area to the expansion area. The other reason is due to inaccuracies in the program and the need to use higher order mathematical models which make use of nodal analysis.

To calculate the coefficient of performance of the engine, the cooling capacity should be measured via experimental means. This can be done by having a water jacket attached to the cylinder's cap at the tip to measure how much the water is cooled down taking whilst taking into account its mass flow rate.

## References:

- [1] Walker Graham. Cryocoolers. Vol. 1. New York : Plenum Publishing Corporation, 1983.
- [2] Martini W.R. Stirling engine design manual. NASA-CR-1353 82, Natl.: Aeronautics and Space Administration, 1978.
- [3] Le'an Sun , Yuanyang Zhao, Liansheng Li, and Pengcheng Shu. "Performance of a prototype Stirling domestic refrigerator." Applied Thermal Engineering 29 (2008): 210-215.



# Muscular Recruitment during Different Modes of Motion

**Student: Andre' Attard**

**Supervisor: Dr. Ing. Zdenka Sant**

**Co-supervisor: Dr. Mark Sacco**

## Introduction

Early humans have been walking fully upright for 3.7 million years [1]. Since then the human gait has improved due to the anatomical changes owing to evolution. Human gait and muscular recruitment during walking has been studied a lot in the past few decades. With the rise of new technological advancement in surface electromyography (sEMG) muscular recruitment can be analysed in more detail. In this project sEMG was used to analyse muscular recruitment in three muscles in the lower extremity of human body during different walking speeds. sEMG was also used to understand the relationship between sEMG signals and the force generated in the muscle .

## Project Objectives

Perform experiments on three specific muscles using sEMG to analyse muscle activation during the gait cycle, and analysing the relationship between the force generated by the muscles and the muscular activation captured using sEMG.

## Project Methodologies

This project was divided into two parts. The first part was to develop and implement a system of tests to study the muscle activation patterns for different walking speeds, followed by post-processing of the resulting signals. The processed signals were then validated with theoretical signals. The second part of testing was to develop a series of tests to investigate the sEMG-Force relationship, including the design and construction of a weight bearing structure. The tests were implemented in order to obtain the force readings and their respective sEMG signals, which were also validated with theoretical results.

## Results and Achievements

The signals obtained during the first part of testing matched with the theoretical graphs. This confirmed that the testing procedure was correct and that the post-processing performed on the raw signals obtained was accurate. A weight bearing structure was designed and constructed in order to apply additional forces to the muscles being tested during the second part. The investigation of the relationship between the force and sEMG is pending. It is expected that a linear relationship will result.

## References

[1] – McLerran, D., 'Study shows Early Human Ancestors Walked Fully Upright Earlier Than Scientists Thought'. Popular Archaeology Magazine, June 2011, Vol. 3.

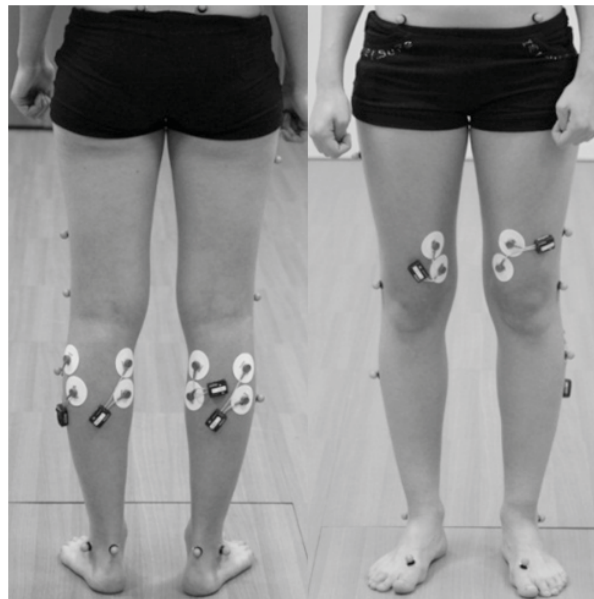


Figure 1: sEMG electrode placement on one of the subjects during testing.



Figure 2: An illustration of the testing set-up for the second part of testing.



# Testing and Modeling of a Windmill Tower and Nacelle - The Structural Aspect

**Student: Redeemer Axisa**  
**Supervisor: Dr. Martin Muscat**

## Introduction

The Chicago type wind pump was introduced to the Maltese country side with the main purpose of pumping water from reservoirs for agricultural purposes. Nowadays, this particular type of wind pump is considered as a part of the Maltese national heritage that forms part of our country side. Lately, with the introduction of the electric water pump, the majority of these wind pumps were abandoned and left to deteriorate. For this reason, together with today's awareness about renewable energy sources, a conceptual project was initiated and built to replace the existing severely damaged wind pumps by a wind turbine which gives clean electric power.

## Project Objectives

The main objectives for this project were;

- To design and construct a blower testing structure for aerodynamic testing to be done in another project.
- To perform a structural integrity analysis to check if the tower would support the loads.
- To implement and modify the tower and nacelle according to the recommended modifications, and do the practical work required.
- Manage the transport, assembly and erection of the 15 meter lattice tower to the site where it is going to be installed.
- To manage the required works on site, including the foundations and a lifting plan to lift the tower in place.
- To carry out a structural test on the lattice tower and nacelle assemblies.

## Project Methodologies

The structural analysis was commenced by the static analysis in order to check that all stresses in the tower are below the allowable. This was done on computer finite element software ANSYS, to check if the steel members of the tower would support the imposed loads created by the thrust produced from the wind turbine. One of the FEA models is shown in Figure 1.

In conjunction with this, a buckling analysis was also carried out to check the tower behaviour and load value up until it fails. A modal analysis was also done by this software to obtain the natural frequencies of the structure. Moreover, given that at the commencement of this project the tower was already

built, an assessment was done to check if it was up to standards. This resulted in a modification to improve the tower connections by using gusset plates, which were designed and analysed analytically.

## Results and Achievements

A fully functional testing structure was built. The tower required modifications were all done by manufacturing the gusset plates and doing all the practical work. The tower was transported and fully assembled on site as shown in Figure 1. Following this a base structure for the foundations was also built. The management of works on site are progressing with the next stage being the erection according to the planned procedure.

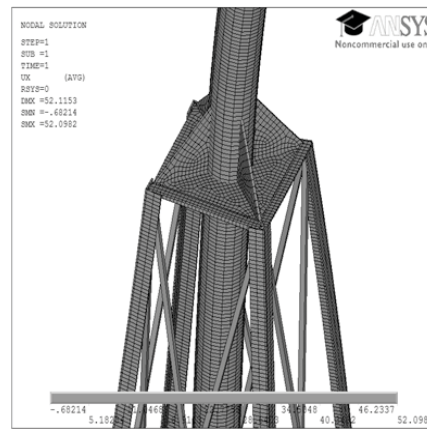


Figure 1: Top part of tower in ANSYS



Figure 2: Tower fully assembled on site

# Mechanical Testing of Sandwich Panels

**Student: Edward Azzopardi**  
**Supervisor: Dr. Claire De Marco**

## Introduction

A sandwich panel, which consists of two thin face sheets adhesively bonded with a thick light weight core, offers various advantages for the design of weight critical structures. By the proper choice of materials and geometry, sandwich constructions having high strength to weight ratios can be achieved, where the face sheets carry the bending and in-plane loads and the core material resists the transverse loads and serves as a separation between the strong face sheets; thus maintaining a high second moment of area of the whole sandwich construction.

## Project Objectives

In this project sandwich panels comprising galvanised low carbon steel face sheets and FOAM CORECELL™ foam core are considered. The main objective of this study is concerned with investigating the performance of these sandwich constructions under different loading conditions. The conditions are intended to simulate flexural, shear, in-plane compression, out-of plane compression and out-of plane tensile loads on the constructions.

## Project Methodologies

In order to meet the objective involved with this study, the following steps were undertaken:

- A literature review was carried out to better understand the area of sandwich structures and testing of such constructions.
- A theoretical analysis on the loading configurations was then performed based on the mechanical properties and the geometrical parameters of the sandwich materials.
- Different testing jigs were designed and constructed to accommodate the needs of the loadings conditions involved. Test specimens were also designed and manually manufactured.
- By means of the jigs constructed, several experimental tests were performed on sandwich specimens having different geometrical parameters. The tests involved include: Long beam flexure tests, Short beam shear tests, Edgewise (in-plane) compression tests, Flatwise (out of plane) compression tests and Flatwise (out of plane) tensile tests.

## Results and Achievements

Short beam shear tests revealed additional shear strength in the core material with increasing face sheets thickness. In the long beam flexure tests two different failing modes were observed, which were confronted with the theoretical models; face yielding for beams with 0.6mm face sheet and 10mm foam

core and core shear for those with 1mm face sheets and 10mm foam core. Under edgewise compression, general buckling and core shear macrobuckling were the prevailing failure modes. Moreover, higher ultimate compressive stress values resulted in specimens with 0.6mm face sheets compared with those with 1mm face sheets. From the flatwise compressive tests it was concluded that sandwich constructions result in higher flatwise compressive strength and compressive modulus when compared with the bare foam core. Ultimately, under the flatwise tensile tests, the sandwich constructions showed an average bond strength of 1.63MPa

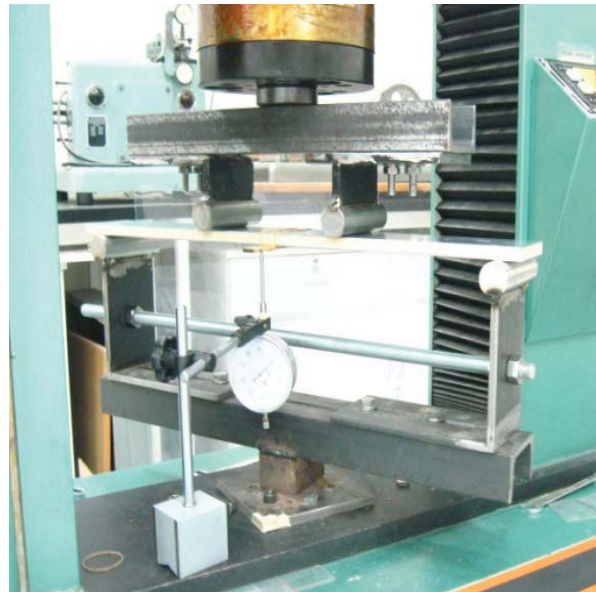


Figure 1: Long beam flexure test setup

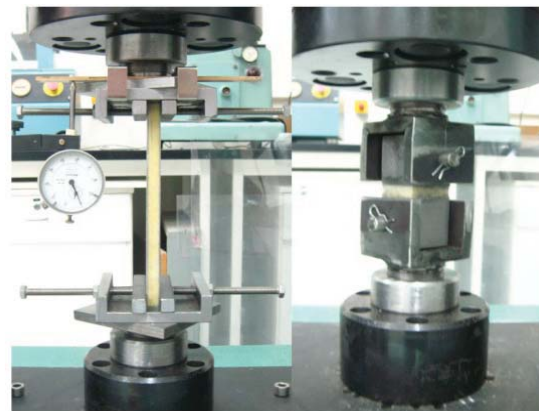


Figure 2: Edgewise compression test setup (left) and flatwise tensile test setup (right)



# A Discontinuous Operation of Reverse Osmosis Plants

**Student: Maximilian Bartolo**  
**Supervisor: Prof. Robert Ghirlando**

## Introduction

The investigation of the performance of Reverse Osmosis (RO) membranes under the effect of repeated start/stop conditions required the design and development of an automated system with robust fault detection and consequence mitigation capabilities.

## Project Objectives

The main objectives of this project are:

- To design and build a control system that would allow the RO Testing Rig in the Department to be operated on a 24-hour basis.
- To rigorously test the automated RO Testing Rig to ensure risk-free operation, allowing the test rig to be operated safely unattended.
- To run trial tests on the automated RO Testing Rig as a proof of concept.

## Project Methodologies

An in-depth literature survey was followed by failure analysis of the existing test rig and the design and development of a fault detection and mitigation control system and a data logging system. The fault detection and mitigation system required the design of a circuit diagram including power circuits, transformer circuit, control circuit, run/trip indication circuit and panel layout which resulted in the development of a control panel in line with industrially accepted standards. The control panel relied on inputs from a flow switch and float switch to detect faults while current and thermal overload protectors provided the required protection to the dual pump system. The panel was designed with the facility to be operated manually by start/stop push buttons for each pump or automatically through the combined effect of a programmable 7 Day timer and an On-Delay timer which starts the high pressure plunger pump after a short delay to reduce deterioration to the membrane from the effect of water hammer as discussed in the literature survey.

The data logging system was affected by financial limitations so a novel solution was found through the use of a web camera and software designed around the RoboRealms™ image processing library with the ability to read the digital conductivity display and convert the image to text, while logging the required parameters. Another program was written to allow the importation into Excel and filtering of unusable logged data.

## Results and Achievements

The control system was tested by fault induction testing for all the potential failure causes highlighted through the Process Failure Mode and Effects Analysis (Process FMEA). The system detected and reacted to the applied faults as required. Flat sheet membrane tests and material analysis on a new membrane module were also performed to provide detailed insight on the fouling components affecting sea water reverse osmosis (SWRO) membranes under discontinuous operation.



# An Alternative Treatment and Pumping System for Landfill Gas Condensate

**Student:** Marco Bonanno  
**Supervisor:** Prof. Robert Ghirlando  
**Co-supervisor:**

## Introduction

The Maghtab landfill was closed down in 2004 to make way for more sustainable alternatives. In compliance with EU regulatory requisites on the closed landfill, a number of wells were drilled so that gases entrained in the landfill (due to bacterial decomposition and chemical reactions) could be directed for treatment. Water vapour captured with these gases condenses along the pipe work which is laid in a way to direct the brown contaminated condensate by gravity to a reservoir. The amount of water collected amounts to approximately 30 cubic metres per day and is transported by bowser to a nearby Reverse Osmosis plant.

## Project Objectives

WasteServ Malta is considering replacing this procedure with a new one where the condensate would be pumped through a piping system, with economic costs and environmental issues being the indicators for choosing one alternative rather than another. The present system also poses problems with sludge accumulation and hence calls for a re-design of the reservoir where the condensate is collected.

## Project Methodologies

Through a methodological design process, the specifications to be met were clearly defined and all possible solutions sought through literature search and analysis of existing technical systems. Potential solutions were evaluated against technical criteria; four systems being chosen for investigation. These included a directly coupled solar pump, an air-operated double diaphragm pump and two grid-connected systems, one using a multistage centrifugal pump and the other being a 'Hydra-Cell' pump.

The design required sizing through the use of standards, manufacturers' data and also a Matlab® solar pumping simulation. This allowed setting up a realistic life cycle cost for every system. An environmental impact assessment based on the carbon dioxide generated by the system was also carried out.

## Results and Achievements

The wastewater treatment method which best satisfied the criteria of treating the landfill gas condensate was found to be the Imhoff Tank (Figure 1). Although such a technology is rarely favoured in developed countries, its simplicity and sustainability is well accepted to be effective as a decentralized wastewater treatment option 1.



Figure 1: Photomontage of proposed Imhoff Tank (cross-sectioned)

The feasibility study showed that all four proposed systems become cost-effective within less than three years from their implementation (when compared to the base case). As indicated in Figure 2, the solar energy case is evidently the best option throughout the whole system lifetime, contrary to popular belief that makes investors sceptic about renewable energy. Solar energy is also favoured by the environmental impact assessment.

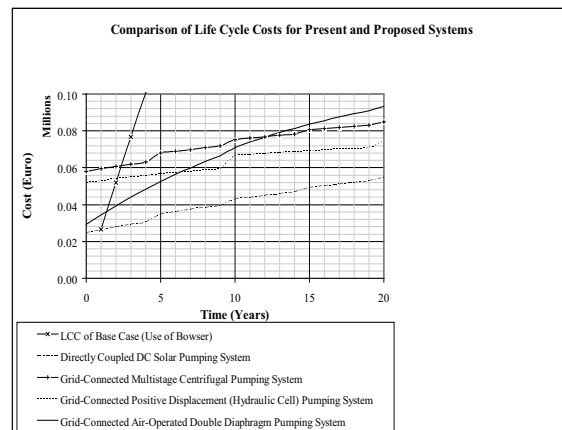


Figure 2: Comparison of the life cycle costs for the present and proposed alternatives

## References

- 1 R. McLean, "Honduras Wastewater Treatment: Chemically Enhanced Primary Treatment and Sustainable Secondary Treatment Technologies for Use with Imhoff Tanks", M. Eng. Dissertation, Massachusetts Institute of Technology, USA, June 2009.





# Reduced Solution Methods Applied to Fusion Welding of Aluminium Plates

**Student: Colin Bonnici**  
**Supervisor: Dr. Ing. D. Camilleri**

## Introduction

'Reduced Solution Methods' provide a computationally efficient, cost effective and a simple means to analytically analyze the final distortions and residual stresses generated by a fusion welding process. These computational methods replace the complex thermo-elastic-plastic analysis with an uncoupled elastic numerical model, to simulate only the important characteristics of a welding process. Such methods are very well suited to investigate the distortions and residual stresses created by fusion welding mild steel plates [1]. However, further research was entailed to determine whether or not these finite element strategies are applicable to butt welded aluminium alloys. Successful application of this method will give rise to means that identify what mitigation techniques are required prior the welding process and ultimately reduce the residual stresses and distortion.

## Project Objectives

The aims of this study were to successfully implement the reduced solution methods for butt welded aluminium plates and provide the necessary experimental validation of the predicted distortions.

## Project Methodologies

These computationally efficient methods are based on the uncoupling of the thermal and structural analysis. First, a symmetric thermal model is created to extract a 2D thermal profile, consisting of maximum temperatures along the transverse direction of the welded structure. This thermal profile is then fed to a symmetric 3D structural model, where the necessary temperature loads are computed using an elastic-plastic algorithm. This algorithm uncouples the transverse and longitudinal deformations to eventually predict the residual stresses and final distortion of an aluminium welded assembly, as shown in Figure 1.

These results are then validated by butt welding small scale aluminium plates using a semi-automated welding system shown in Figure 2 and measure their final deformation using a laser distortion scanning system.

## Results and Achievements

The computational model predicted a hogging curvature along the longitudinal direction of the weld assembly, similar to that obtained from the experimental analysis. Such a result suggests that with further research work, accurate prediction of residual stresses and deformations in butt welded aluminium

alloys could eventually lead to the possibility of using reduced solution methods for such applications.

## References

1 D. Camilleri and T.G.F Gray, "Using computationally efficient, reduced-solution methods to understand welding distortion," in *Minimization of Welding Distortion and Buckling – Modelling and Implementation* P. Micahleris, Ed. Philadelphia, USA, Woodhead Publishing Limited 2011, pp. 124-165.

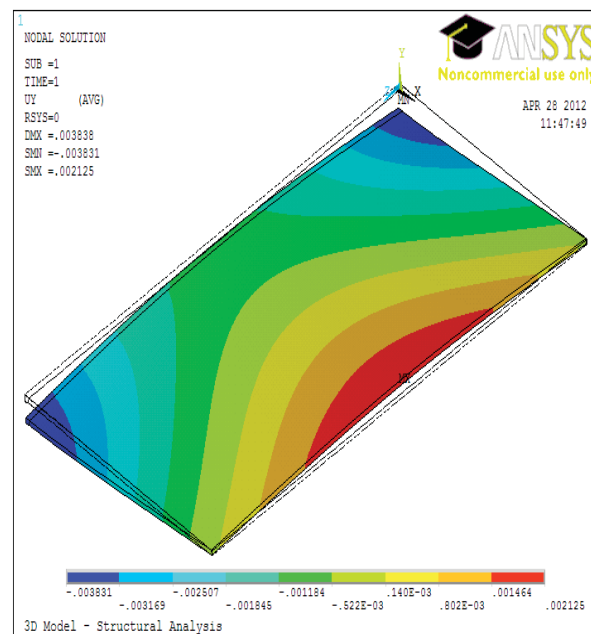


Figure 1: Analytical analysis of fusion welded aluminium plate

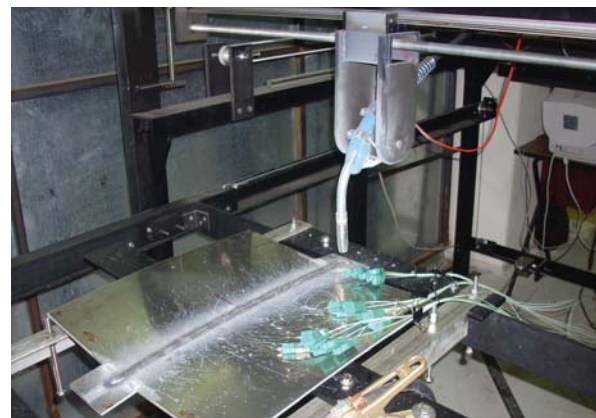


Figure 2: Experimental analysis of fusion welded aluminium plate

# Computational Model of a Human Sternum

**Student: Christabel Borg**  
**Supervisor: Dr. Ing. Zdenka Sant**

## Introduction

Median sternotomy requires the sternum to be bisected in two halves to allow access to the heart. This brings forth a number of post complications [1]; one of the most frequently encountered is when the patient who has just went through the surgery coughs, such that large lateral forces are experienced on the sternum and cause sternal dehiscence. This encourages ongoing studies to help in recuperating the mechanical stability of the bisected sternum, by means of reducing micro-motion between the re-approximated halves. This calls upon an increase in consciousness to excel in sternal closure techniques, particularly by the application of the finite element method engaged in this area [2].

## Project Objectives

The scope of this project were to obtain a virtual human sternum bone model based on realistic three-dimensional geometry which had to be investigated by simulating the biomechanical behaviour during the cough. The objectives of this dissertation were:

1. to create a virtual human sternum bone model, based on CT scans
2. to create a finite element (FE) model using the generated virtual sternum model
3. to provide an analysis of the sternal biomechanical behaviour, and apply boundary conditions accordingly
4. to simulate the loads during the cough and analyse the stress-strain distribution on the virtual model.

## Project Methodologies

This project was achieved through the use of a commercial software package for NURBS (non-uniform rational basis spline) modelling by the manipulation of in vivo computed tomography (CT) scans to generate the three-dimensional geometry based on real human bone. Subsequently, modelling under anatomical and physiological conditions using FEA (finite element analysis) was used to analyse the stress-strain distribution developed. Two models were simulated under this study: one having no attached cartilages and the other having attached cartilages as shown in Figure 1 and Figure 2. Both models were incorporated with the corresponding material properties.

## Results and Achievements

Throughout this dissertation, by means of a strategic and systematic approach, biomechanical analysis was facilitated towards realizing the project objectives.

The attained stress and strain distributions within the two generated models were reasonably realistic mainly since they complied well with the principles of the biomechanics of the thorax whilst some could also be verified through mathematical principles. The larger stresses were induced at the xiphisternal joint i.e. the region between the middle (sternal body) and lower (xiphoid process) parts of the sternum. This implies that further research on sternal closure techniques should consider this location as a critical region which should be well-reinforced with respect to the other parts of the sternum.

## References

- [1] A. R. Casha, L. Yang, P. H. Kay, M. Saleh, and G. J. Cooper, 'A biomedical study of median sternotomy closure techniques' *European Journal of Cardiothoracic Surgery*, 1999, Vol. 15, pp.365-369.
- [2] Shruti Pai, 'In vivo characterisation of respiratory forces on the sternal midline following median sternotomy', Faculty of Worcester Polytechnic Institute, Thesis 2005.

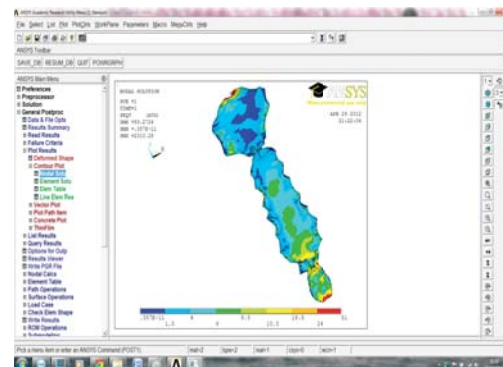


Figure 1: Von Mises Stress on Virtual Human Sternum Model without Cartilages

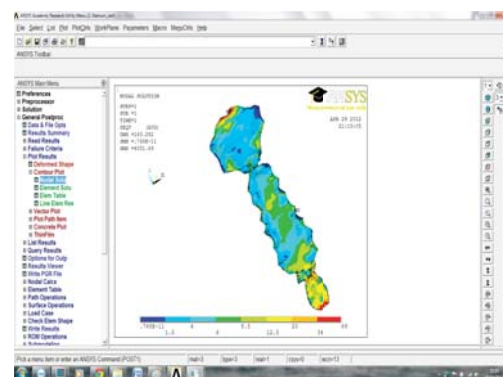


Figure 2: Von Mises Stress on Virtual Human Sternum Model with Cartilages



# Experimental Measurements of Welding Induced Residual Stresses

**Student: Paul Anthony Buhagiar**  
**Supervisor: Dr Ing. Pierluigi Mollicone**

## Introduction

Welding is one of many processes which induce residual stresses and distortion inside a specimen. This alteration in the strength and microstructure of the component is a result of localised heating and non-uniform cooling during the welding operation. The residual stresses introduced inside a component can be of severe consequence to the structural integrity which is why analysis of the performance and reliability of the weld is necessary during the design stage of the component. A hole drilling apparatus was used in this research to compute the residual stresses inside a mild steel specimen.

## Project Objectives

The objectives were:

- Write a manual of how the hole drilling equipment is to be used;
- Use the hole drilling equipment to determine residual stresses both prior and after spot welding;
- Determine residual stresses caused by spot welding.

## Project Methodologies

The hole drilling method was used in this study to determine the residual stresses induced by spot welding. When drilling of a stressed material takes place, the specimen 'relaxes' and causes a small strain relief in the material which is picked up by strain gauges. These values can then be converted into Residual stresses using specialised software.

There are two types of assemblies that can be used; the milling rod assembly and the air turbine assembly (shown in Figure 1). The latter was used in this study. The drilling process was conducted according to the ASTM E837-08 standard which defines the type of analysis required in determining residual stresses.

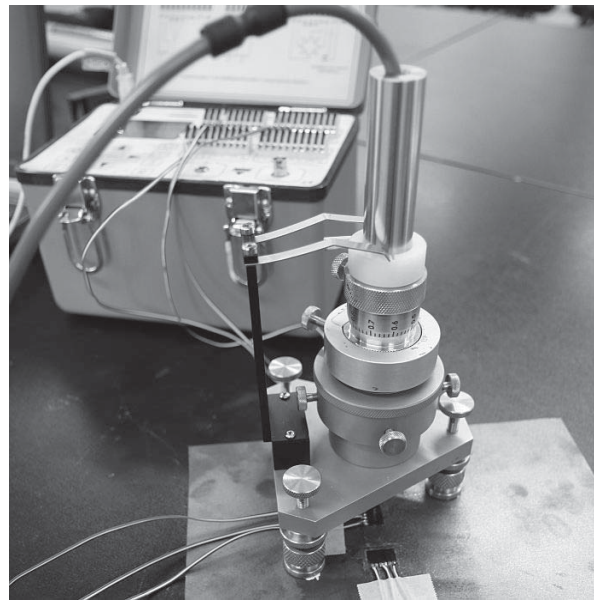
The drilling operation was conducted both prior and after the spot weld was generated on the specimen. Two strain gauges were attached to the steel plate before spot welding was conducted and another three were installed after the spot weld was done. This was done in order to obtain stress distributions of the residual stresses with respect to the distance away from the spot weld.

## Results and Achievements

Once all residual stresses were determined using the software, these stresses were shown to decrease

rapidly away from the spot weld. Residual stresses in spot welding can only be found in the vicinity of the weld. At a distance of 32 mm away from the spot weld, the residual stresses computed were very similar to the stress values obtained prior to spot welding.

As a pointer for further research, one can conduct further studies by comparing different welding techniques and conclude which method introduces the least residual stress. Also, residual stresses may be determined using other methods, other than hole drilling, and their efficiencies are evaluated and compared with one another.



*Figure 1: Air Turbine Assembly*

# Analysis of a Wind Turbine Driven Hydraulic Pump

**Student: Daniel Buhagiar**  
**Supervisor: Dr. Ing. Tonio Sant**

## Introduction

Current research is evaluating the possibility of replacing the gearbox and generator on wind turbines with a large pump. Instead of producing electricity directly, the individual wind turbines would pump seawater at high pressure to a centralized hydroelectric station.

Wind energy has been used for pumping water since the 9th century and traditional windmills can still be seen here in Malta. Inspiration is drawn from this age-old method, in an attempt to create new developments for offshore wind generation.

Replacing the gearbox and generator with a hydraulic pump would reduce costs and lead to a lighter wind turbine design.

## Project Objectives

- Develop a mathematical model of a wind turbine coupled to a positive-displacement pump. This should model the overall system, which includes: rotor aerodynamics, mechanical transmission and the internal mechanics of the pump.
- Devise alternative schemes for controlling the wind turbine, and making best use of the new hydraulic design.
- Convert the mathematical model into a computer program to provide means for simulating the behavior of the system.
- Simulate the different control schemes.
- Simulate internal phenomena occurring within the pump.

## Project Methodologies

Similar systems using hydraulic transmission typically use a radial piston pump. This project introduces a new design with a swash plate pump directly connected to the rotor. As shown in Figure 1, fluid flows up to the nacelle where the pump is situated after which it is passed to the hydroelectric plant.

Mathematical modelling is done using the physical network approach, a method for combining equations that represent the physics of individual components of a system.

Equations representing real systems are complicated and cannot be solved by hand, therefore, a computational solution is required. Put simply, the process is to take a few short, yet very complicated steps and convert them into a lot of simple steps for the computer to solve.

## Results and Achievements

Power generated at the turbine base with respect to wind

speed at hub height is shown in Figure 2. It illustrates the excellent potential of the design. Moreover, the overall results show that by using alternative control schemes, particularly by combining the control of hydraulic pressure and blade pitch angle, the power extraction capabilities of the wind turbine can be dramatically improved with limited structural changes.

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- Diepeveen N., Van der Tempel J., "Delft Offshore Turbines, the future of wind energy," Delft University of Technology, 2008.
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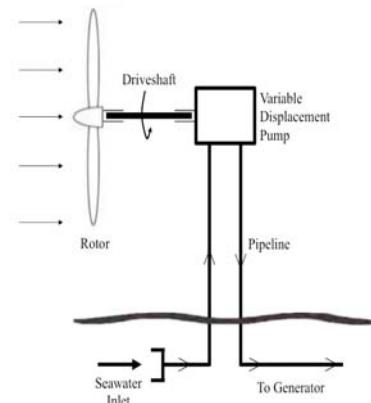


Figure 1: A basic schematic of the overall system.

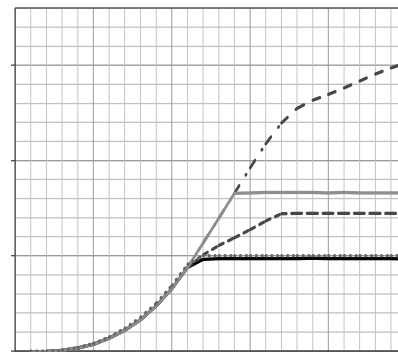


Figure 2: Power developed at the turbine base against wind speed.



# Fracture Forming Limit Diagrams: FFLD

**Student: Matthew Busuttli**  
**Supervisor: Dr. Claire De Marco**

## Introduction

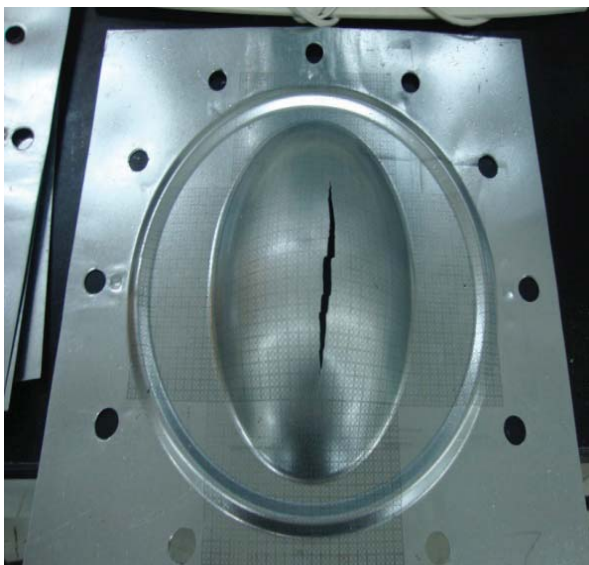
Sheet metal forming is a process which is widely used in the production process in various industries. During the forming process, care must be taken not to exceed the ductility range of the material. The Fracture Forming Limit diagram gives a clear indication of the forming capabilities of the sheet material and provides an indication of the safe region where no necking will take place.

## Project Objectives

The main objective of the project is to construct a Fracture Forming Limit diagram and investigate the effect of sheet thickness on the formability of galvanised steel sheets. A data acquisition system coupled to a displacement and pressure sensor was also added to the existing apparatus.

## Project Methodologies

In order to construct the FFLD two different tests had to be carried out. The first test involved bulging galvanised steel sheets of different thickness through a circular and elliptical aperture using hydraulic pressure until fracture. A specimen that was bulged through an elliptical die until fracture can be seen in figure 1.



*Figure 1: Bulged specimen through an elliptical die*

The second test involved uniaxial tensile testing of a set of notched specimens for different thicknesses. In both cases the strains on the material were measured using etched circles on the surface of

the material of previously known dimensions. As the sheet metal is stretched the etched circles are also stretched with the same amount of deformation. The final measurement of these deformed circles was then translated to strain values. The strains obtained from both tests were then plotted to construct the fracture forming limit diagram.

## Results and Achievements

From the construction of the FFLD it was concluded that in the case of galvanised steel, an increase in sheet thickness from 0.5 mm to 1 mm yields an increase in the forming capabilities of the sheet material. A region which indicates safe deformation of the sheet metal without any risks of necking or any other forms of failure was also obtained. This safe region is very useful during the design of any sheet metal forming process since it helps to ensure that the final sheet metal product is free from any defects.



# Sternal Loading Frame

**Student: Samwel Buttigieg**  
**Supervisor: Dr.Ing. Zdenka Sant**

## Introduction

When performing open heart surgeries the sternum is dissected to provide direct access to the heart. This midline sternotomy incision enables excellent ease of intervention on the heart and is a familiar procedure to surgeons. Various forms of sternotomy closures techniques and devices have been used yet none have proved to be totally satisfactory to avoid completely sternal dehiscence or cut through of the wires. Coughing causes a lateral tensile loading on the sternotomy of around 1500N in an adult. Thus high sternal load often leads to failure of the sternotomy closure which in turn causes a range of complications such as dehiscence, mediastinitis, bacterial infection and a prolonged incisional pain and healing period. 1

Thus a form of testing mechanism to replicate the force as a physiological load causing the maximum stress imposed on the sternum will allow further studies on sternotomy closure techniques and devices.

## Project Objectives

The aim of this project is to design and construct a sternal loading frame. This is to simulate the static force exerted on the sternum in an adult.

## Project Methodologies

- Review of theory and literature to aid understanding of the thorax and sternal physiological anatomy and biomechanics movement while coughing.
- Research on the use of the solid polyurethane foam models for testing was carried out.
- Sternal physiological loads were identified from a simplified mathematical model of the thorax.
- A sternal loading frame was designed using CAD (Computer Aided Design) and detailed calculations were performed on the frame as in Fig 1. And Fig 2. shows the sternal loading frame mounted in the tensile machine with sternum loaded.
- FEA (Finite Element Analysis) was carried out on the designed loading frame.
- The loading frame was finally constructed.
- A methodology of the experimental procedure for successful operation of the loading frame was developed.

## Results and Achievements

Design, computation, finite element analysis and construction of the loading frame have been successfully concluded. Testing on a sternal

polyurethane foam model is to be performed utilizing the loading frame built.

## References

W. E. McGregor, D. R. Trumble and J. A. Magovern, "Mechanical Analysis Of Midline Sternotomy Wound Closure," Journal Of Thoracic and Cardiovascular surgery, no. 117, pp. 1144-1149, 1999.

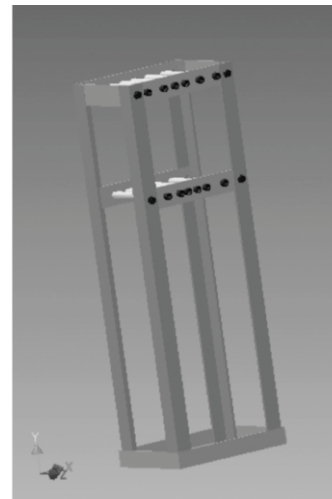


Fig1. CAD model of loading frame

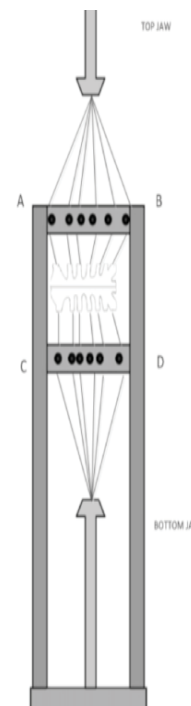


Fig.2 Sternal frame model loaded in frame.



# Variable Compression Engine

**Student: Darren Camilleri**

**Supervisor: Prof. Robert Ghirlando**

## Introduction

The work on the opposed piston variable compression engine started in 1995 at the Faculty of Engineering. The prototype engine built is known to suffer from poor power characteristics which could be due to incorrect engine scavenging. The last time the engine was coupled to a dynamometer, the engine began to stall at the slightest load applied. The building of a working computer model of the engine together with CFD scavenging simulations would help to understand the gas dynamics of the engine and the underlying causes of poor performance.

## Project Objectives

- o To build a working 1-D computer model of the engine using Ricardo WAVE® software.
- o To perform simulations of the 1-D model to obtain the main engine performance parameters.
- o To build a 3-D CFD model of the engine using ANSYS Fluent® software.
- o To perform engine scavenging simulations of the CFD model.

## Project Methodologies

Ricardo WAVE software was used to build a 1-D computer model of the engine. This model was used to perform several simulations of the engine performance at different compression ratios. A study to determine the phase shift to use for optimum fuel efficiency for the entire speed and load range was also performed. Flow bench testing of the engine's ports was performed to determine the flow coefficients. Detailed measurement of the engine's geometrical features was also done.

A 3-D CFD model of the engine was built using ANSYS Fluent with the specific aim of investigating the scavenging process of the engine. For this purpose, several cold flow CFD simulations of the scavenging process were carried out for different engine configurations. Results from the WAVE model were used as transient boundary conditions in the CFD model.

## Results and Achievements

The flow bench testing was successfully performed and the flow data obtained compared reasonably well with published studies. The building of working 1-D WAVE and CFD engine models was also successfully accomplished. This was verified by realistic and comparable simulation results.

WAVE simulation results confirmed that the full potential performance of the variable compression engine was not being reached. CFD scavenging simulation results indicate very good scavenging at low engine speeds but increasingly poor scavenging performance at moderate

and higher engine speeds.

The results obtained from the computer model and scavenging simulations could be analysed further and used to make the necessary physical modifications to the engine.

## References

R. Ghirlando, "A variable compression opposed-piston SI engine," in IMechE Internal Combustion Engines: Performance, Fuel Economy and Emissions Conf., London, 2009.

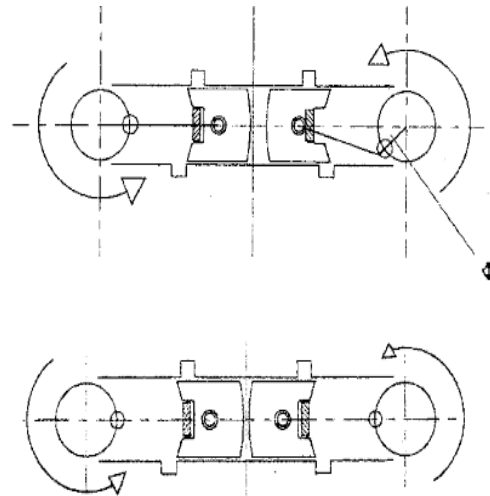


Figure 1: Principle of operation of the variable compression engine 1 pistons out of phase by (top) pistons in phase (bottom)

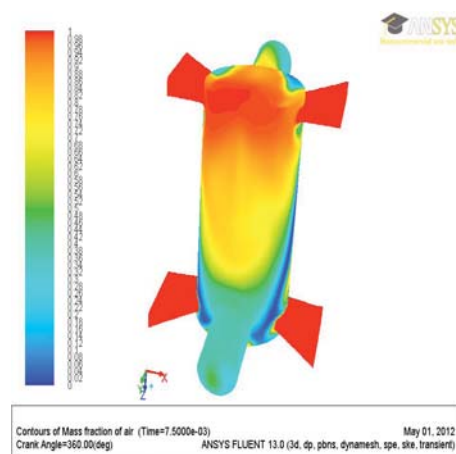


Figure 2: Contours of mass fraction of air at BDC (Bottom Dead Centre) pistons in phase

# Performance Testing of a Multi-Bladed Wind Turbine Rotor

**Student: Josianne Cassar**

**Supervisor: Dr. Ing. Tonio Sant**

**Co-supervisor: Mr. Ing. Robert N. Farrugia**

## Introduction

This project dealt with the preliminary performance testing of a 3.4m diameter prototype multi-bladed wind turbine rotor. This project formed part of the necessary preparatory work required prior to installing the prototype for open field testing at the National Agricultural Research and Development Centre, Ghammieri.

The power performance of the turbine was quantified through the development of a  $C_p$ - curve. Furthermore, the test results were compared to curves obtained from a Blade Element Momentum program.

## Project Objectives

1. Carry out a thorough review on the theory modelling wind turbines aerodynamics
2. Build a Blade Element Momentum program
3. Design and construct a mast used to house wind velocity and direction sensors (to be used to investigate air flow in an open field)
4. Perform static and dynamic balancing of the rotor
5. Investigate the quality of the air flow created by a wind generator used for testing the performance of the turbine
6. Conduct preliminary performance testing on the wind turbine leading to a  $C_p$ - curve
7. Compare the results from the performance measurements with those predicted by BEM program

## Project Methodologies

The project was divided into four phases. In the first phase, a literature review was undertaken. A computer program modelling the performance of the multi-bladed horizontal-axis wind turbine was developed. The program was based on the Blade Element Momentum theory.

The following phase involved the design and construction of a wind monitoring mast. This mast will be eventually erected in an open field to monitor the wind flow through the turbine prototype.

In the third phase, the rotor was balanced statically and dynamically. This was necessary to avoid the turbine and the associated structure from experiencing excessive vibration once installed on the test site.

Testing of the wind turbine was done such that the  $C_p$ - graph could be produced. The curves provided means of assessing the expected output in open field testing. Testing was divided into two major sections. The first involved establishing a velocity profile to which the turbine rotor was exposed to. The wind flow to the rotor was provided artificially by means of four fans supported on a rigid frame. From this analysis, the wind speed going through the rotor was obtained. The second phase involved collecting data for the  $C_p$ - graph. This included: density of air, power output from turbine and the rotor's rotations per minute. The results were processed to construct the curve which was then compared with a similar curve obtained from the Blade Element Momentum Program.



*Figure 1 - Wind Turbine with Wind Monitoring Sensors and Fans*

## Results

The fact that the rotor was experiencing a vast range of velocities along its diameter was a disadvantage as the velocity of the flow through the rotor was not clear-cut. This led to two curves which gave different efficiency values. In general, the test results showed that the turbine's efficiency did not exceed 22%; this was not far less than the maximum of 26% power coefficient obtained from the Blade Element Momentum program. The resulting efficiency was considered to be satisfactory.





# Mixed Mode Ductile Fracture

**Student: Stephen Ciappara**  
**Supervisor: Dr. C. De Marco**

## Introduction

The ductile fracture behaviour of thin sheets under combination of tension (mode I), in-plane shear (mode II) and out-of-plane shear (mode III) has been given a special interest and were investigated in many theoretical and experimental studies due to the similarity to practical loading conditions of engineering structures.

## Project Objectives

The main aims were to find the fracture toughness of the material, which is the minimum work required for a crack to initiate, under mixed-mode by changing the loading angle. Also the percentages of the separate fracture toughness which correspond to each mode were found for each mixed-mode angle in which the applicability of Hill's theory, which gives a relationship between the relative motion for the neck and the crack propagation angle was assessed to predict the fracture type, the transition of the failure mechanism and the crack path angles which then all are compared with the experimental ones.

## Project Methodologies

The DEN (Double End Notched) and the two-legged specimens, shown in figure 1 and figure 2, were designed and manufactured to load them under mixed-mode I/II and I/III loading conditions respectively.

The fracture toughness in mixed-mode I/II loading was assessed by two different methods. In the first method, the total external irreversible work done for the whole deformation is plotted against the ligament for each loading angle and different thicknesses. Then the value of the y-intercept of the plot is equal to the fracture toughness. The second method involves the calculation of the area under the graph of a load-displacement graph only up to crack initiation, which then is divided by the respective ligament length and thickness of the specimen.

In mixed-mode I/III loading the fracture toughness is found by plotting the value of the load per unit thickness at crack initiation versus the leg width for each specimen. The value of the y-intercept of the obtained graph is equal to half of the fracture toughness value.

Then the percentages of the separate fracture toughness are calculated to do a theoretical analysis of the fracture type and the direction of crack path which are based on the fracture criterions of maximum hoop stress and maximum shear stress.

Then the theoretical and experimental values are compared.

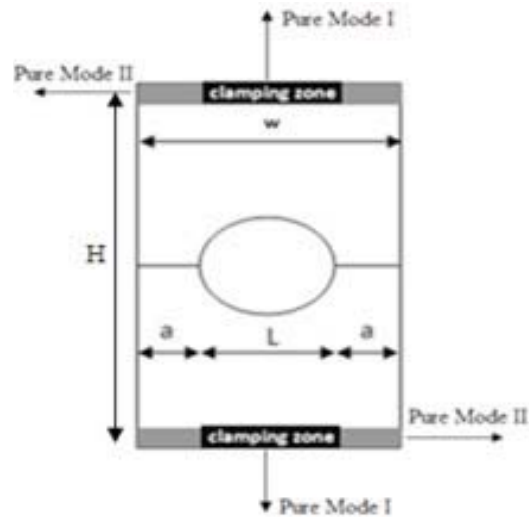


Figure 1

## Results and Achievements

For mixed-mode I/II loading, the predicted directions of the crack propagation were in close agreement with those obtained from testing, however in mixed-mode I/III loading, the values differed from each other which discrepancy is believed to be either because Hill's theory is not applicable for out-of-plane shear loading or due to possible imperfections in the manufacturing of the two-leg specimens.

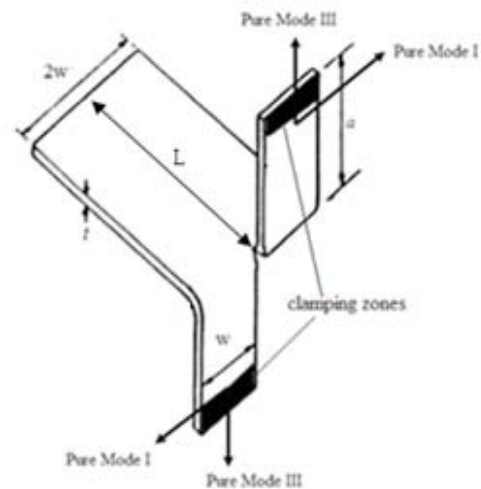


Figure 2

# FEA Models of Spot Welded Structures valid for Cyclic Loading Analysis

**Student: Nicol Cremona**  
**Supervisor: Dr. Ing. Martin Muscat**

## Introduction

Resistance spot welding (RSW) is widely used in mass production industries to join sheet metal parts together. A vehicle's body structure contains several thousands of spot welds which contribute to its structural stiffness 1. Due to the existence of this large number, it is highly impractical to model each and every spot-welded joint in detail when performing a full-scale structural analysis. To this end, simplified models must be used to represent spot-welded joints.

## Project Objectives

- Review of the finite element modelling of spot welded joints, including methods for fatigue analysis.
- Fabrication of spot welded beams for simple bending tests.
- Finite Element modelling of the experimental spot welded beams.
- Experimental validation of the finite element model.

## Project Methodologies

Literature on the methods for the stress determination for fatigue analysis of spot welded structures was reviewed. Different finite element models of a spot-welded joint used by researchers were also studied. The main models focused on in this study were the elastic beam model, the rigid beam model, the umbrella model and the multi point contact model.

Three box-profile specimens of different thicknesses were fabricated using spot welds and tested in simple bending mode. The structural model was adapted from the experimental procedure carried out by Dinçer et al. 2. It was then modelled using the finite element software ANSYS® incorporating the different spot weld models.

Validation checks for the shear and bending stress of the beam were carried out. Furthermore the stress distribution for the FE spot weld models was analysed.

## Results and Achievements

The validation checks for the bending and shear stress of the specimen model were successful. The finite element results for the spot weld models presented almost the same characteristics for the overall stress distribution. However it was found that on and around the spot weld nucleus, the stress

distributions and the amplitude of the stress differ from one model to another. The single beam models, i.e. the elastic beam model and the rigid beam model presented identical results for different loadings and varying material properties. Also the single beam models give higher stress values in comparison to the multi contact and umbrella models.

## References

1. Houldcroft, P.T., Resistance Welding, in Welding Process Technology. 1977, Cambridge University Press: Cambridge. p. 137-160.
2. Dinçer, S., et al., A Comparative Study on the Finite Element Models for Spot Welds and Their Verification, in SAE World Congress. 2006, SAE International: Detroit, Michigan.

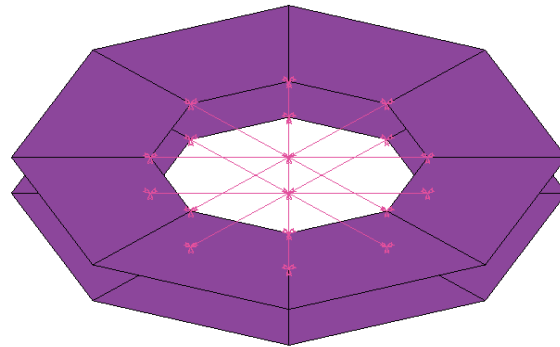


Figure 1: Finite Element Umbrella Model of a Spot Weld Joint

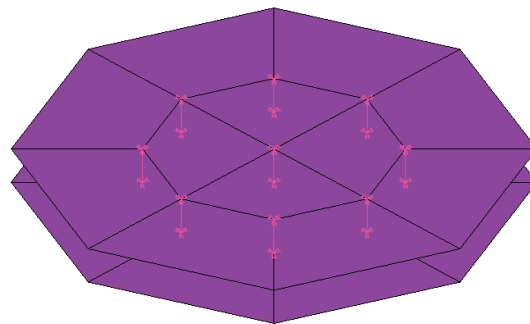


Figure 1: Finite Element Multi Point Contact Model of a Spot Weld Joint



# Modal Analysis of Composite Structures

**Student: Karl Dimech**  
**Supervisor: Dr Ing. D. Camilleri**

## Introduction

Fiber reinforced composites are finding more and more use in engineering applications in recent years. The use of composites extends itself from civil engineering applications to transportation vehicles, aerospace, marine, aviation, and even recently to applications in the chemical industry. This is due to their excellent features, such as high strength-to-weight and stiffness-to-weight ratios and the ability of having different strengths in different directions. Many high-performance structures are made up of laminated composite plate sections. For any composite structure that may be subjected to dynamic loads, the determination of the natural frequencies is the first step in a dynamic analysis since a great deal may be deduced concerning the structural behaviour and integrity from knowledge of its natural frequencies.

## Project Objectives

The objectives of the project were to carry out modal analysis to investigate the natural frequencies and mode shapes of E-glass-Polyester composite plates with different angle layups and different boundary conditions. FEA results from ANSYS® were compared with experimental results obtained from PULSE®. Impact testing and shaker testing results are also compared.

## Project Methodologies

Plates were prepared with layups 0/903s, 30/-603s and 45/-453s using the hand layup method. For free hanging and clamped configurations, the dimensions of plates were 380mm by 240mm while the dimensions for the cantilever plate were 304mm by 240mm. The thicknesses of the plates were 2.7mm, 2.6mm and 2.2mm for the 0/903s, 30/-603s and 45/-453s layups respectively. A calcination experiment was carried out to find the proportions of matrix and fibres in the plates. Samples of approximately 5cm by 5cm were cut from each composite plate. These were burned inside a furnace at 625°C for approximately 20 minutes until all the matrix material was burnt. The fibres were then weighed and using the formulas relating densities and volume fractions, the corresponding proportions were found. Impact testing was carried out on all plates and configurations where the accelerometer was in a fixed position and the hammer was moved to all degrees of freedom (DOFs). Shaker testing using a random signal was also carried out for the clamped plates. Here the shaker assumed a fixed position while the accelerometer was moved from one DOF to the next.

*Figure 1: Impact testing of a free hanging plate (top)*

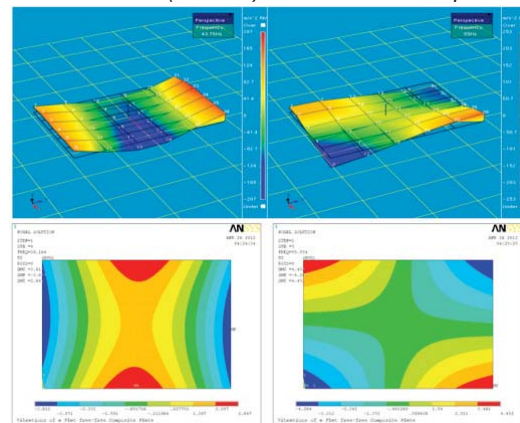


*and shaker testing of a clamped plate (bottom)*

## Results and Achievements

There is a good agreement between the experimental and theoretical results for the free-hanging and cantilever configurations. The agreement for the clamped results is poor. This indicates that the clamps for the fixed-fixed configuration are not ideal and that they introduce some uncertainty in the boundary conditions. The clamped results can be used to provide possible explanations for the discrepancies between the measured and calculated natural frequencies reported in literature.<sup>1</sup>

*Figure 2: First two mode shapes from PULSE (top) and ANSYS (bottom) for the 45/-453s plate*



## References

A. Anderson and T. Nayfeh, "Experiments and FEA Natural Frequencies and Mode Shapes of Laminated Composite Plates," *Journal of Vibration and Control*, vol. 2, p. 381, 1996.

# Design and Build of a Prototype Hydrofoil Craft

Student: Jean Paul Farrugia  
Supervisor: Dr C. De Marco

## Introduction

Hydrofoils are classified as vessels that lift above the water surface due to the lift forces generated by the water flow over the attached wing-like structures called hydrofoils or just foils. Hydrofoils date back to the Wright brothers. It is said that they tested their prototype wings in water. In the 1960's, the US and Canadian's Navy invested in few military hydrofoils with some success, but presently none remained in service. Today, most vessels are one of a kind and are used either for experimental purposes or to break world speed records. These modern designs are very efficient, where very high speeds can be attained with relatively low powers.

## Project Objectives

The main aim of this dissertation is to bring about the great benefits of the hydrofoil technology and at the same time suggest why these could be the vessels of tomorrow. Other objectives include:

- Research on the various hydrofoil vessels that have existed;
- Design and build a prototype, one-person hydrofoil pleasure craft;
- Simulate the designed vessel on the Naval Architecture software and come up with the necessary stability and dynamic characteristics;
- Test the constructed hydrofoil prototype to safely lift-off and travel in a straight line for a small distance;
- Suggest any design improvements in order to improve the manoeuvrability and the overall efficiency of the vessel.

## Project Methodologies

A one-person pleasure craft hydrofoil vessel is designed with the aid of the Naval Architecture software Maxsurf, as shown in figure 1. The necessary calculations are then made to come up with the required foil dimensions to achieve take-off safely and fly a level-flight.

Consequently, the boat is then built using normal boat building techniques. Furthermore, static and dynamic tests are then simulated from the Maxsurf package in order to compare these results with the previous calculations. Once ready, actual sea trials are performed to establish whether the required objectives have been achieved. The resistance and powering results from the CAD software resulted in values very close to those previously calculated.

## Results and Achievements

The final results showed that when testing the hull

without the foils, the boat planed at a speed of about 7.5 knots with an approximate power of 2.5 hp. When testing the complete vessel with its submerged foils, the vessel (as shown in figure 2) took-off at a speed of about 5 knots with an approximate power of 1 hp.

An uncommon type of marine craft was designed and constructed. As was seen, submerged hydrofoils reduces the power consumption while at the same time provides a possibility of attaining higher speeds.

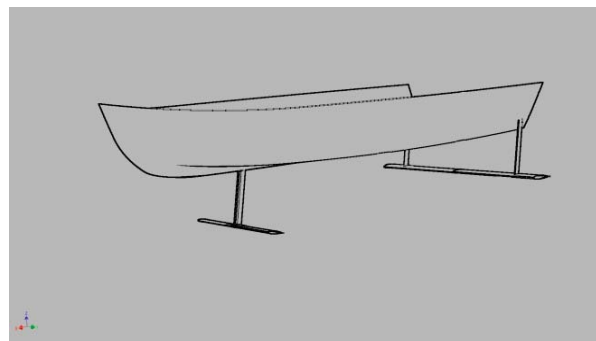


Figure 1: Hydrofoil Design



Figure 2: Foil-borne



# Measurement and CFD Analysis of a Low-Speed Wind Tunnel and its Application for Testing a Model Vertical Axis Wind Turbine

**Student: Russell Farrugia**  
**Supervisor: Dr. Ing. Tonio Sant**

## Introduction

Fluid dynamics is an important area of study for many industrial applications. Wind tunnel testing is an experimental technique which provides practical advantages over open field testing. Limitations in such an experimental technique led, over recent years to an increase of interest in computational fluid dynamics (CFD) among the research and industrial communities. It can be seen that for reliable aerodynamic analysis, a judicious compromise between the experimental and numerical approaches should be sought.

### Project Objectives

- To analyse the performance and improve the flow quality of a low speed open circuit wind tunnel.
- To develop a simplified CFD model of the wind tunnel in order to provide a comprehensive analysis of the flow quality in the wind tunnel.
- To carry out experiments on a model vertical axis wind turbine (VAWT) in the same wind tunnel, shown in Figure 1 in order to obtain power and flow measurements.
- To develop a simplified CFD model of the above wind turbine experiment and carry out a comparison between the experimental and numerical results.

### Project Methodologies

Preliminary testing of the wind tunnel was carried to assess the quality of the flow using pitot static tube and hot wire measurements. The reduction of the turbulence intensity at the maximum wind tunnel speed with the installation of a turbulence reduction screen was analysed. A simplified 2D CFD model of the wind tunnel was created by using ANSYS® Fluent. Thorough geometrical sensitivity, mesh independence and experimental validation studies were performed to reduce any uncertainties in the numerical simulation.

A wind tunnel experiment was carried out on a model VAWT designed by Daniel Micallef. The experiment required the setting up of a supporting rig and a data acquisition system. Hot wire measurements in the near wake were carried out through a method for measuring 3D velocity components with a single hot wire probe. The experimental results were compared to a transient flow numerical model of a VAWT integrated to the above wind tunnel model as depicted in Figure 2.

## Results and Achievements

The turbulence levels at the test section of the wind tunnel in question can be deemed as being below an acceptable level. The installation of a turbulence reduction screen at the tunnel intake slightly reduced the turbulence levels at the expense of a significant reduction in mean flow velocity. It was found that a simplified and validated CFD model of the wind tunnel proved advantageous in providing an extensive analysis of the flow quality with the potential application in the wind tunnel's design optimization. However the CFD model of the VAWT experiment required a considerable amount of computational time and was unable to completely capture the full complexity of the flow. This shows the importance of advanced experimental techniques for the complex analysis of wind tunnel experiments.



Figure 1: The VAWT model operating in the wind tunnel

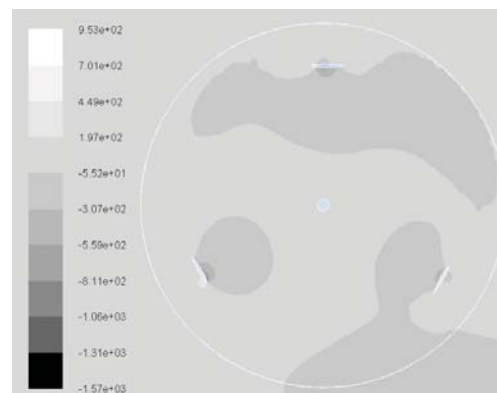


Figure 2: Static pressure contour plot of the VAWT CFD model

# Evaluation of Muscle Force during Walking, via Inverse Dynamics

**Student: Andrew Fiorini**

**Supervisor: Dr. Ing. Zdenka Sant**

## Introduction

The actual force developed in the muscles during walking is of great interest to physiotherapists and doctors. Currently electromyography (EMG) is the only truly reliable way to study muscle force. However EMGs lack accuracy, as surface EMGs, which are the most common and least invasive type, cannot be placed over a single muscle. They tend to record groups of muscles. More accurate EMGs tend to be highly invasive. A solution to this is to simulate the walk using a musculoskeletal model and get the muscle force via mathematical modelling of the muscles. This simulation is what the AnyBody Software is all about and the main aim of the project is to see what muscle forces are developed when simulating using AnyBody.

## Project Objectives

The main aims of this dissertation are.

- Learn how to use and operate the Vicon System available at the Biomedical Laboratory of the University of Malta to record a person's walk.
- Then process the data collected into a .c3d file that can be opened by the AnyBody Software.
- Simulate the walk in the AnyBody system based on the data recorded using the Vicon System.
- Analyse the results for the muscle force developed during the walk, obtained from the simulation.

## Project Methodologies

The study was carried out using two volunteer subjects, and was supervised by the physiotherapist Dr. Mark Sacco.

The first thing that had to be done was to record the walk using the Vicon system. It was established that only the lower limb would be recorded, since due to lack of cameras and space the full body could not be properly recorded. It was decided to use the Lower Body PlugInGait marker set, based on the Oxford Gait Model that comes pre-made with the Vicon Nexus Software. This consists of 20 markers 4 on the hip and 6 on each leg.

The six Vicon cameras available were positioned and the system calibrated. Then a number of walks at different speeds were recorded.

The recorded data was then post-processed and exported to a c3d file that could be read by AnyBody. This was done by using two post-processing pipelines. The "Reconstruct and Label", which is pre-

set in the software and the "c3d AnyBody" which was created for this study.

The AnyBody model called GaitLowerExtremiy, from the 1.3.1 version of the model repository was used. Its code was modified to match the subject and parameters of the study. The c3d files were used to move the model and the inverse dynamic simulation was carried out, then the results for muscle force were obtained and analysed.

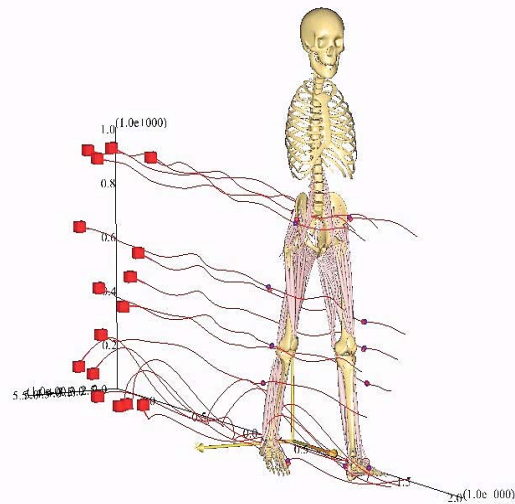


Figure 1: The musculoskeletal model simulation

## Results and Achievements

The results obtained were compared to each other and to established EMG data. It was found that whilst certain muscles, such as the Gastrocnemius Medialis agreed in certain aspects with the established EMG data. Other muscles, for example the Vastus Medialis, did not agree at all. Whilst all the objectives of the project were accomplished there is the need for further improvement and study.



# Experimental and Finite Element Contact Mechanics

**Student:** Mark Formosa  
**Supervisor:** Dr Ing. Pierluigi Mollicone

## Introduction

Contact mechanics are complex non-linear problems. Being this the first study in this section, it was decided to perform analysis on simple cases which are flat-flat surface, flat-circular surface and flat-concave surface.

## Project Objectives

This study investigates the contact behaviour created by 2-D round and flat mild steel surfaces using experiments and finite element software Ansys. The experimental method was based on the same finite element models and enabled to study the behaviour of pressure sensitive films mainly the contact parameters. Both FEA and experimental method were compared and validated with the Hertzian contact theory.

## Project Methodologies

- Review of several sections covered by contact mechanics
- 2-D simulation by Ansys based on three previously mentioned models
- Design and manufacturing of the finite element models using mild steel.
- Testing of components under various compressive forces using a pressure sensitive film; Fujifilm Prescale HS-type.
- Calibration and interpretation of the pressure film using a Java-based image processor; ImageJ.

## Results and Achievements

The simulation revealed agreement between the computational values and theoretical ones. This confirmed that the finite element conditions were applied in the correct manner. Moreover the experimental results showed high dependence on the surface conditions, but still these provided good comparison with the theoretical method. This indicates that both methods can provide contact solutions for further analyses under complex conditions.

The roughness effect on the pressure films was not investigated. The experiments were all based on models which owned sufficient surface finish performed by a grinding process. On the other hand the concave plates were manufactured with an Electric Discharge Machine which created a relatively inferior surface finish. This did not seem to affect the pressure film. Noticeably, these films are extremely sensitive to changes in surface flatness and roundness. These errors caused deviation from the ideal theoretical assumption. Such defects were highly visible in the experiments of cylinder on a flat and concave surface. Primarily contact always

occurred at the outer sides of the pressure films due to bending in the flat plates (warpage problem in compression jaws). Furthermore, lack of flatness was always present in all the plates since grinding was performed only on one surface.

The finite element simulations show that this process produced results similar to the theoretical prediction since both methods are centred on the same ideal assumption of perfect surface conditions. Therefore this method was found to be suitable for further prediction of the contact parameters combined with other conditions including; frictional effects, modelling of surface roughness and a non-linear material behaviour.

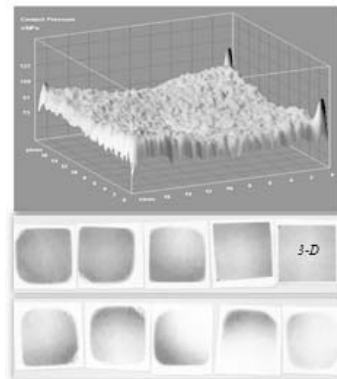


Figure 1: Pressure films of flat on flat surface experiment together with a 3-D plot of the pressure film named 3-D

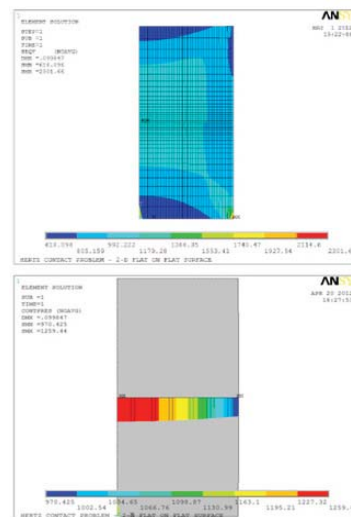


Figure 2: (a) 2-D Von Mises Stress of flat on flat surface simulation, and (b) Contact Pressure distribution at the contact interface

# A study on Beam and Shell elements

**Student: Paul Gafa`**

**Supervisor: Dr. Ing. M. Muscat**

## Introduction

The finite element technique is a mathematical procedure applied for analyzing structures. This method is used when the difficulties being dealt with are so complicated that it is impossible to solve using analytical approach. The finite element method solves equations with incomplete variances by transforming them into the smaller equivalent parts within its range. This transformation is carried out over small areas of simple forms called the elements. It produces matrix equations related to the input at particular points in the elements called the nodes to the output at that point.

Basic models can be used for effective savings in mesh production, computer resources, run-time and results interpretation. The level of freedom and output measure of these elements are most to the time those directly needed from the analysis and are placed at location of high importance such as principle axes. Accordingly, a beam or shell element representation should be considered.

## Project Objectives

The main objective of this project, were the following:

- Review the theory behind the formulation of Beam and Shell elements with emphasis on limitations, input, output, etc
- Review of the Beam and Shell elements available on the finite element software ANSYS
- Design and assemble a testing rack to carry out experimental studies related to beams and shell structures
- Use of Examples to demonstrate the proper use of Beam and Shell elements
- Validate numerical results of simple models with some experiments

## Project Methodologies

In order to gain a full understanding of how the beam and shell element families behave, it was necessary to understand the basic theories behind these finite elements families. A detailed description of all the structural beam and shell element available on ANSYS was developed to depict clearly the advantages, limitations, inputs and outputs of all the elements.

A design and assemble of a testing rack was developed to allow the carrying out of experimental studies related to beams and shell structures for the validation of such elements while running simulations.

A manual was compiled in order to provide a list of applications to act as an example and demonstrate

the proper use of Beam and Shell elements. The Manual consists of APDL scripts in an attempt to also demonstrate as many feature related to these elements as possible. Finally a series of experiments were carried out to validate numerically some examples of the manual.

## Results and Achievements

This dissertation is an in depth study of the beam and shell finite element families and through this analysis, their behaviour and formulation were validated by means of experiments. This provided a full understanding of the characteristics and performance of these elements. The results achieved provided knowledge on how such elements may be implemented.

Furthermore this research provides the basis for further studies on the subject.

## References

T. Hellen, How to - Use Beam, Plate and Shell Elements, NAFEMS, 2007.

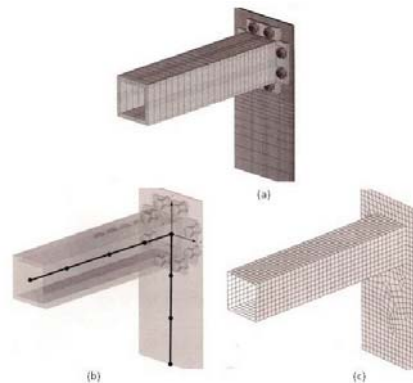


Figure 1: Beam Connected to Wall (a) Full 3D Mesh (b) Simple Beam Element Mesh (c) Mesh of Shell Elements 1

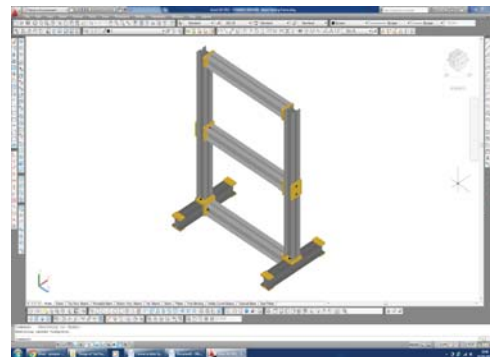


Figure 2: Testing Frame





# Mechanical Testing and Finite Element Analysis (FEA) on Novel Wind Turbine Structural Components

**Student: Andre` Galea**

**Supervisor: Dr. Ing. Pierluigi Mollicone**

## Introduction

Vertical Axis Wind Turbines (VAWT) are more suited to urban wind conditions. They do not need to turn to face the wind, are more aesthetically pleasing and cause lower noise levels than their horizontal counterparts. However, they suffer in low wind speed start-ups. A Self Adjusting Torque VAWT (SATVAWT) is being developed in this project to overcome this limitation by automatically changing the geometry of the blades.

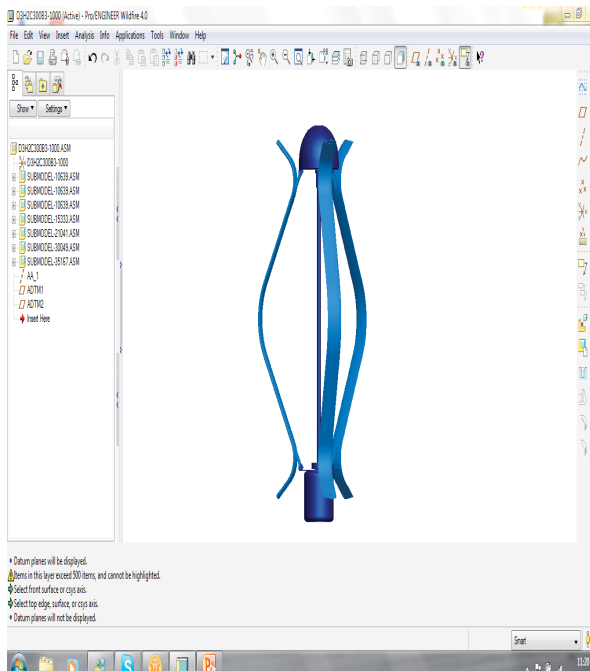


Figure 1 SATVAWT 3D Geometry

## Project Objectives

Perform mechanical testing of the material to be used in the novel turbine blade. To simulate and analyse the structural response of the turbine blade to working loads using Finite Element Analysis (FEA).

## Project Methodologies

Standard mechanical tests were carried out to determine the tensile, compressive and flexural properties of glass fibre reinforced polymer (GFRP) used for the turbine blades.

The geometry of the hollow section blades was modelled on ANSYS® for simulations under working loads defined by the centrifugal and lift loads

generated by the rotating turbine. Simple models were first generated using beam elements in 2D. Shell elements were then used on a 3D model constructed on computer aided design (CAD) software. Separate models were created to investigate the behaviour of a continuous blade as opposed to a blade with a revolute pin in its mid-span. The response of the two designs was compared and analysed.

The models were validated with theory using simple structural problems and studies were performed to investigate the effect of mesh densities and material thickness of the blade. The results were compared and analysed to investigate the applicability of the material and the structural response of the blade.

## Results and Achievements

The mechanical properties of GFRP were determined and used in the FEA simulations of the blade. The beam model simulations produced reasonable stress and deformation results. The shell model did not comply with the beam model behaviour. Stress concentrations caused the simulation to fail. This was concluded to be caused by the type of supports or from the structural behaviour of the geometry of the blade. The continuous blade design was preferred over the pinned models due to the lower stress levels generated when loaded.

The beam model was found to give a good general analysis of the structural response of the blade while the shell model was more precise for investigating the local behaviour of the material.

# Multi-Functional aid for People with Neuromuscular Disorders

**Student:** Lara Grech

**Supervisor:** Dr. Zdenka Sant

## Introduction

The biomechanical studies combine the knowledge of medical science and engineering into a multidisciplinary area that can help in treatment of a medical condition or improve a patient's life. People suffering from neuromuscular disorders are facing serious challenges when it comes to independently fulfilling their everyday tasks.

The aim of this project is to better understand the needs of people suffering from such diseases in an attempt to develop a device to assist their needs, focusing on the simple task of reading a book.

## Project Objectives

- Provide an analysis of the skill impairment associated with neuromuscular disorders
- Design a multifunctional book holder that would cater for all the patient's needs
- Analyse the design for structural integrity and stability

## Project Methodologies

From a series of discussions with patients and their close relatives at Mater Dei Hospital, a key attribute emerged which the design would have to satisfy: versatility. Neuromuscular disorders take many forms and patients have a variety of symptoms. This implies that any mechanisms designed for such applications need to be versatile; particularly in the way that the patient and machine would interact.

**Interaction in this case was categorized into:** Human to Machine: This encompasses the way a patient controls the machine. In this case the main issue was that patients tend to have limited to no mobility. Technologies considered include: joysticks, specialised control pads, voice control and optical control.

**Machine to Human:** This relates to the way a patient receives information from the machine. The primary function is to aid in reading a book, however most patients found it difficult to sit in bed and read from a flat surface. This problem was solved by using a camera that transmits an image of the book to a monitor that can be adjusted to any required position. Products currently available on the market were studied to determine the factors that made similar devices successful or not. Research was also carried out on existing technologies that could be adapted for the purpose of this project. Numerous design tools were used to help guide the design process in an efficient and effective manner to

produce a design that meets the requirements of the intended users.

## Results and Achievements

A final design was established. It consists of adjustable, modular components connected together, offering a wide range of versatility. Part of the design also required some programming to create an interface for the machine.

Mechanical analysis of the structure was carried out to ensure an optimal and safe structure. The functionality of the proposed design was physically tested by building a Proof-of-Principle prototype (Figures 1 and 2).

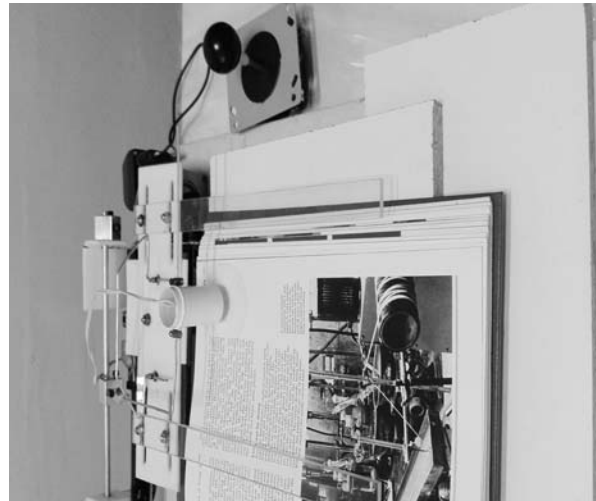


Figure 1: A prototype of the page-turner.

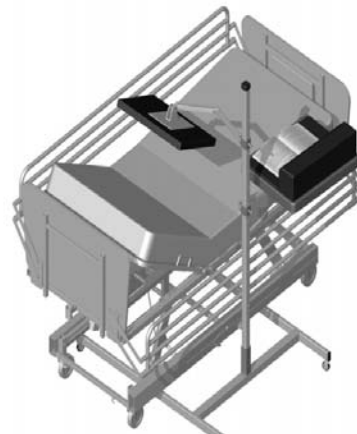


Figure 2: Rendering of the designed multi-functional aid being used in conjunction with a hospital bed.



# Optimization of Laminated Composite Structures to Attain Higher Structural Efficiency

**Student: Mireille Micallef**  
**Supervisor: Dr. Ing. Duncan Camilleri**

## Introduction

The importance of composites for structural use is continuously increasing as the demand for lighter and more efficient structures is on the rise. For the purpose of this thesis, a fibre-reinforced composite consisting of polyurethane and e-glass was investigated with respect to manhole covers.

## Project Objectives

The aim of this project was to optimize a laminated composite structure to attain higher structural efficiency.

## Project Methodologies

Initially, literature for the current, available and accepted theory was reviewed. Tests were then conducted on composite specimens and their validity was checked with respect to standards and results obtained from theory.

Table 1 Properties obtained from testing and theory  
 The values of  $E_1$  and  $\nu_{12}$  are in close agreement however, the values of  $E_2$  and  $X_t$  differ drastically.  $E_2$  is in such disagreement due to fibre misalignment with the direction perpendicular to the applied force. Apart from fibre misalignment, the values of  $X_t$  might not be in good agreement since the prediction of strength of fibre-reinforced composite materials has not yet achieved the levels of accuracy achieved by the prediction of stiffness. Another reason may be the presence of voids and defects within the composite specimens which were not a rare occurrence. Error! Reference source not found. shows that experimental and theoretical values for  $X_c$  are in very good agreement.

The theoretical values were calculated for a composite with 14.72% fibres by volume (as obtained from the

calcination method to determine glass fibre content) and using equations and constituent material properties found in literature.

The resulting mechanical properties from testing were then used in a finite element model which simulates the loading of different composite laminates. The load versus deflection curves were obtained from the simulations. These were compared to testing results conducted by the industrial partner to check the validity of the model.

The composite laminate was optimized by varying the fibre orientation and by introducing webs. The orientation, composition and geometry of the webs were altered in order to achieve the final optimized structure.

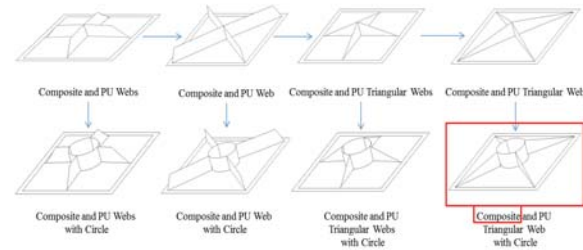


Figure 1 Final optimized structure – triangular webs configured as an ‘X’ with circular feature

## Results and Achievements

The final optimized structure consists of composite triangular webs configured as an ‘X’ with a circular feature. The web is 20 mm thick and is made up of one layer of e-glass fibres oriented at  $0^\circ$  in a polyurethane matrix.

## References

R.M. Jones, Mechanics of Composite Materials, 2nd ed. London: Taylor & Francis, 1999, pp. 2-165.

Property	Experimental Value	Theoretical Value (where applicable)
$E_1$ (GPa)	11	10.7
$E_2$ (MPa)	2900	66.1
$\nu_{12}$	0.381	0.331
$X_t$ (MPa)	168.27	534.7
$Y_t$ (MPa)	15.58	
$X_c$ (MPa)	142.40	143.44
$Y_c$ (MPa)	39.04	



# Investigating the Air Flow Behaviour around Lattice-Type Towers

**Student: Jean-Paul Mollicone**  
**Supervisor: Dr. Tonio Sant**  
**Co-supervisor: Robert N. Farrugia**

## Introduction

The air flow behaviour around towers has a significant effect on the wind speed measured by anemometers. Wind resource assessments heavily rely on the accuracy of measuring instruments to determine the viability of installations such as wind turbines. Towers interfere with the wind by changing its velocity around the entire tower and inducing evident turbulent flows behind it. The effect of the tower on the wind's velocity in front of the tower is relatively less but cannot be neglected. Investigations of air flow around towers is important since the slightest discrepancies in wind velocity can result in significant performance deficits in future installations reliant on wind velocity such as wind turbines.

## Project Objectives

The aim of the dissertation was to investigate the air flow behaviour around lattice-type towers by comparing and combining wind tunnel experiments, Computational Fluid Dynamics (CFD), International Electrotechnical Commission (IEC) centre-line wind speed deficit estimations 1 and available wind data from a lattice-type tower located at Wied Rini in Bahrija, Malta, at a height of 23 metres.

## Project Methodologies

- Design of a wind tunnel experiment to measure air velocity around various models along pre-defined paths and to measure the drag on the models.
- Familiarisation with two dimensional CFD simulations by modelling the experiments carried out in the wind tunnel and comparing results. Figure 1 shows the CFD simulation of the air flow around the tower model with the tower's face at 45° to the incoming flow.

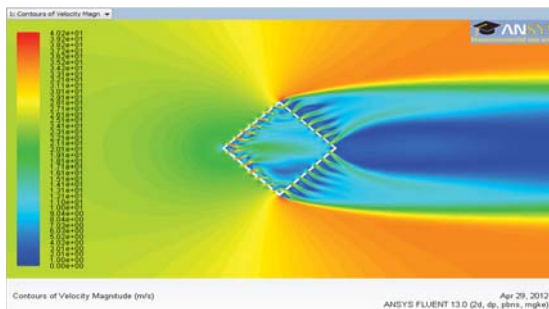


Figure 1 – CFD simulation contour plot of the tower model (velocity of 25m/s)

- Finding an appropriate CFD turbulence model to simulate tower interference.
- Applying the developed CFD modelling techniques to towers with different solidities in order to compare the centre-line wind speed deficit and drag coefficient results with the IEC estimations and wind velocity flow fields from other literature. Figure 2 shows the CFD simulation of a 2 metre wide tower with solidity,  $t = 0.19$  that models the Wied Rini tower section at a height of 23 metres.

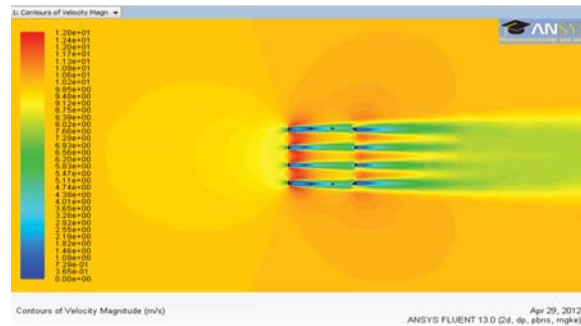


Figure 2 – CFD simulation contour plot of the Wied Rini tower section (velocity of 25m/s)

- Comparing the ratio of wind speed measurements from the two anemometers at a height of 23 metres at the tower in Wied Rini to the ratio of wind speeds from CFD simulations at corresponding points.

## Results and Achievements

Computational Fluid Dynamics (CFD) proved to be an accurate tool to investigate the air flow behaviour around lattice type towers. Experimental results compared well, both qualitatively and quantitatively, to CFD results and allowed a suitable CFD turbulence model to be chosen for studying and evaluating the IEC Standard estimations and Wind Rini wind data.

## References

1 IEC 61400-12-1. Wind Turbines – Part 12-1: Power Performance Measurements of Electricity Producing Wind Turbines. IEC: 2005(E).



# Finite Element Analysis of Welding Induced Residual Stresses

**Student: Matthew Said**  
**Supervisor: Dr Ing. Pierluigi Mollicone**

## Introduction

Welding is a very common and important joining process. However, the high temperatures formed may lead to a number of problems such as residual stresses, stresses that remain present in the structure even without any loads applied.

Computational mechanics techniques such as finite element analysis (FEA) are used to predict the formation of such stresses.

## Project Objectives

The aim was to apply FEA simulations of resistance spot welding processes to determine the distribution and formation of the temperature history and residual stresses.

## Project Methodologies

The modelling was done using ANSYS® software. It was important to create a simulation that is not so computationally expensive. In order to do this the finite element model was based on a decoupled thermo-mechanical analysis. This means that first the thermal analysis was computed and then the results obtained were inputted in the structural analysis. The setup was modelled as a 2D, axi-symmetric model. This is shown schematically in Figure 1.

To make the thermal analysis simpler, the electrical part of the welding process was not included in the simulation and a simple volumetric heat source was used. Thermal boundary conditions were used to represent any heat losses by convection. The thermal analysis was made more precise by calibrating the value of the heat input through experimental temperature readings using thermocouples. In fact the simulation parameters were the same as the parameters of the experiment's setup. Also the weld dimensions were obtained from macrographs of an actual weld. The heat input was left only for the actual time of heating during the experiment but then removed in order to simulate the cooling process that took for a longer period of time.

The temperature results were then inputted in the structural analysis where the setup was given structural properties and boundary conditions representing the constraints caused by the welding electrodes. Also pressure was applied to represent the load implied by the electrodes. The value of the load was found in an experiment using a load cell.

For a correct welding simulation it was essential to include an algorithm that simulates the effects caused on material elements that undergo melting and solidification. However this approach led to convergence problems and had to be partly omitted but the results obtained were still satisfactory.

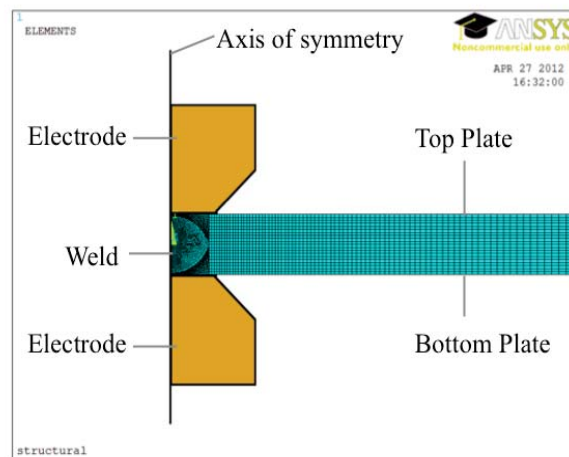


Figure 1: Schematic diagram of the Setup including the FEA mesh

## Results and Achievements

The temperature distribution results computed by the simulations matched well the experimental temperature results. These involved a rapid increase in temperature during heating and followed by an exponential decrease in temperature during cooling. Also, points further away from the weld had lower temperature values.

Results for residual stresses after sufficient time for cooling were obtained as well. As expected, the radial component of the residual stresses decreased exponentially to zero along the radial line away from the weld.

Improvements could be made to the simulations by including a more advanced heat input model in the thermal analysis. Furthermore, the structural analysis could be improved by including the algorithm simulating melting and solidification.



# A Study of the Performance of the Wasteserv Renewable Energy Sources

**Student: Claude Spiteri**

**Supervisor: Prof. Ing. Robert Ghirlando**

**Co-supervisors: Ing. Charles Yousif & Ing. Robert Farrugia**

## Introduction

Since the discovery of oil, the world has undergone major changes in progress and technology, but at the same time a number of challenges have been created, namely the decline in oil reserves and environmental issues 1. However, these challenges are opening up new opportunities for exploitation of renewable energy sources (RES) 2. WasteServ Malta Limited, which is mainly responsible for Malta's waste management, has installed a number of photovoltaic panels and micro-wind turbines at their four Civic Amenity (CA) Sites around Malta in addition to the present campaign in favour of the environment.

## Project Objectives

The two main objectives of this project are related to these Renewable Energy Resources (RES), namely:

- To study the performance of the various RES at the CA Sites of Wasteserv.
- To make recommendations on how to improve their performance.

## Project Methodologies

A literature review was carried on both wind and solar renewable energy.

Throughout this project several visits were made to the CA sites, where important parameters were measured and noted. With this data, an analysis was made of when and how much effect shading has on the photovoltaic panels. The location of the wind turbines and the obstacles in the vicinity were measured and their effect was noted.

After having gathered the data of the actual irradiation, wind speeds and wind direction, an analysis of the systems was made.

The results obtained were also compared to the results from software packages and were double checked. In some cases the data from software served as a reference to the actual data.

An analysis on the performance of the inverters used was also made.

Finally, for each of the four sites, some suggestions for improvements on present and future issues were made with an estimate of the improved power generation.

## Results and Achievements

- The best inclination of solar panels is between 300 and 320 and these should be installed

facing the true geographic South.

- Shading and soiling of solar panels leads to a drastic decrease in their power generated which, in some cases, was even up to 25 percent.
- Excessive heat is detrimental to the performance of both the modules and the inverters since it decreases their efficiency.
- Wind turbines must be located on high-lying areas and above any obstacles such as buildings and trees within the vicinity of the turbine. When this was not observed the power generated from the effected direction was reduced.
- By a combination of wind and solar technologies, the reliability of output can be improved and the combined power output is more constant throughout the year.

## References

David E., A Solar World - Climate Change and the Green Revolution., UK, Green Books 2003.

Daming Xu, Lonyun Kang, and Binggang Cao, "Graph-Based Ant System for Optimal Sizing of Standalone Hybrid Wind/PV Power Systems," Xi'an Jiaotong University, 2006.



*Figure 1: Combination of wind turbine and solar panels at Mriehel.*

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

**Student: Alan Vassallo**  
**Supervisor: Dr. Tonio Sant**

## Introduction

When designing an offshore structure to support a commercial wind turbine one has to keep in mind that such wind turbine support structures are subjected to aerodynamic loads, wave and current-induced hydrodynamic loads and occasionally ice loadings. Offshore wind turbine support structures have to be built to withstand these harsh environmental conditions, but on the other hand must not be overdesigned as such structures would not be economically feasible.

## Project Objectives

The objectives of this project were to design and construct an instrumented test rig which is capable of measuring wave-induced loads on model bottom-fixed offshore wind turbine support structures. Subsequently the test rig was used in experiments to measure the wave-induced loads parallel to the direction of wave propagation which are subjected onto two different types of support structures: Jackets and Monopiles. The results were analysed and compared to theory.

A model wind turbine which attaches to the constructed model support structures was also designed and constructed for showcasing and for further experimentation on combined aerodynamic and hydrodynamic loading of the structures.

## Project Methodologies

Scaled models of a monopile and a jacket support structure were designed and built. An instrumented test rig was designed and built to measure the hydrodynamic loads on the model support structures. Using the constructed test rig, experiments were carried out on the models which involved using the rig in a wave generating tank and measuring the wave-induced loads for a variety of wave conditions. Subsequently, the results were analysed and compared to theory. Theoretical results were calculated using the appropriate wave theories in conjunction with Morison's equation. The hydrodynamics analysis software ANSYS® Aqwa was used to calculate the theoretical loads on the complex jacket structure.

## Results and Achievements

The instrumented test rig successfully measured the intended loads. This was confirmed by performing

tests on a monopile, which is the most basic of structures, and the results obtained compared to theory. The percentage error between the average experimental peak load and the theoretical peak load was calculated for each wave and was found to be in the range of -8.273% to 15.282%.

The results for the model support structure clearly indicated that the orientation of the structure with respect to the direction of wave propagation affects the magnitude of the wave-induced loads and must be taken into consideration when designing a full scale structure.

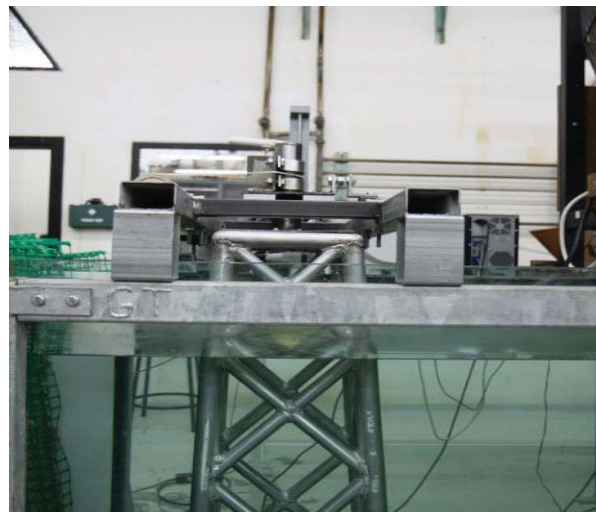


Figure 1 – Model Jacket Structure Mounted on Instrumented Test Rig.



Figure 2 – Model Jacket Structure Mounted in Wave Tank



# Conceptual Design of a Low-Speed Displacement Hull

**Student: Billy-Joel Zammit**  
**Supervisor: Dr. Claire De Marco**

## Introduction

Any marine vessel as it passes through the water produces waves. The pressure variation along the water hull peaks at the bow and stern and these pressure differences generate the waves on the surface that can be seen spreading out from the vessel's sides.

## Project Objectives

The aim of this project was to produce a conceptual design of a displacement hull for the conditions of reduced hull resistance and wave generation by optimising the hull form shape. The Maxsurf suite software was utilised in testing the iterative design and in performing resistance tests to the different hull configurations.

## Project Methodologies

After carrying out an extensive analysis on resistance theory, a resistance prediction method by Holtrop and Mennen was identified. This method subdivides the total ship resistance into components by using basic hull dimensions. These components were studied in detail to get to know the theory behind them. It was shown that for the displacement type of vessels, the viscous resistance constitutes a far larger percentage of the total resistance than the wave-making resistance. The design considerations on various parameters of the hull such as the forebody design and the optimum position of the longitudinal centre of buoyancy (LCB) were described.

Three dimensionless parameters were chosen for the iterative design procedure, making sure that the values are within the ranges applicable to the Holtrop method as indicated by Maxsurf. The parameters varied were:

- Length/beam ratio
- Beam/draught ratio
- Block coefficient

Using Hullspeed (FormSys application software), the resistance of each configuration could be identified. Once the optimal design was chosen, a bulb was then fitted to the hull. Resistance tests were again carried out, varying two other parameters:

- The bulb's length
- The bulb's diameter

## Results and Achievements

From the results achieved, resistance characteristics were identified in relation to hull form dimensions. For the displacement hull type, an increase in both

length-beam ratio and beam-draught ratio reduced the total calm water resistance. On the other hand, increasing the block coefficient increased the total calm water resistance, due to the fact that the vessel would have a fuller form. With regards to the addition of the bulb to the naked hull, the results showed that with increasing diameter, the total calm water resistance decreases. The effect of the bulb's length showed that increasing this parameter would increase the total calm water resistance.

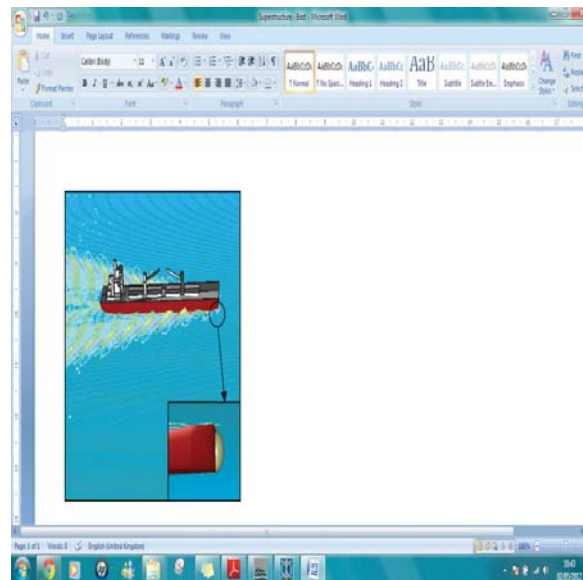


Figure 1 – Optimum hull



# An Investigation of the Anti-Corrosion Properties of Inorganic-Organic Hybrid Coatings Based on Silica

**Student: Jessica Aquilina**  
**Supervisor: Daniel Vella B.Sc., M.Sc.**

## Introduction

Inorganic-organic hybrid sol-gel coatings are a new class of materials where the inorganic and organic components are mixed at the nanoscale level 1. These inorganic-organic based coatings are known to give good anti-corrosion properties due to the synergy that arises between the two components. In the sol-gel process a stable polymeric suspension termed a 'sol' is produced from precursor starting material. The sol is used to deposit the coatings. The deposited sol film quickly forms a gel which can be dried and cured into a non-porous coat film. In this work the potential use of sol-gel coating technology for the field of conservation of historical artefacts will be investigated.

## Project Objectives

The aim of this project is to develop anti-corrosion coatings based on sol-gel technology for use in the field of conservation of heritage metal artefacts. Apart from offering protection against atmospheric corrosion, conservation-friendly coatings must be optically transparent and free of tints. Coatings should ideally be very thin such that they interfere minimally with the aesthetics of the underlying metal. Furthermore these coatings should be reversible such that the coating treatment can be removed in the future to make way for a better performing alternative.

## Project Methodologies

The following steps were conducted throughout the course of this project:

- Literature review on the current developments of sol-gel technology and the effects of adding nano-particles to coating lacquers
- Preparation of 3 inorganic-organic hybrid coating lacquers with different molar ratios of tetraethoxysilane (TEOS) and methyltriethoxysilane (MTES) and the addition of 10nm silica particles to the sol which exhibited the highest amount of organic component
- Application of the coating lacquers by dip-coating technique onto planar low carbon steel samples and glass slides
- Coatings inspection through an optical microscope to check for any defects. Characterisation of the lacquer done through UV/Vis spectrometry and Infrared Spectroscopy. Coating thickness on glass slides measured through scanning electron microscope and the

hydrophobicity of the coating was assessed by measuring water contact angles on the surface of the coatings

- Testing of the hybrid coating through electrochemical corrosion tests (polarization and open circuit) and cycled fog tests to assess coatings under accelerated corrosive environment.

## Results and Achievements

- Infra-red spectrometry results confirmed the inorganic-organic nature of the coatings
- Coating thicknesses (double layered) ranged from 0.74 to 1.65 $\mu$ m.
- Deposited coatings were fully transparent in the visible region of the spectrum. Some absorption of light was recorded for coatings loaded with nano-particles.
- Inorganic-organic hybrid coating combinations provided different levels of protection over bare steel. As a general trend, the higher the content of methylsilane (MTES) in the coating the better the anti-corrosion properties of the coating. Furthermore the addition of nano-particles seems to have further improved the corrosion properties of the coatings

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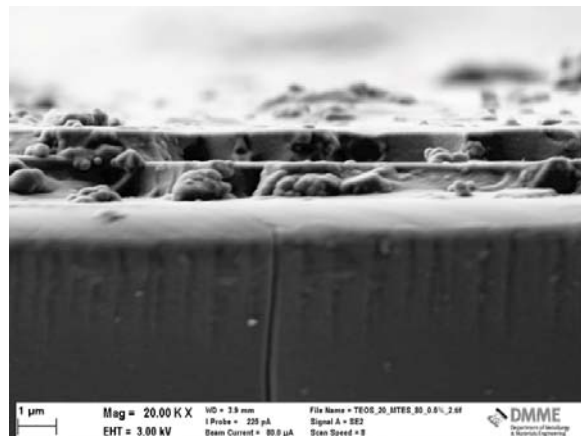


Figure 1 – Double coating layer on glass of mol% 20:80 TEOS:MTES + 0.5% Silica nano-particles



# Triode Plasma Oxidation of Aluminium Coated Titanium Alloy

**Student: Bonnie Attard**  
**Supervisor: Dr. Ing. Glenn Cassar**

## Introduction

Titanium alloys exhibit a range of attractive properties; a unique combination of excellent mechanical and physical properties and superior corrosion resistance. Unfortunately, the tribological performance of these alloys is very poor making them very susceptible to seizure and galling. The use of surface engineering techniques involving the deposition of a coating to the Ti-6Al-4V alloy surface and its subsequent oxidation could be viable as a way to protect the material and improve its suitability for engineering applications involving relative motion under load.

## Project Objectives

The main aim of this research was to improve the wear properties of Ti-6Al-4V via the deposition of a metal layer using an Electron Beam-Triode Plasma Assisted Physical Vapour Deposition (EB-PAPVD) process and its subsequent Triode Plasma Oxidation (TPO). Consequently the technique was assessed for its viability as a surface engineering process for titanium alloys.

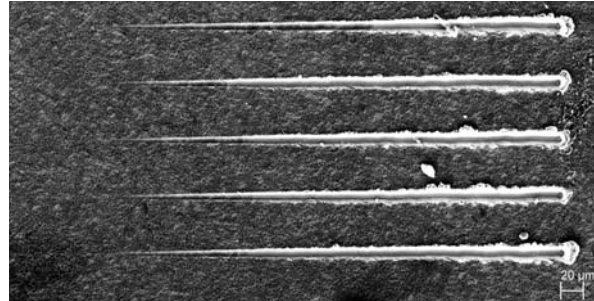
## Project Methodologies

The project methodology consisted of:

- i. A review of the existing literature on the subject;
- ii. Preparation of a number of test samples;
- iii. Determination of the optimum deposition parameters for aluminium;
- iv. Deposition of an Al coat onto the pre-polished Ti-6Al-4V coupons using EB-PAPVD;
- v. Oxidation of the Al coat using TPO;
- vi. Characterisation of the resulting coatings using methods such as nanoindentation, nanoscratch testing (see Figure 1) and scanning electron microscopy (SEM).

## Results and Achievements

- i. The development of a process routine for evaporating Al using EB-PVD;
- ii. The study of the substrate and coating using EDX and XRD techniques;
- iii. Hardness and elastic modulus value for the oxidised coatings – obtained via instrumented nanoindentation;
- iv. Topographical study using SEM and stylus profilometry;
- v. An evaluation of the adhesion strength of the coating – nanoscratch testing and the resultant critical loads of failure of the different coatings.



*Figure 1: Nano-Scratches on a coated substrate to evaluate the coating's adherence*

# Bulk mechanical properties of laser generated tool grade Martensitic Stainless Steel

**Student: Claude Busuttli**  
**Supervisor: Dr. Bertram Mallia**  
**Co-supervisor: Ing. Maurizio Fenech**

## Introduction

Martensitic stainless steels are very important and highly used materials for the manufacture of tools. These tools are subjected to conditions which demand high wear resistance, toughness and general corrosion resistance. The production of such tools involves a number of manufacturing operations which make them very expensive. A plausible solution to minimise machining costs and repair of such tools could be achieved using laser material deposition. The DMME has embarked on a project where martensitic tool steels modified using chromium carbide additions are being developed using a laser to address this problem. Tribological performance and bulk hardness of such deposits have been investigated in previous studies. This work focuses on the bulk impact properties of laser generated martensitic stainless steel modified with carbide additions.

## Project Objectives

The aim of this project is to investigate the effect of the variation in the carbide addition and heat treatment of laser deposited AISI 410 based freeform walls on their impact characteristics. Commercially available AISI 420 martensitic tool steel has been used as a benchmark.

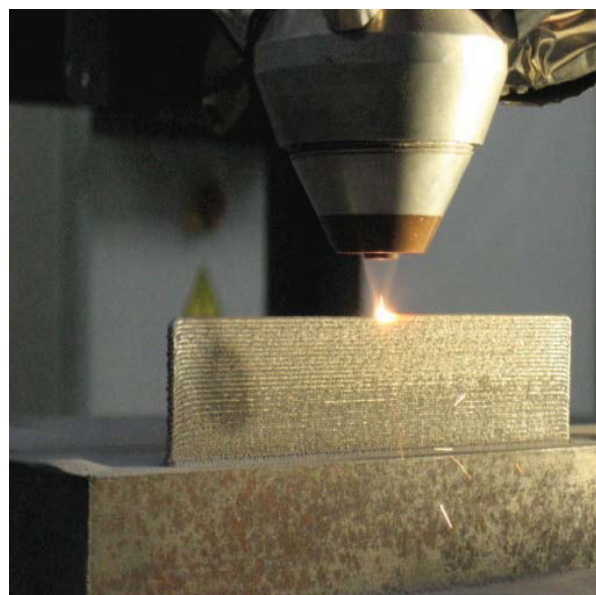
## Project Methodologies

- A thorough literature review covering laser cladding, martensitic stainless steels and fracture dynamics was performed.
- A specimen production regimen via laser deposition, heat treatment (austenitising and tempering), wire cutting, surface grinding and electric discharge machining was determined.
- Various specimen batches in the form of freeform walls were produced with different carbide additions to AISI 410 stainless steel powder using laser material deposition. The resultant clads were heat treated using different tempers and subsequently prepared for impact testing.
- Modified Izod impact tests were performed and repeated results were acquired for each percentage carbide powder additions and heat treatment.
- A full analysis was made on the microstructures of the different specimen batches using X-ray diffraction, optical and scanning electron

microscopy. The microstructure was correlated with fractured surfaces following impact testing.

## Results and Achievements

The results showed that by increasing the percentage dissolved Cr<sub>3</sub>C<sub>2</sub>, a change in the fracture mode occurred. An increase in the Cr<sub>3</sub>C<sub>2</sub> addition showed a transition from a ductile to a brittle mode of fracture with a corresponding reduction in fracture toughness. Microstructural analysis of the test specimens revealed higher re-precipitated carbide content in batches having high Cr<sub>3</sub>C<sub>2</sub> additions. Austenitising was not sufficient to entirely homogenise the as-deposited microstructure. Carbides were observed to preferentially form along dendritic regions with high carbon content during austenitising. This has adversely affected the impact characteristics of the test specimens. Increasing tempering temperature was shown to reduce the maximum impact force to fracture but increase the fracture time base. It was shown that the right combination of carbide addition and heat treatment can produce tool material with similar or superior fracture response to the benchmark material (AISI 420 martensitic stainless steel). The results obtained from this work in combination with those available from previous studies will serve to guide the selection of the composition and heat treatment of laser built tool material according to application conditions.



*Figure 1- Freeform wall produced using laser material deposition*



# Materials Selection by Artificial Neural Networks

**Student: Diane Chircop**  
**Supervisor: Dr. Ing. John C. Betts**  
**Co-supervisor: Dr. Kenneth Scerri**

## Introduction

Materials Selection is an integral and complex part of the design process. Advances in the field of artificial intelligence has led to the increased perception and recognition ability of Artificial Neural Networks (ANNs) making them applicable to various fields. ANNs exhibit similar functions of the human brain in terms of learning and decision-making, which have encouraged the use of ANN for materials selection. These characteristics eliminate the need for the user to carry out complex calculations to infer the optimal material for the problem at hand, and thus, would be of great advantage to develop a system for materials selection that could be used by users having limited background in engineering.

## Project Objectives

The objective of this project is to develop and test a methodology; one, which develops a method for applying artificial neural networks (ANNs) to materials selection problems, and furthermore, to justify whether this methodology can be successfully implemented.

## Theoretical Procedure

ANNs undergo a process of training before being ready for use. An individual network is trained for one particular application. This entails the process of presenting the network with sufficient input and target output examples from which the network learns to emulate the relationships within the data, whilst acquiring the ability to generalize to new input data [14]. ANNs were applied to two material selection problems – a spring system and a spring-intake valve system in an engine block. For each problem, the objectives were selected as the inputs to the network. The first step to generate the output training data for both problems was by calculating an acceptable material index ( $M_{acc}$ ), described by the aggregation of these objectives. Candidate materials were chosen, for which the unique MI for each material was calculated. By calculating the differences between each material's MI and  $M_{acc}$ , materials which are suitable for the application would return a positive value whereas those which are unsuitable would return a negative value. The material having the highest positive value is the one farthest away from the  $M_{acc}$  and thus, the one most fit for this application. In both problems, the training data sets were generated by assigning different random values of the objectives, each time calculating a new  $M_{acc}$  for which a new set of distances would

be generated. A generic illustration is depicted in figure 1. The user interface of Mathwork's Matlab© was used for training the network. Once trained, the user can then use the network by inputting new values of the objectives.

## Results and Achievements

In both cases, reliable results were obtained due to the high level of accuracy and consistency which was achieved. The main conclusion to this research is that ANNs can be successfully to materials selection problems, as long as they are fed with a sufficient amount of training data. The main difficulty is to obtain this data, which is required for a high level of network training and generalization performance to be achieved. It is only when a network is trained with realistic data can its results be checked for consistency with other materials selection methods.

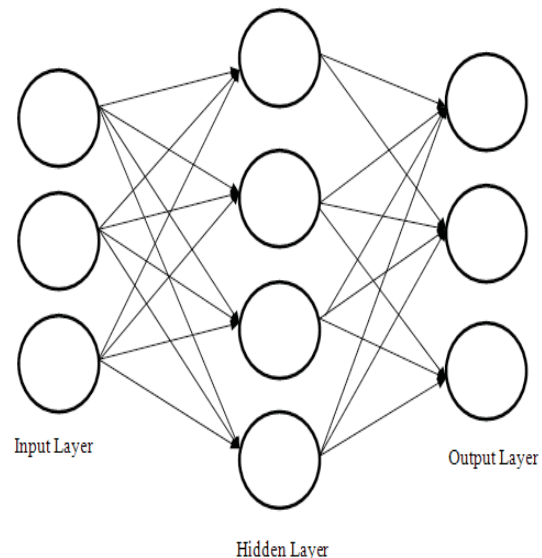


Figure 1: A feed-forward Neural Network

# Investigation of the properties of a novel multipurpose material for use in dentistry

**Student: Lukas Grech**

**Supervisor: Dr. Bertram Mallia**

**Co-supervisor: Prof. Josette Camilleri**

## Introduction

There are a number of commercially available materials, developed specifically as root-end fillers. A widely used root-end filler is Mineral Trioxide Aggregate (MTA) and has been the subject of numerous research studies. The literature available on other commercially available root-end fillers is somewhat limited and often restricted to the manufacturer's data sheet. An important requirement for root-end fillers is to be radiopaque. This is achieved by the addition of various radiopacifying agents to the material. Additions to enhance specific characteristics of tricalcium silicate (TCS) based materials (all materials under investigation in this study except Intermediate Restorative Material (IRM) which is a polymer reinforced zinc oxide-eugenol based material) such as radiopacity, setting time or workability often result in effecting the hydration and properties of the material and is investigated in this work. Four root-end filler materials were studied. Three of these (Biodentine, Bioaggregate and IRM) are commercially available while the other is a prototype material; tricalcium silicate with added zirconium oxide radiopacifier.

## Project Objectives

The aim of this project is to characterise and investigate the chemical and physical properties of commercially available root-end filling materials, in addition to a prototype cement based material on the MTA model with more pure components.

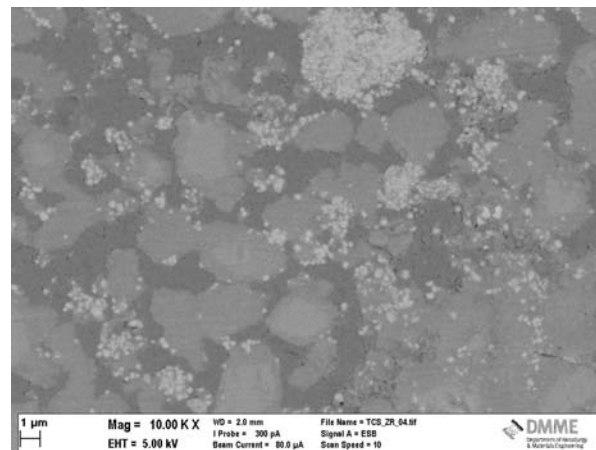
## Project Methodologies

Extensive testing was conducted to study the chemical and physical properties of the test materials. All materials were prepared in accordance to the manufacturer's instructions. Tests were conducted in accordance with European standards (BS-EN ISO 9917-1:2007 and BS-EN ISO 6876:2002). All samples were stored and tested in a simulated body fluid, to emulate the blood and saliva present in a clinical situation, and thus give more realistic results. Testing to determine the radiopacity, pH of test solution, calcium ion leachate, setting time, micro-hardness, compressive strength, porosity, water uptake, sorption, and solubility was carried out. Material microstructural characterisation and phase analysis was done using scanning electron microscopy (SEM), energy dispersive X-ray analysis (EDX), X-ray diffraction (XRD) and Fourier transform

infrared spectroscopy (FTIR). Fluorescent dyes and micro-spheres in conjunction with confocal microscopy were used to simulate the ingress of bacteria into extracted filled teeth.

## Results and Achievements

The chemical constituents of commercially available test materials were found to agree with those specified by the manufacturer, and their radiopacity satisfied ISO 6876:2002 requirements. The TCS based cements displayed significantly weaker mechanical properties compared to IRM and their chemical characteristics indicated that they are well suited for root-end fillers. The prototype material investigated exhibited similarities to the commercially available TCS cements. The tricalcium-silicate based cements leached calcium ions in solution and displayed hydroxyapatite formation on their surface when immersed in biological simulated fluid. This promotes tissue growth making such materials bioactive. It was shown that the properties of TCS based cement (radiopacity, setting time, and hydration characteristics) may be modified through various additives.



*Figure 1 Electron backscattered SEM micrograph of the prototype material comprising TCS cement and ZrO radiopacifier after 28 days immersed in Hank's Balanced Salt Solution.*



# Tribocorrosion of Biomaterials

**Student: Julia Sammut**  
**Supervisor: Dr. B. Mallia**

## Introduction

Passive metals such as stainless steels are known for their good corrosion resistance owned by the spontaneous formation of a self-heal thin surface passive film. This film provides a barrier between the metal and the corrosive environment and protects the material from corrosion. In tribocorrosion systems, corrosion is combined with mechanical action that may result in the partial or complete removal of this passive film. This would result in a synergetic increase in corrosion due to mechanical action (wear-accelerated corrosion). There are various synergistic and antagonistic effects that may occur between wear and corrosion 1. More often the overall combination of mechanical and electrochemical processes in a tribocorrosion process results in an increase of material degradation 2. Tribocorrosion is present in various applications including metallic parts implanted inside the human body which experience relative sliding in the presence of a corrosive environment. Tribocorrosion research has become an active area of research. This is to better understand multi degradation mechanisms, and thus be able to mitigate them.

## Project Objectives

The main aims of this project are to study the tribocorrosion response of biomedical grade AISI 316 LVM stainless steel in a reciprocating sliding configuration and to investigate the mechanical and electrochemical contributions to material loss.

## Project Methodologies

In this undergraduate research project, tribocorrosion testing was performed using a reciprocating sliding corrosion-wear tester in a simulated biological environment. These tests have been carried out under different electrochemical conditions, applied forces and sliding frequencies against an alumina ball counterface material. The sliding distance was kept constant throughout all the tests. Analysis of the AISI 316 LVM scar morphology, debris generated, and the counterface surface were done using a light optical microscope (LOM) and a scanning electron microscope (SEM). Figures 1 and 2 are sample images of the alumina counterface contact area and scar on the 316 LVM stainless steel respectively. The volume material lost on the stainless steel specimens was measured using a contact profilometer. Vickers micro hardness testing was carried to investigate the effect of the test parameters on the microhardness values inside the resultant scars on the AISI 316 LVM specimens.

## Results and Achievements

The electrochemical conditions investigated had a high influence on the amount of material loss. When

the specimens were polarised in the anodic direction during the tribocorrosion tests, the material loss was larger compared to tests under cathodic polarisation or open circuit potential. The smallest material loss was recorded following tests under cathodic protection where the stainless steel specimens were protected against oxidation. The applied load and the sliding frequency also affected the material loss. Under different electrochemical conditions, the morphology of the resultant AISI 316 LVM scars was observed to differ. The hardness measurements inside the wear scars increased significantly indicating work hardening during the test. An interesting observation was that in all tribocorrosion tests under anodic polarisation, a pit was forming as soon as sliding was stopped.

## References

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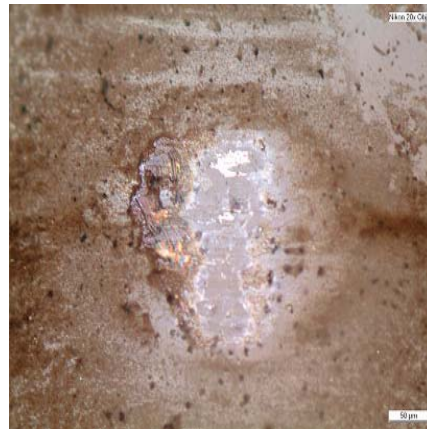


Figure 1: Alumina counterface appearance as viewed using LOM, showing debris around the contact area. (Sliding direction left to right)

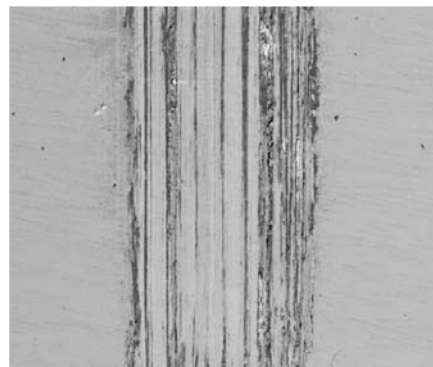


Figure 2: SEM image of tribocorrosion wear scar on polished 316 LVM stainless steel. (Sliding direction bottom to top)

# Laser Surface Processing of Cast Aluminium Alloys

**Student: Alistair Paul Zammit**  
**Supervisor: Dr Ing John C Betts**  
**Co-supervisor: Mr Clayton Damato**

## Introduction

Aluminium alloys are widely used in many technological fields, such as in the aeronautic and automotive industry. However, the widespread use of aluminium alloys in industry has been limited due to their poor tribological properties in terms of resistance to surface wear. Surface engineering techniques have been introduced to improve the surface properties of materials which possess good bulk properties, but which lack fundamental surface properties such as corrosion resistance and wear resistance. Laser surface alloying is a versatile surface engineering technique used to produce a modified surface layer of newer alloy composition 1.

## Project Objectives

The main objectives of this study were to:

1. Perform single laser track alloying by varying the nickel powder flow and the laser beam diameter.
2. Perform laser surface alloying by varying the predetermined nickel powder flow and the amount of surface overlap between one track and another.
3. Perform wear testing of the laser surface alloyed samples in order to test whether laser surface alloying of cast aluminium alloys improves their resistance to surface wear.

## Project Methodologies

The single tracks were produced by varying the laser beam diameter and the nickel powder flow. The laser beam diameters tested were 2mm and 2.5mm and the powder flow was varied between 0.02 – 0.06g/s for each laser beam diameter.

For the laser alloyed surfaces produced in this study, the nickel powder flow was varied between 0.03 – 0.05g/s, while keeping the laser beam diameter and the co-axial gas flow rate at 2mm and 20lit/min respectively. The percentage overlaps tested were 25% and 50% and the surfaces were produced in a spiral shape.

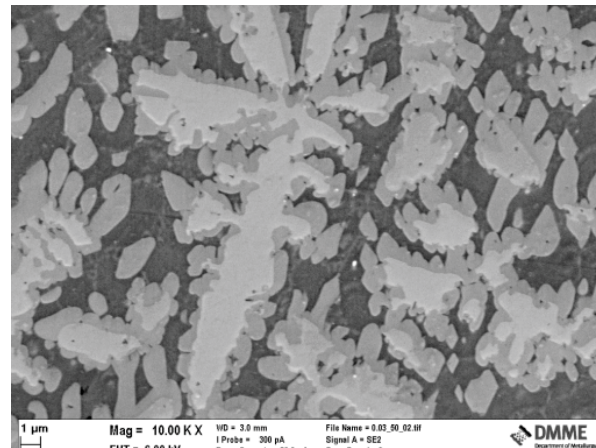
Wear testing was carried out a pin on disc testing machine. Wear testing was performed using a 15N load on surfaces produced with 0.03g/s, 0.04g/s and 0.05g/s having 25% overlap, and was also performed on untreated samples of cast aluminium plates.

## Results and Achievements

Micro hardness testing of the cross sections of the single tracks produced revealed that the hardest

alloyed layers were achieved using a laser beam diameter of 2mm and a co-axial gas flow rate of 10lit/min. Results also demonstrated that as the laser beam diameter increased, the hardness of the alloyed layer decreased. Micro hardness testing of the surfaces produced by laser alloying revealed that as the surface overlap increased, the hardness of the laser surface alloyed layer increased.

X-Ray Diffraction testing of the surfaces revealed that the phases present in the microstructure were aluminium, nickel, Al<sub>3</sub>Ni and Al<sub>3</sub>Ni<sub>2</sub>.



*Figure 1: Microstructure showing the dendritic structure composed of nickel aluminide intermetallic phases.*

Wear testing results performed at a load of 15N demonstrate that laser surface alloying increases the wear resistance of cast aluminium alloys. Results also show that increasing the powder flow increases the wear resistance of the laser surface alloyed layer. Scanning electron microscopy images of the wear tracks produced for the untreated and laser alloyed surfaces show that the mode of wear changes from a predominantly adhesive mode for the untreated samples to a predominantly abrasive mode for the laser surface alloyed samples.

## References

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