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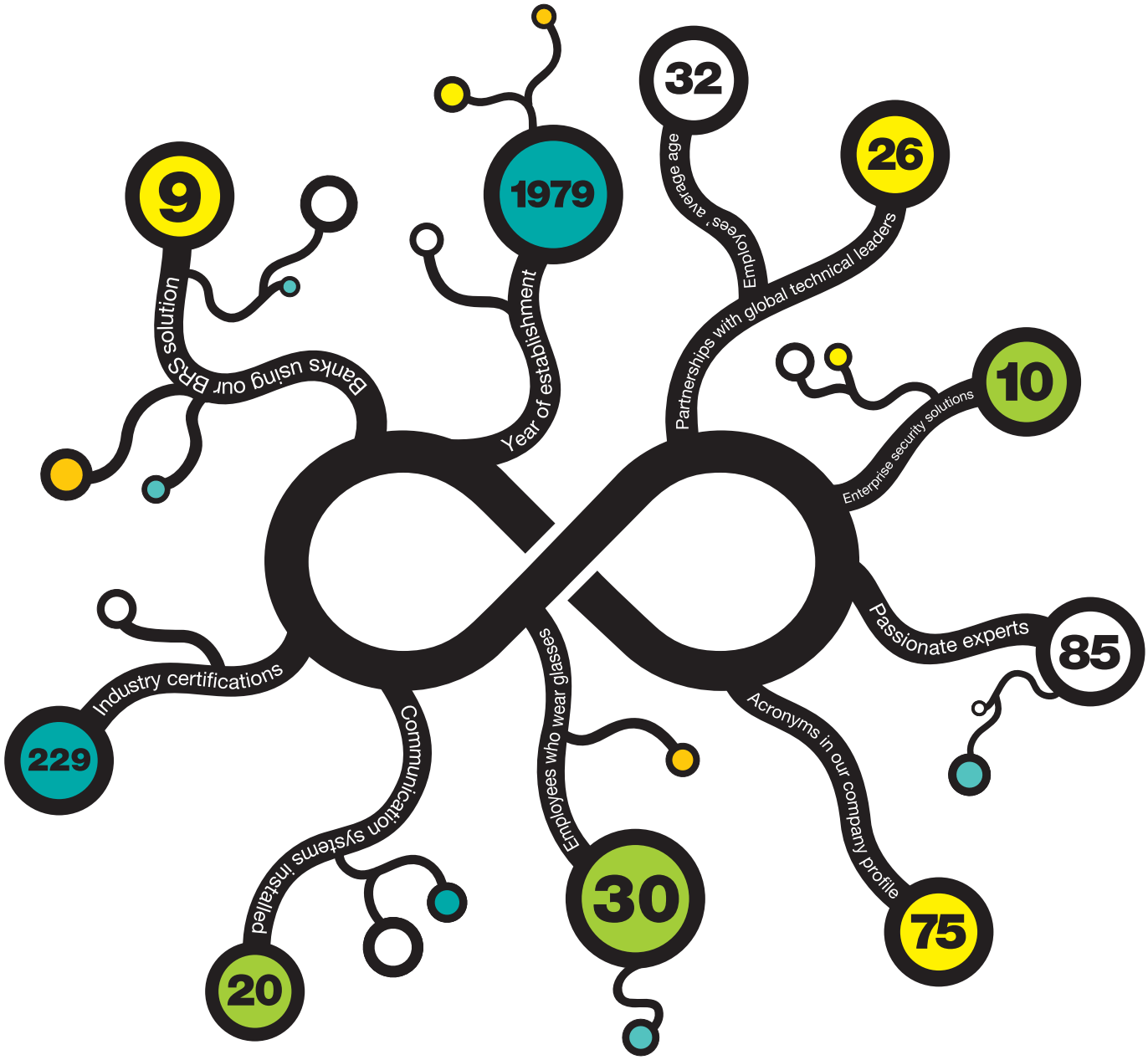
UNIVERSITY OF MALTA
L-Università ta' Malta

Final Year Engineering Projects Exhibition

Friday 3rd & Saturday 4th July 2015
Faculty of Engineering - University Campus



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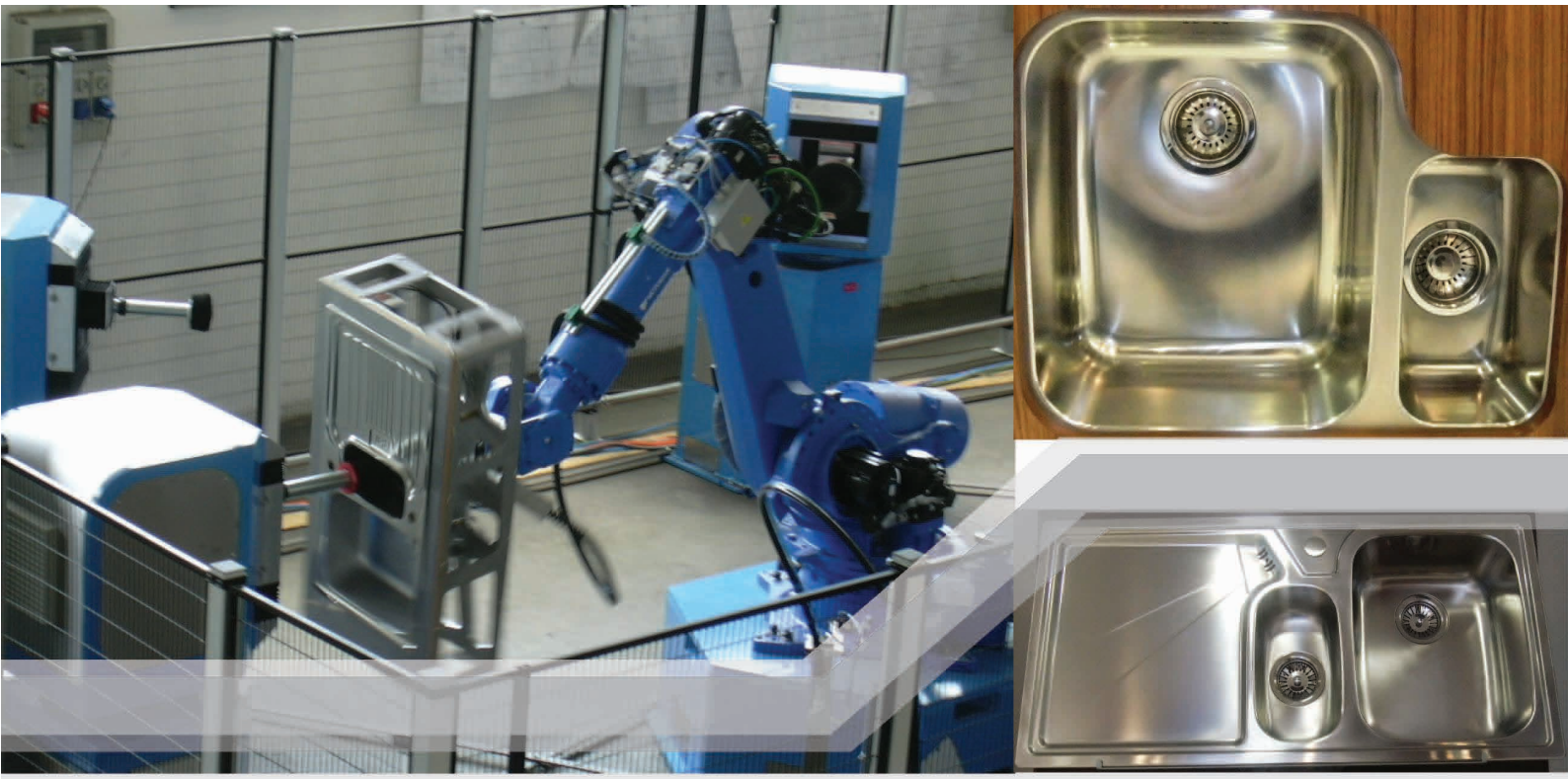

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FINAL YEAR ENGINEERING PROJECTS EXHIBITION 2015

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

FOREWORD

The academic year at the Faculty of Engineering of the University of Malta culminates with the Final Year Engineering Projects Exhibition. This is the annual event, now in its 26th edition, whereby the Faculty opens its doors to formally welcome its industrial partners, alumni, current and prospective students and their parents, as well as the general public, to sample the on-going activities within the Faculty. This event provides the opportunity for the Faculty to showcase the ability of its undergraduate students with potential employers as well as entice prospective students to steer their studies towards a professional degree in engineering. During this exhibition, prospective students are given the opportunity to listen in first hand to the experiences of our students, as well as discuss with both the academic and technical staff the meaning of the engineering profession, the potentials for job opportunities in the local, European and international markets, as well as opportunities for eventual further studies.

The Bachelor course in Engineering (B.Eng (Hons)) within the Faculty is a four-year long course and is essentially composed of two streams, Electrical and Electronics or Mechanical Engineering. The courses offered within our Faculty are highly challenging and demanding, as may be confirmed by our students and alumni. It is however an intensely formative and developmental process in the development of any Engineer. Apart from delivering subject content and ensuring a solid foundation in the fundamental engineering concepts, the engineering courses strive to discipline students in their problem solving skills, giving particular attention to detail, time management and teamwork. The Faculty has over fifty years of experience in the above, with the majority of the Maltese graduates in engineering being alumni of this Faculty.

Undeniably, the role of the Engineer is crucial to our society, ranging from the more traditional power generation and distribution, resource management and support to the food and electronic manufacturing industries amongst others, to the more recent high-profile activities such as aircraft maintenance and logistic planning, online gaming and financial modelling. There is also no denying that the strength of our engineering is one aspect that makes Malta a viable option to some of the larger industries having presence here. Weakening of this discipline, therefore, could have significant adverse effects on employment opportunities and consequently on our economy. It is for this reason that we take the preparedness of our students very seriously with no compromises on the rigour and quality of their education. Subsequently, the Faculty continues to advance its capabilities, both in terms of development of its staff as well as the facilities it makes available for use by its students. In the past few years the Faculty has invested close to 7M€ in facilities through ERDF structural funding, has published roughly sixty academic papers annually in high ranking journals and conference proceedings and has been awarded ten patents for innovations developed in house. In order to achieve this, the Faculty continues to work in collaboration with the local and European industries and high-ranking Universities worldwide on various levels and is involved in a number of European expert groups and multi-national research consortia.

This booklet is primarily intended as an overview of the projects that our final year undergraduate students have developed over the past academic year. It demonstrates the diversity of the projects and the capability of our students in completing a set task through the application of the skills and knowledge they would have acquired throughout their course.

The Faculty also offers courses at postgraduate level. To date, the faculty has roughly thirty students registered annually for either a Masters of Science by Research, taught Masters of Science in Integrated Product Development or Doctoral studies. The first few pages of the booklet also give an appreciation of the research activities held within the Faculty, through brief descriptions of funded research projects and postgraduate research areas. The Faculty is proud of these accomplishments.

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

Andrew Sammut

Dean, Faculty of Engineering

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The B.Eng.(Hons) in Electrical Engineering incorporates both technical and practical knowledge to provide the ideal springboard for satisfactory industrial careers and further academic development. This degree is a full-time four-year course, structured as follows:

Year 1 and 2

The first two years consist of initial background courses on electrical and electronic circuits, mechanical engineering, computer-aided design, modelling of dynamic systems, computer programming and architecture, electrical machines and microcontrollers.

Year 3 and 4

During the final two years the students take optional courses to further their knowledge and expertise in the fields of microcontrollers; advanced electronic and power circuit design; electrical and renewable energy; advanced drives; signal processing; control systems; and artificial intelligence. The technical knowledge acquired during the course is put to use in a final year thesis, a showcase of the students' development and their future aspirations.

B.Eng.(Hons) in Mechanical Engineering

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

Year 1 and 2

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

Year 3 and 4

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

UNDERGRADUATE ENTRY REQUIREMENTS

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

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

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

POSTGRADUATE COURSES

Master of Science in Electrical Engineering by Research

The M.Sc. in Electrical Engineering by research is a 3-semester degree which is based on a research project implemented by the student. It includes a 5 ECTS unit on research methods, and a research seminar in which students reading for this degree present their work to the Faculty. Some subject areas covered in this programme include: Electrical Drives, Electrical Machine Design, Electric Transportation, Control and Grid Integration of Renewable Energy Sources, Energy Storage, Building Services, Power Systems, Power Electronics, Microgrids, Power Quality and EMC, Electrical Energy Efficiency, Signal, Image and Biomedical Signal Processing, Computer Vision, Distributed Computational Intelligence, Machine Learning, Automatic Control, Adaptive and Intelligent Control, Robot Control, Spatio-temporal System Modelling, Swarm Robotics, Human-machine Interface Design, Analysis and Evaluation, Aircraft Flight Trajectory, Prediction/Management, Autonomous Navigation Systems, Analogue/Digital Signal Processing, Air/Road Traffic Management, Intelligent Transportation Systems, Biomedical Electronics, Industrial Electronics and Precision Instrumention.

Master of Science in Mechanical Engineering by Research

The M.Sc. in Mechanical Engineering by research is a 3-semester degree which is based on a research project implemented by the student. It includes a 5 ECTS unit on research methods, and a research seminar in which students reading for this degree present their work to the Faculty. Some subject areas covered in this programme include: Applied Mechanics & Biomechanics, Strength, Stability, and Integrity of the Structures, Applied Multi-physics Modelling, Composite Structures, Mechanics of Welding, Environmental Engineering, Offshore Renewable Energy, Solar Energy, Aerodynamics and Wind Energy, Air-conditioning Systems, Heat Transfer in Electrical Machines, Internal Combustion Engines, Naval Architecture, Laser Material Processing and Surface Engineering for corrosion and wear resistance, Nanomaterial Modelling, Biomaterials, Austempered Ductile Iron (ADI), Product Design and Development, Design of Biomedical and Assistive Devices, Artificial Hand Design and Development, Rapid Prototyping, Tooling and Manufacturing (RPTM) using Fused Deposition Modelling (FDM) and Electron Beam Melting (EBM), Polymer Processing (injection moulding and thermoforming), Lean and Agile Manufacturing, Micro and Nano Manufacturing, Sustainable Manufacturing, Industrial Automation, and Robotics.

Master of Science in Integrated Product Development

The M.Sc. in Integrated Product Development is a taught Masters offered by the Faculty of Engineering and has been running for over 10 years. The Course is built on two fundamental pillars of Product and Process Engineering, and Business. The programme blends these topics together and even allows the student an element of specialisation or focus in any one of these two pillars within the programme itself. This course runs over a 3-year period over a part-time basis and is intended to fortify skills and maximise performance and success in the industry by integrating all the aspects of product development, including product function and design, product materials and manufacturing, product use and environmental impact, product marketing and costing, entrepreneurship and business management.

Doctorate Degree by Research in Engineering

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

POSTGRADUATE ENTRY REQUIREMENTS

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

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

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

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

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

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Triple Output programmable precision bench power supplies

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Microcontroller Development Boards

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Electronics Manufacturing Laboratory

PCB Structuring Laboratory

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CNC PCB structuring system

Multilayer Press

Stereolithographic 3D Printer

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

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

PCB Finishing Laboratory

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Brushing machine

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Weller Hot air station

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Semi-automatic pick and place systems

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- High voltage and current DC supplies
- Electrical Drives and Control Simulation Software
- Harmonic Voltage and Current Measurement Set-up
- 100kVA Flywheel UPS

Power Electronics Laboratory

- Vector controlled Induction Motor, Permanent Magnet Synchronous Motor and Switched Reluctance Rigs
- Switching Frequency Current Sensing for Power Electronics and Control
- High Bandwidth Instrumentation for Power Electronic Measurements
- Water Tank for Electric Outboard Testing
- Low to Medium Power Machine Loading Units
- 50kW regenerative machine loading unit

Electrical Machines Laboratory

- Domestic Scaled Combined Heat and Power Plant
- Vertical Axis Wind Turbine Setup

Electrical Mobility Laboratory

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

Department of Industrial and Manufacturing Engineering

CAD/CAM Systems Laboratory

CAD Systems (2D, 3D, Animation)

CAD/CAM Systems

MoldFlow, 3D Studio max, AutoCAD, Autodesk Inventor

Tecnomatix - manufacturing development and simulation package,

Statistical process control and AI software

Picza LPX-250 3D Laser scanner

HP Plotter (up to A1 printing)

Concurrent Engineering Research Unit (CERU)

Concurrent Engineering Research Facilities

Thermoplastic Design Guidelines

Robotics and Industrial Automation Laboratory (RIAL)

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

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

Two Cognex/DVT smart image sensors (machine vision)

Six Mitsubishi FX1N-24 PLCs

Two flat belt conveyors (one with variable speed)

Machine vision lighting (ring light, strobe)

Other sundry equipment, oscilloscope, components and tools

Metrology Laboratory

Metrology Equipment Including CMM and Surface Roughness Measurement

Calibration of Metrology Equipment in Roundness, Linear and Angular Measurements

CNC Laboratory

CNC Vertical Milling Machine 2 ½ axis

CNC Vertical Machining Centre 3 axis

Advanced Manufacturing Laboratory

CNC Electric Discharge Machining (EDM) with Micro EDM capabilities

Rapid prototyping equipment Plastic – Dimension 1200es

Rapid prototyping equipment Titanium - ARCAM EBM S12 (Electron Beam Machining)

Thermoforming machine

Injection moulding machine (Boy 22E) with a clamping force of 200kN equipped with a second vertical injection unit

University (Engineering) Workshop

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

Department of Mechanical Engineering

Thermodynamics Laboratory

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

Structural Mechanics Laboratory

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

CAE Lab - Computer Aided Engineering Laboratory

Computer facilities to run the following engineering software:

- Ansys Mechanical and CFD
- MATLAB/ Simulink
- CAD – Computer Aided Design
- SOLIDWORKS
- WindPRO (EMD)
- WAVE/ VALDYN (Ricardo)
- Mechanical Analysis Design Package (Mentor Graphics)
- Bentley Academic SELECT
- Naval Architecture & Offshore Engineering Software
- MAxsurf Enterprise
- Multiframe Advanced
- Sac Marine Enterprise
- SACS Offshore Structure Enterprise
- MOSES Advanced

3D CAD and design Modelling

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

Fluids Laboratory

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

Department of Metallurgy and Materials Engineering

Process Equipment

- Plasma Assisted Physical Vapour Deposition (PA-PVD)
- Ion Beam-Assisted Deposition
- Gas Nitriding Furnace
- Vacuum Furnace with 5 bar overpressure
- Laser Added Manufacture Centre
- Air Furnace
- Low temperature foundry furnace
- Martempering/ Austempering salt bath
- 3-axis CNC machining station

Mechanical Testing Equipment

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

Calibration Equipment

- Load cell calibration system
- Temperature calibration system

Sample Preparation Equipment

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

Characterisation Equipment

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

Scanning Electron Microscope (SEM) with:

In-lens backscattering detector

In-lens secondary electron detector

External secondary electron detector

Solid state angular selective backscatter detector

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

Energy dispersive spectroscope (EDS)

Wavelength dispersive spectroscope (WDS)

Electron Backscatter Diffraction (EBSD)

Ultra high vacuum Integrated Characterisation Facility including:

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

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

Quadrupole mass spectrometer

Low energy electron diffraction (LEED)

Secondary electron detector

Surface analysis by surface probe microscopy through:

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

X-ray diffraction analysis with:

θ/ 2θ Goniometer

Parallel beam/ Bragg Brentano optics

Variable temperature (cryo to 450 °C) reaction chamber

High temperature reaction chamber

Thin film attachment

Capillary attachment

4 axis + tilting attachment

SDD/ scintillating detectors

X-ray powder diffraction with:

θ/ 2θ Goniometer

Cu/ Mo primary X-ray source

Bragg Brentano optics

Variable high temperature reaction chamber

Nano Indentation equipment with:

Wet cell attachment

Resistive high temperature reaction chamber

Peltier cooled low temperature attachment

Dynamic testing attachment

Piezo nanopositioner

Department of Systems and Control Engineering

Biomedical Engineering Laboratory

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

Control Systems Engineering Laboratory

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

DEAN'S AWARD

In December 2014, Ms Anthea Agius Anastasi and Mr Kenneth Hili were awarded the Dean's Award for best students graduating in the Mechanical and Electrical and Electronic Engineering Degrees respectively, offered by the Faculty of Engineering and sponsored by Farsons Foundation. Ms Agius Anastasi and Mr Hili consistently proved to be hard-working students of high capability in the engineering discipline, and achieved a 1st class honours degree in their respective streams, with the highest average score in this degree in their year of graduation. Dean Dr Ing. John C. Betts together with Ms Antoinette Caruana presented these awards.

From left: Mr Kenneth Hili, Dr Ing. John C. Betts, Ms Antoinette Caruana, Ms Anthea Agius Anastasi

ONGOING EXTERNALLY FUNDED RESEARCH PROJECTS

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

For mass production of micro parts, micro injection moulding has become a key technology since it combines the capabilities of a low cost production process with the requirements of a micro part. However whilst studies have been conducted on the fabrication of single-material micro injection moulding, knowledge on the design and manufacture of multi-material parts replicated through micro injection moulding is lacking. To address this research gap, the aim of the EX-MMIM project is to generate and transfer new knowledge on micro part design, mould design and manufacture and the multi-material moulding process itself. A case study part, consisting of an endoscopic micro optical component, made up of a transparent optical component moulded as the first shot and an opaque housing moulded as the second shot, was designed and fabricated (see Figure 1). This also required the design and manufacture of the mould tool. A series of simulations and experiments ensured that (i) major defects such as weld lines and air entrapment wound not be occur on the lens area and (ii) no deformation would occur around the lens area when the second material is injected over the optical component. An e-learning course on injection moulding was also developed. Interested stakeholders can also participate and exchange their ideas in an on-line forum. Further information on the project including the e-learning course and forum are available at www.exmmim.com

Funding Body: **Project financed by the Malta Council for Science & Technology through the National Research & Innovation Programme 2012**

Project Fund: **€ 141,871**

UoM Workshare Value: **€ 107,061**

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

Co-Investigators: **Dr Arif Rochman, Ing. Pierre Vella, Mr Christian Camilleri**

Consortium/Partners: **Department of Industrial & Manufacturing Engineering, University of Malta (Project Coordinator), Tek-Moulds Precision Engineering Ltd, Techniplast Ltd and Playmobil Malta Ltd.**

Project Start date: **November 2012**

Project Duration: **3 years**

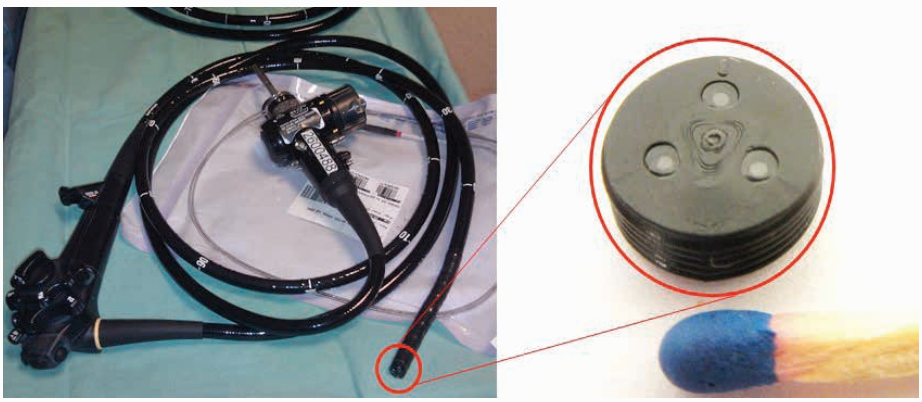


Figure 1: Distal end of an endoscope designed and fabricated in the EX-MMIM project

Design & Manufacture of a Novel Rib Bridge (RiBridge)

Chest wall reconstruction surgery is a common procedure, in which a portion of the patient's chest wall is removed. This operation is mostly used to treat cancer invading the lungs or ribs, and trauma. Amputation of a part of the rib is the only solution for removing the cancerous lump and must be followed by bony chest wall reconstruction to maintain the patient's normal physiology. The research team has invented a novel 'rib-bridge' in order to safely and effectively reconstruct chest wall defects. This rib bridge can easily be made to match the contour of the patient's chest in order to avoid any visible deformities after the operation. A detailed structural analysis was carried out via simulation and also experiments (including tensile and bending tests) on sample Titanium rib-bridges. The final design has been evaluated with surgeons who gave positive feedback. The design of the rib-bridge is protected through a registered community design in Europe (No. 001420863-0001) and a registered design patent in USA (No. 29519235.). So far all the tasks were done at a non-clinical prototyping stage. It is planned to pursue the novel rib-bridge further on to the pre-clinical, and eventually clinical stage. Further details on this research project are available at: www.ribridge.com

Funding Body: **TAKEOFF Seed Fund Award Project TOSFA-14-20 financed by the Ministry for the Economy, Investment and Small Business**

Project Fund: **€ 16,000**

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

Co-Investigators: **Dr Aaron Casha, Ing. Quinton Calleja**

Project Start Date: **July 2014**

Project Duration: **9 months**

Artificial rib-bridge takes the contour of the native rib

Towards Long Lasting Hip Joint Replacements

This project aims at understanding the degradation phenomena experienced on the bearing surface of metallic hip-joint prosthesis and aims to mitigate such damage through surface engineering. New surface treatments are being developed and their tribo-corrosion performance and biocompatibility are investigated in simulated body environments.

Funding Body: **Think10k (Faculty of Engineering, UoM); ESF (Malta), Bodycote Hardiff GmbH (Germany), UoM internal research grant and MGSS**

Project Fund: **€ 115,000**

Services In Kind: **Boride Services Ltd. (UK), Technion- Institute of Technology (Israel), Bodycote Hardiff GmbH (Germany) and Wallwork Heat Treatment Ltd. (UK)**

UoM Workshare Value: **€ 35,000**

Principal Investigators: **Dr Ing. Joseph Buhagiar, Dr Ing. Bertram Mallia, Dr Ing. Glenn Cassar and Dr Pierre Schembri Wismayer MD**

Co-Investigators: **Mr Malcolm Caligari Conti (MGSS funded Ph.D. student); Ms Sarah Farrugia, Ms Michelle Cortis, Mr Shaun Maniscalco, Ms Antonella Scerri, Ms Thelma Bonello and Mr Nicholas Brincat (MASTER it! funded MSc by Research Students); Ms Josianne Cassar (STEPS funded MSc by Research student); Ms Kristina Agius (Malta Hip Project); Mr Aaron Farrugia, Mr Andre Spiteri, Prof. Emmanuel Sinagra; and Ing. Pierre Vella.**

Consortium/Partners: **The Department of Metallurgy and Materials Engineering (UoM), in collaboration with the Department of Anatomy in the Faculty of Medicine and Surgery (UoM); the Department of Chemistry in the Faculty of Science (UoM); the Department of Industrial and Manufacturing Engineering (UOM), Bodycote Hardiff GmbH (Germany), Boride Services Ltd. (UK), Wallwork Heat Treatment Ltd. (UK) and Technion- Institute of Technology (Israel)**

Project Start Date: **October 2010**

Project Duration: **6 Years**

Research Group Working on the Project (Courtesy of Elisa von Brockdorff)

BioDiValue - Biodiversity and Sustainable Development in the Strait of Sicily

Sea water pollution monitoring can be carried out using various methods. A method that is quite convenient to use when a large area of sea needs to be scanned is to use a towfish equipped with the necessary sensors that can detect various pollutants. The same towfish can also be used as a platform for cameras to capture images or video of jellyfish and plankton populations. The towfish is towed behind a surface ship and hydroplanes and elevators are used to control the depth of dive. In this way pollution level readings, images and video can be taken and recorded at various sea level depths. The Department of Mechanical Engineering designed such a towfish within the BIODIVALUE project. The towfish has been fabricated by the lead partner ARPA and will be tested towards the end of summer 2015.

Funding Body: **ERDF Italia-Malta 2007-2013**

Project Fund: **€ 220,000,000**

UoM Workshare Value: **€ 218,000**

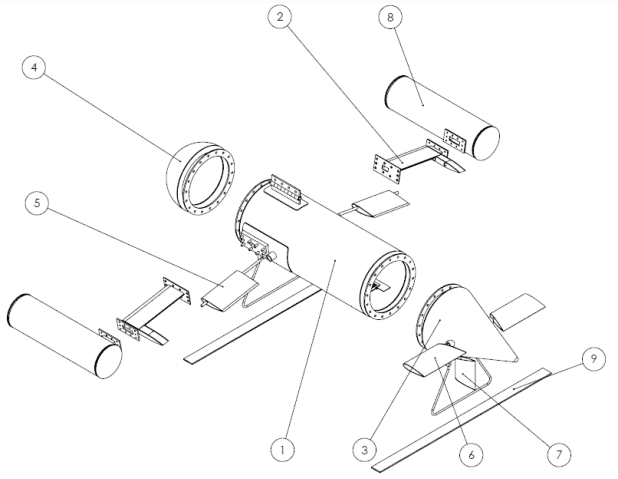
Principal Investigator: **Prof. Martin Muscat**

Co-Investigators: **Mr Mark Formosa, Mr Germen Alejandro Salgado MartÌn**

Consortium/Partners: **ARPA (Agenzia Regionale per la protezione del'Ambiente), Lead partner, Siracusa, Consorzio Plemmirio Area Marina Protetta, Siracusa, Department of Mechanical Engineering, Faculty of Engineering, University of Malta, International Ocean Institute - Malta Operational Centre, University of Malta, ISPRA (Istituto Superiore Protezione Ricerca Ambientale), Roma, Area Marina Protetta ñ Isole Pelagie Sindaco del Comune di Lampedusa e Linosa, Lampedusa, Gal XLOKK, Malta, Universita` degli Studi di Catania, Sicilia, Green Life Soc. Coop. a r.l., Agrigento**

Project Start Date: **July 2012**

Project Duration: **2.5 Years**



The towfish designed at the Department of Mechanical Engineering as a tool to monitor sea water pollution and plankton activity over a large area

Italia Malta 2007 - 2013
Italia-Malta Programme – Cohesion Policy 2007-2013
A sea of opportunities for the future
Project part-financed by the European Union
European Regional Development Fund (ERDF)
Co-financing rate: 85% EU Funds; 15% National Funds
Investing in your future

HILDA – High Integrity Low Distortion Assembly

The research goals and objectives of this project is to develop the scientific foundation for a reliable friction stir welding process applicable to steel and thus enhance and advance the scientific and practical knowledge on an innovative high performance welding process and its potential application in the maritime industries.

HILDA will improve the metallurgical knowledge to predict phase changes and stress regimes in the welded condition. The project will develop numerical methods of the process, providing an insight on the most important welding parameters leading to enhanced properties of the joints and the structures. The models will be validated with realistic test data. The outcome of the project will include reliable process parameters, an expert system for the prediction of related distortions, a road map towards approval of the process and a cost benefit estimation to support commercial application at a later stage.

Funding Body: **European Commission in Call FP7-SST-2012-RTD-1**

Project Size: **€ 2,200,000**

UoM Workshare Value: **€ 254,000**

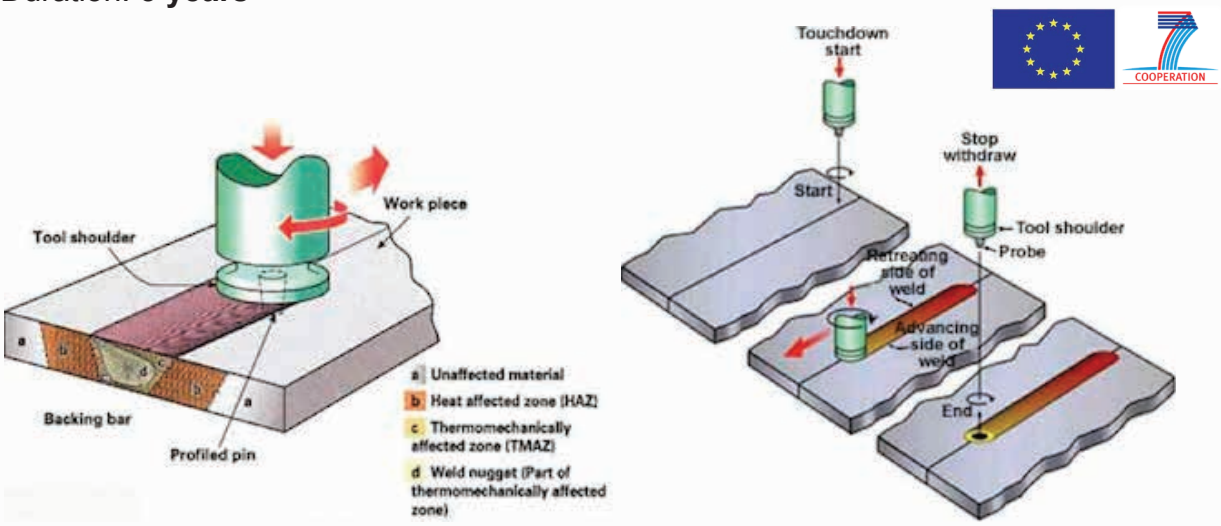
Principal Investigator: **Prof. Duncan Camilleri**

Co-Investigators: **Dr Pierluigi Mollicone**

Consortium/Partners: **Department of Mechanical Engineering, University of Strathclyde, U.K.(Project Coordinator); Department of Mechanical Engineering, University of Malta, Malta; Centre de Recherche en Aeronautique ASBL (CENAERO), Belgium; The Welding Institute (TWI) Ltd., U.K.; Lloyd's Register EMEA, U.K.; Center of Maritime Technologies e.V. (CMT), Germany; Naval Architecture Progress, Greece; GeonX sprl, Belgium**

Project Start Date: **September 2012**

Project Duration: **3 years**



Generic principle of friction stir welding (Courtesy of TWI Ltd)

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

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

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

Project Fund: **€ 165,252**

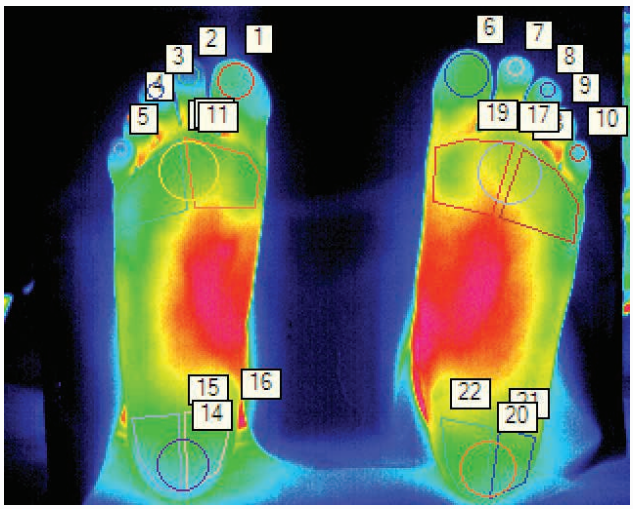
UoM Workshare Value: **€ 121,602**

Principal Investigator: **Dr Owen Falzon**

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

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

Project Duration: **32 months**



Foot temperature monitoring using thermography

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

The prospect of communicating via the eye movements alone as an alternative communication channel for persons with limited motor abilities is gaining increasing worldwide interest. This project concerns the field of eye-gaze tracking and proposes to investigate suitable methods to address the open issues associated with this field, while at the same time seeking low-cost solutions that may be afforded by the consumer.

Funding Body: **Malta Council for Science and Technology through the National Research and Innovation Programme 2012**

Project Fund: **€ 167,683**

UoM Workshare Value: **€ 124,883**

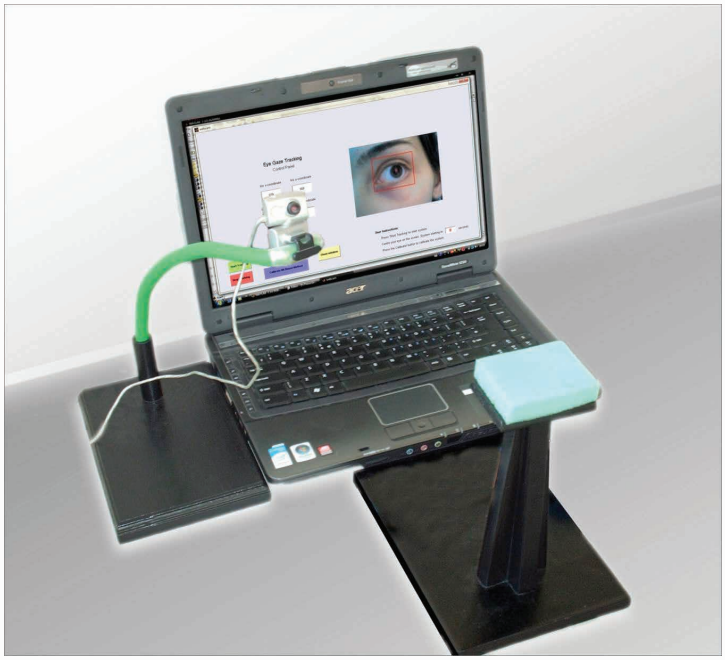
Principal Investigator: **Prof. Ing. Kenneth P. Camilleri**

Co-Investigators: **Ing. Stefania Cristina, Ms Marica Gatt**

Consortium/Partners: **Department of Systems and Control Engineering at the University of Malta, in collaboration with the School Resources Department at the Directorate for Educational Services, Ministry of Education and Employment**

Project Start Date: **1st November 2012**

Project Duration: **2 Years (extended till the end of September 2015)**



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

WALNUT Brain-controlled Music Player

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

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

Project Fund: **€ 7,500**

Principal Investigator: **Dr Owen Falzon**

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

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

Project Start Date: **June 2014**

Project Duration: **1 year**

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

ONGOING MASTERS AND Ph.D. RESEARCH PROJECTS

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

M.Sc. IPD

Alan Attard Kingswell	Integrated Product Development Framework for Global Information Management in Cosmetic Packaging Industry.
Alan Coppini	Converting from a Fixed to a Reconfigurable Manufacturing Automation System.
Joseph Axiak	An IPD approach to sustainability improvement using simulation and experimental analysis: A medical device manufacturing processes case study.
Keith Vella	Understanding & Modelling Emotional Dynamics of IPD Stakeholders.
Luke Camenzuli	An IPD approach for Developing a Novel Product for Children with Language impairments.

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

M.Sc. by Research

Antonella Scerri	Study of Corrosion Response of PIRAC-treated Titanium Alloy in a Body Simulated Fluid
Chris Abela	Diamond polymer matrix composite for thermal management and bio-medical applications
James Camilleri	Study of Fluorine-Containing Surface Active Agents Epilame Deposited on Ti-6Al-4V-Alloy
Michelle Cortis	Biocompatibility and Surface Characterization of PIRAC – Treated Titanium Material
Nicholas Brincat	Tribological Enhancement of biomedical stainless steel using duplex surface treatments – Master by Research
Sarah Farrugia	Surface coatings for improved tribocoosion response of biomedical stainless steel – Masters by Research
Shaun Maniscalco	S-Phase Surface Engineering for Longer Lasting Metal-on-Metal Implants: A Tribocorrosion Evaluation
Thelma Bonello	Investigation of duplex PIRAC-PVD coated Ti-6Al-4V

Ph.D.

Anthea Agius Anastasi	Molecular Simulation and Atomic Probe Studies of Graphene
Malcolm Caligari Conti	In-vitro Studies of Surface Hardened Cobalt-Chromium-Molybdenum Alloys

Projects supervised by members of the Department of Electronic Systems Engineering

M.Sc. by Research

Karl Buhagiar	Determination of the Current Centre Line of the ITER TF Coils
Kenneth Hili	Design of an Indoor Pedestrian Tracker

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

M.Sc. by Research

Andrea Brincat	Design and Development of an Electonic Control Systems for Hybrid PV+CHP Residential Grid Connected Set-Ups with Battery Back Up
David Zammit	AC Motor Integrated Inverter Drive for Industrial Applications
Diane Cassar	Design and Implementation of an Auto-Pilot Drive System for Steering of the Solar Catamaran
James Attard	Design of an Isolated Bi-Directional Battery Charger for an Electric Vehicle
Joseph Azzopardi	Analysis of Malta Freeport Terminals Power System
Jurgen Bonavia	Energy Storage Systems for Self-Consumption of Energy from Grid-Connected Photovoltaic Sources
Noel Darmanin	Investigation of the Effects of Integrating Large Scale Photovoltaic Systems on the Maltese Power System

Samuel Bonanno	Analysis and Simulation of Power Quality, Distributed Generation and Interconnection of an Island's Power System to an Infinite Busbar System
Shawn Azzopardi	Emulator Test Rig for the Control and Grid Interfacing of Wave Energy Converters
Terence Moses Bartolo	Sensorless permanent magnet synchronous motor drive for scroll compressors in heat pump applications

M.Phil.

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

Ph.D.

Alexander Micallef	Control and Management of Distributed Generation and Energy Storage Systems in Low Voltage Microgrids

Projects supervised by members of the Department of Mechanical Engineering

M.Sc. by Research

Annemarie Zammit	Engineering Stress Analysis using PhotoStress and Computational Techniques
Claire Ellul	Investigating the Reliability of Wind Anemometers on Floating Tension-Leg Platforms
Colin Bonnici	Engineering Analysis of the S.S. Ohio
Damian Agius	The effect of pre-stressing structural members of an aircraft wing
Gary Galea	Modelling Fluid-Structure Interaction on Vertical Axis Wind Turbine Blades
Jean Paul Azzopardi	Analysis of Engine Downsizing: An Experimental Investigation of In-cylinder Pressure and Knock
Kurt Cuschieri	The Influence of Floating Structure Dynamics on the Energy Yield Characteristics of Offshore Floating Turbines

Marisa Micallef	Load and Motion Analysis of a Floating Wind Monitoring Mast in Deep Sea
Mark Formosa	Theoretical and Computational Analysis applied to a towfish design
Matthew Galea	Exploiting Offshore Wind Energy with Thermocline Thermal Energy Extraction for Large Scale Cooling Applications
Matthew Spiteri	Design and Build of a Domestic Scale Micro-CHP for Local Application
Miryea Borg	Numerical Modelling and Experimental Testing of Novel Materials for LHC Collimators'
Nicholas Farrugia	Loading Conditions on Human Sternum
Redeemer Axisa	Structural Evaluation and Testing of a multiple bladed wind turbine prototype
Rudie Vella	Quasi-Static Impact Mechanics of Flat Composite Sandwich Structures

Ph.D.

Brian Ellul	Assessing the structural performance of fibre-reinforced composites through numerical modelling techniques
Daniel Buhagiar	Design and Analysis of a Hydraulic Power Transmission System for an Offshore Wind and Thermocline Energy Production (OWTEP) System
Marija Cauchi	Thermo-Mechanical Studies of Large Hadron Collider Collimators in Accident Scenarios
Moutaz Aljammi	Wind Turbine Aerodynamics in Combined Yaw and Shear
Paul Refalo	Analysis of Solar Thermal Distillation
Robert N. Farrugia	Evaluation of Wind Flow Phenomena in Maltese Complex Terrain
Salem M. Osta Omar	A Solar Powered Absorption Air Conditioning System

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

M.Sc. by Research

Jean Luc Farrugia	Swarm Robotics for Object Transportation
Joseph Agius	Data Monitoring and Control of Solar Cooling Systems for Industrial Wine Production
Rachael Darmanin	Autonomous Exploration and Mapping with Mobile Robots

M.Phil./Ph.D.

Alexandra Bonnici	Vectorisation and interpretation of Drawings with Artistic Cues
Clifford De Raffaele	Representation and Knowledge Extraction from Multiview Image and Video
Luana Chetcuti Zammit	Autonomic Control for Road Network Management using Geocomputational Tools
Mark Borg	Modelling Spatial Context in Maltese Sign Language Recognition from Video Sequences
Stefania Cristina	Eye-Gaze Tracking for Human-Computer Interaction, Behaviour Analysis and Communication

FINAL YEAR
ENGINEERING PROJECTS
ELECTRICAL STREAM

Development of a Rowing Performance Monitoring System

Student: Herbert Attard / Supervisor: Prof. Carmel Pule` / Co-Supervisors: Dr Owen Casha, Prof. Joseph N. Grima

Introduction

Rowing races require long term practice so that the rowers drive the boat at the required optimal speed during their performance. In order to obtain good results during a competitive race, it is well understood that training needs to be monitored. In various parts around the world, where rowing is practiced in open water, as in the case of Malta, coaching and monitoring of athletes may be rather challenging, as it is difficult for the coaches to observe the performance of each rower during the rowing session, due to the long distance between them and the rowers.

Project Objectives

The objective of this project was to develop a rowing performance monitoring system that records the orientation of the oar together with the mechanical movements to which it is subjected during a rowing session. In addition, the system also monitors the total forces acting on the oar shaft from which the power generated by the rower can be determined.

Project Methodologies

Since there is no direct way to measure the power transmitted by the rower, this work proposes to estimate it from the deformation of the oar shaft and the net force applied to the oar during each stroke. Such forces are a function of the applied effort transmitted by the rower at the handle side of the oar. Data from two triple axis gyroscopes and accelerometers was fused using the on-chip digital motion processor (DMP) available on the sensors themselves. From this fused data, the two main parameters (oar orientation angles and acceleration) were obtained.

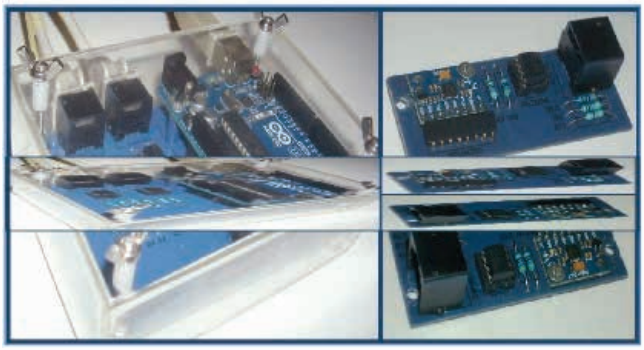


Figure 1: Hardware Implementation

In addition to this, other important parameters in rowing biomechanics were determined, such as:

- The actual and expected Cartesian coordinates of the blade, from which the deformation was calculated;
- The net force applied by the rower;
- The velocity of the oar;
- The power transmitted by the rower.

Results and Achievements

All the essential data relevant to the rowing performance is logged and displayed on the GUI viewport shown in Figure 2. Such data includes:

1. Oar orientation angles;
2. Expected and actual Cartesian coordinates of the blade;
3. Representation of the deforming oar, which bends and unbends according to the material properties;
4. Expected and actual blade loci;
5. Oar acceleration;
6. Oar velocity;
7. Velocity, Force and Power curves;
8. Plot legend with the value of the corresponding quantity;
9. 3D virtual model of the oar which emulates the rotation and movement of the actual physical oar in real time.

All the above parameters are estimated with an error of less than $\pm 1°$ in the orientation angles and $\pm\ 0.1\mathrm{m\ s^{-2}}$ in the acceleration measurement.

Figure 2: Graphical User Interface

PC Controlled Stress Path Triaxial Cell System

Student: Ryan Bugeja / Supervisor: Ing. Evan Dimech / Co-Supervisor: Dr Ing. Andrew Sammut, Perit Adrian Mifsud

Introduction

Triaxial Testing is commonly used to measure the mechanical properties of rock and soil samples by applying all round pressure to the specimen and loading it axially until failure occurs. This test consents researchers to find the shear strength and stiffness of the specimen [1]

Project Objectives

The aim of this dissertation was to upgrade the triaxial equipment at the Faculty for the Built Environment, which was operated manually and had minimal research applications. The main objective was thus, to design a system that could monitor and control all the different test parameters such as: pressures, displacement, volume change and load.

Project Methodologies

The proposed system consists of a master-slave architecture between the PC and a designed Data Acquisition and Control Board. This board is capable of acquiring data from different sensors, sending warning messages and also performing the necessary control and actuations of test parameters.

Furthermore, a designed user interface enables control of all the operations of the test such as: closing solenoid electro-valves, switching an air compressor and controlling a modified Load Frame. This interface is also responsible for saving the acquired data and performing diagnostic tests to detect faults such as power-cuts.

Figure 1: Data Acquisition and Control Board

Results and Achievements

The work in this dissertation involved the modification of a Load Frame, achieving a minimum loading rate of 0.000085 mm/min from its previous 0.5 mm/min capability. This was achieved by introducing a system of cascaded gearboxes while tweaking the machine's motor drive. Additionally, the linear responses of the main parts of the system were verified and the characteristic equations were obtained.

The designed Data Acquisition and Control board is capable of acquiring data from 18 sensors. For this project, pressure and temperature sensors, LVDTs and a Load Cell were utilised. Additionally, this board includes 8 relays, provides control of servo motor drives and has two DAC outputs to control the Load Frame loading rates and to provide control for electro-pneumatic regulators. This board is also capable of sending diagnostic SMSs. Furthermore, an SD Card and a Real Time Clock were also included so as to offer standalone capability. The designed system was backed up by a UPS and data was backed up online. If errors are detected by the user interface, warning messages are displayed or a warning SMS is automatically sent to the administration.

Hence, the design of a backed-up robust system was presented in this dissertation, to safeguard results of tests that could be running for weeks and even months.

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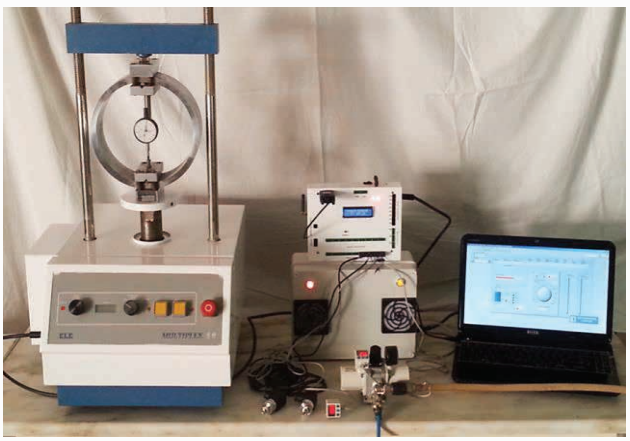

Figure 2: The main parts of this system connected.

The Design and Construction of 4-Axis CNC Milling Machine Which Operates Directly from a CAD Model

Student: Keith Callus / Supervisor: Prof. Carmel Pule'

Introduction

Computer numerical control (CNC) machining technology has been a prominent contributor to the advancement of manufacturing systems for quite some time due to its numerous benefits and applications. From its onset, to the present day, technological research has always been done and is still ongoing, to further improve the performance of CNC machines.

Project Objectives

The aims and objectives of this project can be summarised as:

- The design and construction of a 4-axis CNC milling machine, capable of manoeuvring through a 3D workspace, in order to move the tool through the necessary toolpath to machine the respective 3D part.
- The understanding and implementation of a computer aided manufacturing (CAM) software, integrated with a computer aided design (CAD) software, to acquire the G-code necessary to machine a respective part.
- The understanding and implementation of a motion controller software to convert G-code to the respective toolpath and pulse trains required to machine a part.
- The implementation of the 4-axis CNC milling machine, accompanied by accuracy and reliability performance testing of the machine

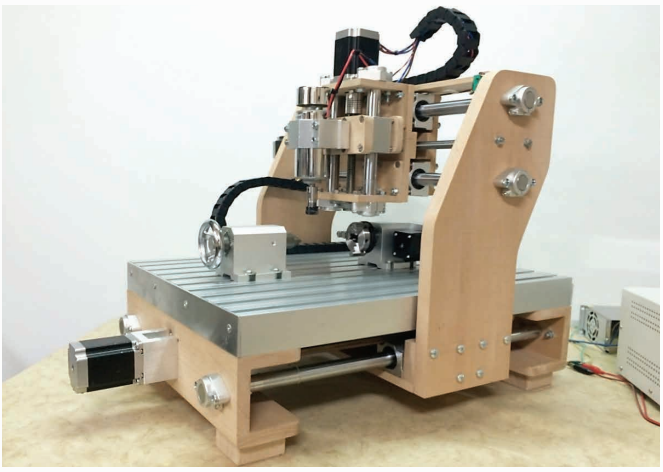

Figure 1: Final Designed 4-Axis CNC Milling Machine

Project Methodologies

Initially, extensive research and study on different aspects of CNC machining was performed, including the study of existing machine mechanical and structural aspects, and several machining technologies. The mechanical structure of the machine was then designed, designing each part to best suit the scope of this project. This was followed by the manual construction of the designed parts and their assembly, forming the machine depicted in Figure 1. The electronic system, which is responsible for the accurate and precise positioning of the machine's tool, was then designed and implemented. The next step was the understanding and implementation of a CAM and motion control software, and integrating it with the machine's motion controller. The machine was then calibrated and tested by means of custom designed test programs. Finally, the machine was programmed to machine a wide range of different objects, implementing several machining technologies, as used in real-life applications. An example is the machining of the 3D human face depicted in Figure 2, implementing the 3D machining technology.

Results and Achievements

All of the objectives were satisfied, and the results obtained from the machine implementation and testing stages were all satisfactory, exceeding initial expectations. This dissertation serves as a study, outlining the specifications that can be obtained from a customized design and construction of a CNC milling machine, considering a €2000 budget limitation.

Figure 2: Part CAD Model (left) Machined Result (right)

A Platform Design for Distributed Computational Intelligence

Student: Reuben Ferrante / Supervisor: Dr Ing. Marc Anthony Azzopardi

Introduction

Recent developments in artificial intelligence (AI) and swarm robotics have shown that collaboration amongst robots can have many benefits and practical applications. This field is still in its infancy, as most robots used in different industries are either static, or work independently. However, swarm robotics involves the use of small and mobile robots, capable of sensing the environment, communicate wirelessly together, and perform tasks as a team in an efficient and constructive manner. This leads to decentralized information, collective behaviour, and an overall robust system, where robots optimize their task as a collective, rather than stand alone units. In the lab, small robots are used to provide a hardware foundation, as well as test the AI logic used in real-world scenarios, such as unsupervised military engagement.

Project Objectives

The primary objectives are:

- Identify limitations, and basic hardware needed for the robot to be able to contribute positively to the swarm in different applications.
- Plan, and design the form factor and physical constraints of the robotic platform.
- Design the electrical circuits and printed circuit boards (PCBs).
- Design the mechanical housing using computer aided design software.
- Design the software infrastructure for the robotic platform in the context of a swarm, and implement behavioural logic.
- Implement a group of robots that communicate and collaborate using behavioural logic.

Project Methodologies

The robotic platform needed to be as cheap as possible, without restricting any functionality. To this end, the electrical and mechanical designs were built concurrently. Miniaturisation lead to part sourcing of the battery and motors first, since these are the largest components of the robot. After choosing the mechanical and electrical hardware required, the form factor of the robot was laid out with the smallest footprint possible. The electrical circuit and three PCBs were designed, manufactured, hand-soldered, and tested. Following multiple iterations and improvements, the software infrastructure, communications, sensor fusion, and motor control, were characterized and implemented. The mechanical housing was then built around the robot and PCBs using Solidworks. An accurate, exploded view of the robot's model (with true relative dimensions) is shown in Figure 1. Figure 2 shows the final model of the robotic platform. Two robots were built to demonstrate swarm robotics by implementing open loop obstacle detection and path following on the microcontroller located on the main (top) PCB. This marked the final stage of the project.

Results and Achievements

The robot was verified to work on all fronts, including autonomous motor control, collaborative communication, and sensor fusion. Robots were also successfully implemented in a small network executing behavioural logic, satisfying all objectives. This robot will be improved and used in future studies.

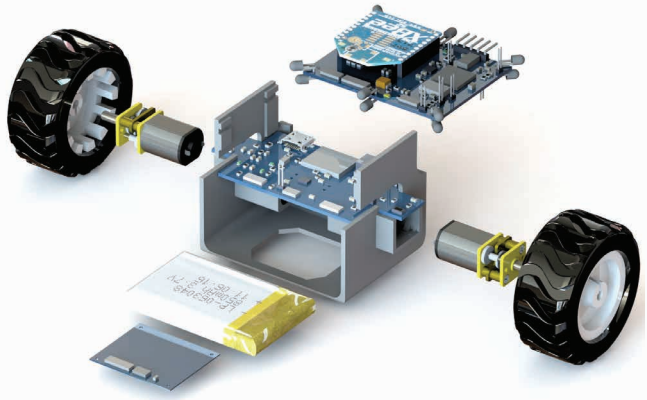

Figure 1: Exploded View of the Robotic Platform

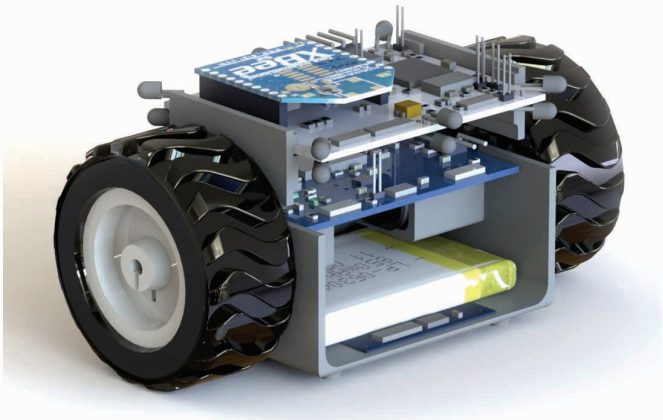

Figure 2: Final Model of the Robotic Platform

Autonomous Parking Using an FPGA

Student: Adam Sant / Supervisor: Dr Ing. Kenneth Chircop

Introduction

Autonomous Vehicles (AVs) come equipped with specialised software and dedicated hardware, which allows them to facilitate, or completely perform, a driver's job. Autonomous vehicles employ a large number of various sensors so as to acquire the utmost information about the surrounding environment to enable algorithm execution. In this project, an AV testing platform is developed and parking algorithms are implemented.

Project Objectives

The main objective of the project is to construct a car-like mobile robot (CLMR) and equip it with the necessary hardware to enable autonomous behaviour. A fully embedded solution was desired; thus, this was achieved through the use of a Field Programmable Gate Array. Furthermore, car parking algorithms were to be implemented.

Project Methodologies

The system was built with the idea of maintainability and adaptability; a hierarchical approach was adopted to achieve this. System hardware was chosen to be as flexible as possible to enable different algorithms to be implemented; furthermore, the designed system allows for substantial changes in hardware without requiring a holistic system redesign.

The problem was divided into a number of modules. The designed modules are divided into three categories: input interfaces, data processing and output interfaces. The input interfaces sample and decode all input data from sensors. Decoded data is then passed to the data processing modules. Mathematical calculations and artificial intelligence algorithms are applied so as to formulate a trajectory for the CLMR to realise autonomous parking behaviour. Once this trajectory is computed, the output module generates the required signals, which are then fed to the actuation hardware of the CLMR. All of the designed modules are designed independently from one another; thus, system changes can be applied by simply altering the effected module.

Results and Achievements

A CLMR was successfully set up and equipped with the necessary hardware to enable implementation and execution of AV algorithms. A framework was established to isolate and run in parallel a variety of modules, which are required for such an application. These modules include a motion controller, a camera interface with image processing, sensor data acquisition and decoding, navigation controller, parking controller, an external RAM interface and data logging.

Using these modules, parallel parking and right angle parking algorithms were successfully implemented with various CLMR navigation algorithms.

This project highlights the strengths and great potential of using FPGAs for controlling AVs. Their nature allows for high performance and system reliability using a single controller. Furthermore, project costs could be cut down by reducing expensive interface hardware due to their versatility and parallel execution capabilities. Development for the same functionality would have been considerably shorter had sequential controllers been used; however, the system would not have been as flexible, adaptable, fast and reliable.

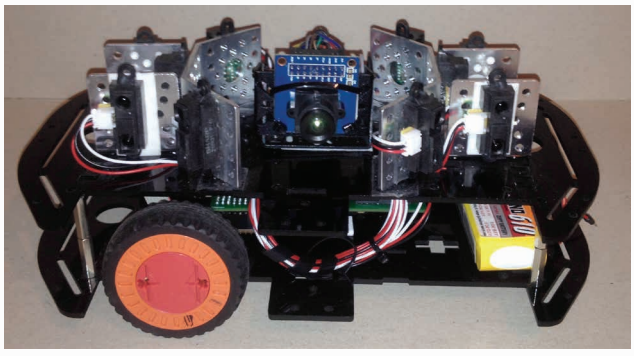

Figure 1: Car-like mobile robot hardware

An Optical Data Link for Line of Sight Communications

Student: Emanuel Scicluna / Supervisor: Dr Ing. Marc Anthony Azzopardi

Introduction

Reliable long distance communications is crucial for Unmanned Aerial Vehicles (UAVs), especially in military applications. Free Space Optics (FSO), using focused, line-of-sight laser communications, can provide the required reliable bi-directional communications channel at high data rates.

Project Objectives

The aim of this project is to design and develop a hardware platform which enables a high throughput through an Ethernet based connection. The designed hardware was required to maintain a high Signal to Noise Ratio (SNR) in order to ensure data reliability.

Utilising an optical Link with an UAV does not only set the requirement for increasing the maximum possible range of the FSO, as the system is required to automatically adjust to continuous changes in received optical power.

Special attention has been given to maintain a low power consumption, as UAV's can be battery powered with limited energy storage capabilities.

Project Methodologies

In order to achieve a reliable design which is comparable to commercially available systems, a review of existing literature related to FSO has been carried out. Significant attention was given to various laser light attenuation models, as this could not be tested within the laboratory facilities.

The first step involved exploring different circuit topologies, and eventually simulating and prototyping different solutions, until the required level of performance was achieved. The next step involved combining all the separate building blocks onto a single Printed Circuit Board, as shown in figure 1.

Finally, a dedicated test setup had to be designed in order to generate a set of results to validate the designed system. The designed test equipment comprised of a Bit Error Rate (BER) testing application and a separate testing board, that enables injecting of signals through an Unshielded Twisted Pair (UTP) cable and observing the return signal.

Results and Achievements

The designed system has been successfully tested at a data rate of 10Mbit/s, with negligible bit error rate.
Comparison with other commercially available systems show how the designed system achieved superior optical range performance, even though the system has not as yet been fine-tuned for optimal operational range. This level of performance was achieved at a power consumption of 3.6W when the system was operated from a 12V supply.

Modern information technology demands an ever increasing network data rate, which has exceeded 10Gbit/s over the last few years. However, a reliable 10Mbit/s connection would still be practical in applications involving telemetry, single-user internet connections and where a single video stream is required to be transmitted over a reliable, secure communication channel, or in situations where data rate is not a priority.

The designed system also turned out to be an extremely cost effective, reliable solution that can transmit data at 10Mbit/s. With some additional engineering effort, further cost reductions and increases in link speed are readily possible.

Figure 1: The Final Prototype

Hardware Implementation of a Pedestrian Navigator

Student: Andrew Spiteri / Supervisor: Dr Ing. Andrew Sammut

Introduction

Pedestrian navigation focuses on providing accurate positional information of users travelling on foot. Since these users can be located virtually anywhere on land, including indoor and underground locations, pedestrian navigation systems cannot depend solely on GPS data [1]. As a result, inertial sensors are often incorporated in such systems to address the shortcomings of GPS receivers. However, inertial sensors suffer from noise and drift errors, often restricting the obtainable accuracy of the system.

Project Objectives

The primary scope of this project was to develop a MEMS-based inertial pedestrian navigation system which can provide accurate positional data even when used in GPS-degraded environments for extended periods of time.

Project Methodologies

Extensive research on existing literature was first carried out in order to identify the strengths and limitations of similar implementations.

An embedded navigation algorithm was proposed and implemented, building on the existing work carried out at the Department of Electronic Systems Engineering [2]. The necessary hardware for the system was then designed and incorporated onto the system's PCB (Figure 1).

Finally, a series of tests were conducted in order to quantify the performance of the implemented system in terms of accuracy and reliability.

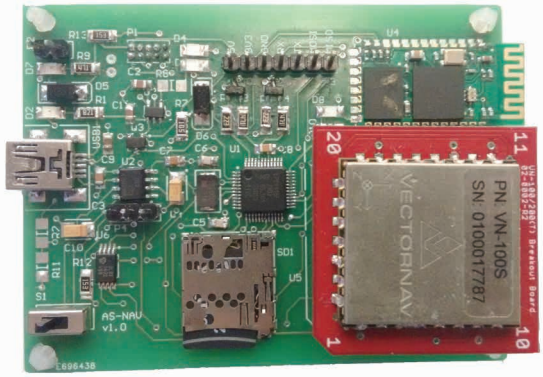

Figure 1: Circuit board of the implemented system

Results and Achievements

The system implemented in this project was developed to be small and light, consisting of a single PCB mounted in its own 3-D printed casing (Figure 2). Positional data was designed to be sent via Bluetooth to a remote device on the user's person through a wireless data link.

From the tests conducted, average percentage errors of the total distance and of the end point deviation were calculated to be 5.5% and 3.5% respectively. These results were obtained from a 200m route around a residential circular block with a normal walking style having a gait of 60cm and a pace of 0.6m/s.

The accuracy of the results obtained for the implemented system were deemed to be satisfactory, hence showing that such an implementation is effective in providing reasonably accurate positional information for relatively long distances regardless of GPS data availability. Further testing would of course be required to ensure reliable performance under different conditions.

References

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[2] Hili, 'Design of a Pedestrian Tracker in GPS Degraded Environment', 2014

Figure 2: 3-D printed PLA casing mounted on shoe

Comparing the Performance of Two Control Strategies for a Variable Speed Wind Turbine

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

Introduction

Energy generation through burning of fossil fuels is leading to global warming and fossil fuel depletion issues. These issues are leading to a huge transition from fossil fuel energy sources to renewable energy sources particular wind energy. This is fuelling research on variable speed wind turbine control systems to ameliorate energy yields such that the return of investment is improved. This was the main motivation for conducting an investigation on typical control systems used in fully rated converter wind turbines.

Project Objectives

The objectives of this work were to develop a detailed model of a 2MW variable speed wind turbine and implement and compare two control strategies used in fully rated converter variable speed wind

Project Methodologies

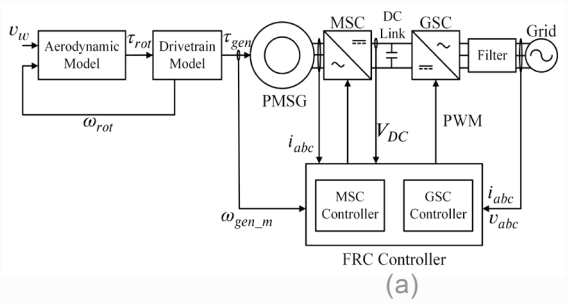
The structure of the work was as follows:

- Reviewing existing literature on fully rated converter variable speed wind turbines, with particular focus on the two control strategies.
- Developing a model (Figure 1 (a)) of a 2MW wind turbine using MATLAB® Simulink®. The model comprises of a rotor, drivetrain, permanent magnet synchronous generator (PMSG) and the fully rated converter (FRC).
- Design and investigation of appropriate filtering strategies to meet Total Harmonic Distortion (THD) requirements when connecting with the utility grid.
- Implementing the two control strategies on the designed model. In the first (traditional) strategy, the machine side converter (MSC) controlled the maximum power extraction while the grid side converter (GSC) con-trolled the DC link voltage. The second control strategy is effectively the reversal of the first and is termed the alternative control strategy.
- Implementing an inertia response controller (IRC) as an auxiliary controller, which comes into play when extra power is needed momentarily by the utility to support the grid during frequency events.
- Performing simulations to compare the two control strategies. This was done by subjecting the wind turbine to different wind profiles such as wind gust, turbulent wind and finally a grid support event. These wind profile were chosen due to the fact that they are easily encountered by real life variable speed wind turbines. Frequency event response of the WT is shown in Figure 1 (b).

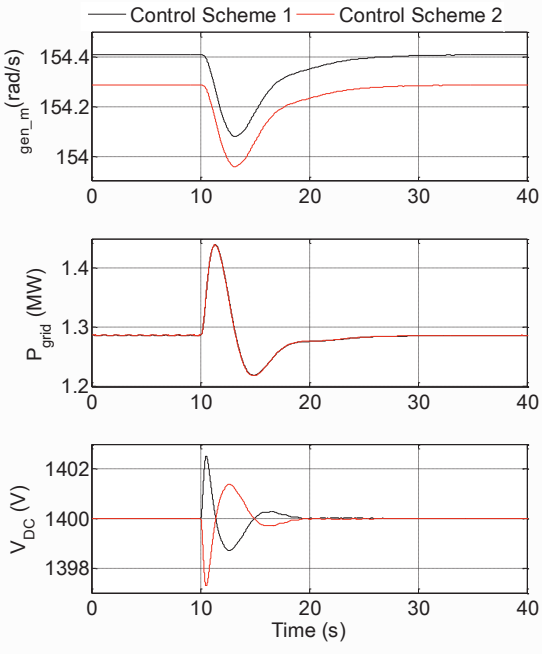
Results and Achievements

The two control strategies are quite different in how the control of the wind turbine is addressed. However the simulation outcome highlights their similarity in terms of the results achieved.

This is so because the grid output power in both control strategies is almost the same with control scheme two taking a slight edge of 0.1% (< 2kW). A slight variation in the settling value of the generator shaft speed was noted but this results from how the two control schemes work. This was expected as the rotor is the primary stage of energy extraction and no power can be extracted more than it is capable of; considering that minor losses are present in both cases.



(a)



(b)

Figure 1: PMSG based FRC WT model (a) and WT frequency event response (b)

Design of a Grid Connected Inverter for a Small Wind Turbine

Student: Luca Ciappara / Supervisor: Dr Ing. Reiko Raute

Introduction

The rapid increase in oil prices and higher concern with regards to serious environmental issues has reignited interest in renewable sources of energy such as wind energy. Considering how heavily built up Malta is, onshore wind farms are not a solution and offshore wind farms are too expensive due to the deep waters surrounding the Maltese islands. Therefore, a possible solution for the immediate future is small scale wind turbines.

Project Objectives

The main objectives of this project were the following:

- To design an LCL filter to interface the inverter with the grid
- To design a current controller for current magnitude control and grid synchronisation
- To design a voltage controller for regulation of the inverter DC link voltage
- To control boost converter inductor current for regulation of the generator electrical loading
- To simulate the wind turbine control strategy in Matlab®
- To implement all control algorithms in a microcontroller
- To test the performance of the grid-connected inverter.

Project Methodologies

The initial stage of the project dealt with a thorough design of an LCL filter in order to filter out the inverter switching harmonics. Followed was the design of the wind turbine control strategy, which consists of three controllers. The first controller is the grid current controller, which controls the current supplied to the AC grid. It ensures a near unity power factor and current magnitude control. The reference current magnitude is provided by an outer control loop, the inverter DC link voltage controller. The DC link voltage controller will regulate the inverter DC link capacitor voltage by controlling the power flow from the generator side to the grid. The third controller is a current controller of the input boost converter. This controller regulates the electrical loading of the wind turbine generator and supplies the electrical power to the inverter DC link. The system was modeled in Matlab® where each controller was tuned for optimum performance

Results and Achievements

The control strategy was implemented in the microcontroller (STM32F407) on-board the 1.4KVA inverter prototype after which a number of tests were carried out. From these tests it can be concluded that power from the generator side was successfully harvested into the grid (Figure 2) and that the inverter output current was synchronised to the grid voltage.

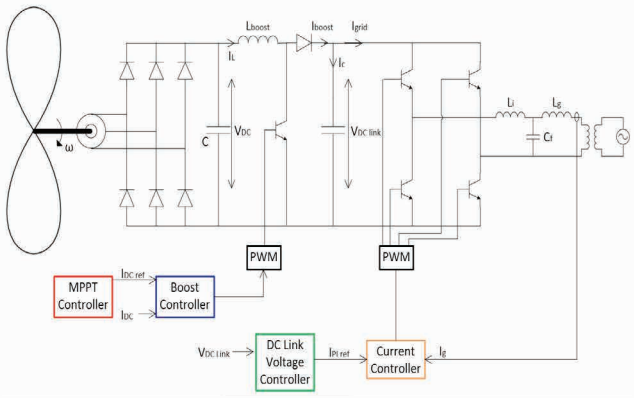


Figure 1: Wind turbine control strategy

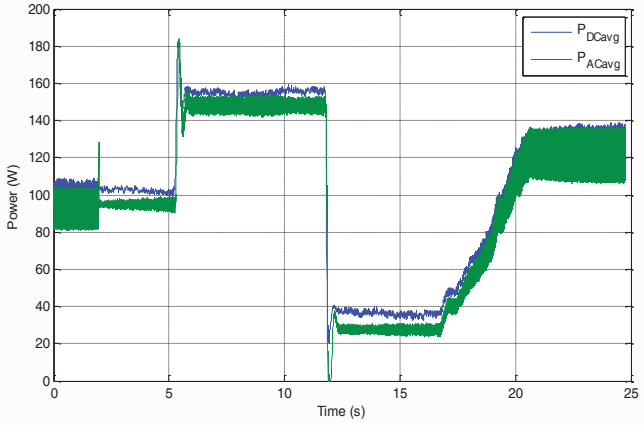


Figure 2: Average input DC and output AC power

Investigation of a Wind Integrated Compressed Air Energy Storage System

Student: Diego Debono / Supervisor: Dr Cedric Caruana / Co-Supervisor: Dr John Licari

Introduction

In today's world, the ongoing social and economic developments are constantly increasing the demand for energy. To limit the consumption of fossil fuels and carbon dioxide (CO_2) emissions during the provision of such energy, renewable energy sources such as wind energy are slowly being introduced by most countries around the world. Although large-scale renewable energy systems can help in reducing harmful emissions, several power quality problems may arise with the introduction of such systems. Due to their intermittent nature, undesirable fluctuations in the generated power will negatively affect the net power flowing into the grid. A promising solution to mitigate such problems is to store the energy from renewable energy sources during peak times and when the demand is low. The stored energy can then be used to level out the fluctuating power and thus contribute towards a more reliable

Project Objectives

This project aims to illustrate the details of how an innovative storage concept, known as *Compressed Air Energy Storage* (CAES) works. In particular, it examines the performance of the CAES system in smoothing the output power of a wind system to improve the quality of the net power flow to the grid.
The objective of this study is to develop a software model of a CAES system and design a suitable controller. The CAES performance is to be investigated under various wind profiles and two control strategies; one using a hysteresis limiter and the other using a feedback control system.

Project Methodologies

By comparing the performance obtained when implementing the hysteresis limiter with that obtained when implementing the feedback control system, it was conclude that the latter is far more desirable as it aims to avoid significant and sudden interruptions in the net export power being fed into the grid. A positive aspect provided by the feedback control system is that it tends to maintain a more stable energy level inside the CAES storage reservoir compared to the hysteresis buffer implementation. This implies that the storage capacity requirement may be reduced, resulting in a more financially viable CAES system.

Results and Achievements

Results show that the CAES system is effective at improving the quality of the net power transfer to the grid when it is engaged to smooth the output power of wind systems. Given a particular wind profile, variations in the net power transfer to the grid reached only 7.5%.
It was also shown that the CAES system is capable of supplying reactive power to effectively regulate the system voltage level. A test was carried out in which an inductor was connected to the terminals of a wind system, and by supplying the required reactive power, the CAES system was successful in restoring the original voltage level of the system.

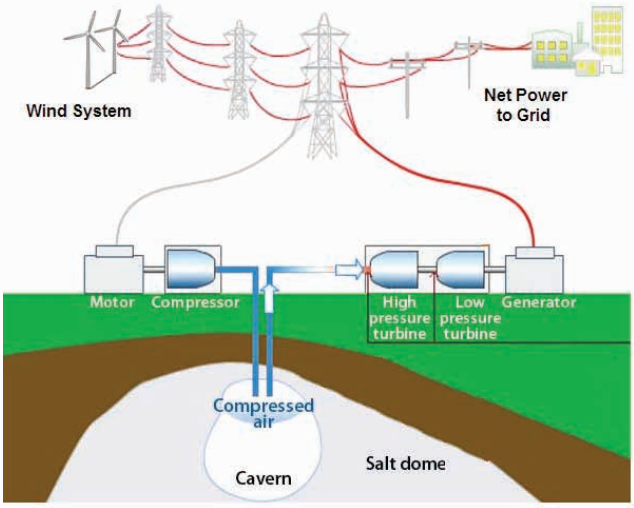


Figure 1: Wind-Integrated CAES System

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[1] Ha Thu Le, Surya Santoso, 'Operating compressed-air energy storage as dynamic reactive compensator for stabilizing wind farms under grid fault conditions'.

[Book:]
[2] P.Kundur, 'Power System Stability and Control' McGraw-Hill, Inc.

Primary Control of DC Microgrids

Student: Clayton Farrugia / Supervisor: Mr Alexander Micallef / Co-Supervisor: Dr Ing. Maurice Apap

Introduction

Due to the recent advancements in the electrical and electronic industries, the demand for DC has increased significantly to power consumer equipment such as laptops, mobiles and LED lighting. In addition, most of the renewable energy sources such as photovoltaics and fuel cells generate DC power. Hence, it would be much more efficient to generate the DC power and use it to directly power the DC loads since in this way the required power conversions are minimized. This project studies the operation of a 24V DC microgrid which consists of two identical DC-DC buck converters connected in parallel which share the power consumed by a common DC load.

Project Objectives

The goals of the project were to:

- Design the LC output filter of the DC-DC converter
- Design the inner control loops which consists of cascaded voltage and current loops
- Design the primary control loop to ensure equal load sharing between converters
- Simulate the DC microgrid in MATLAB®
- Build the hardware
- Implement the inner control loops and the droop control on a digital signal controller (DSC)

Project Methodologies

A low voltage DC microgrid has been constructed to form a 24V common DC bus so as to supply a resistive load from two identical regulated buck converters connected in parallel. The microgrid was controlled by a 32-bit floating point DSC which manages the cascaded control loops and the primary control loop of both converters. The current and voltage control was achieved by using PI controllers in which the negative feedback is provided by the DSC's analogue-to-digital converter. A 10 kHz switching frequency was used to control the IGBT switches of the parallel converters.

Prior to building the microgrid, the modelling and simulations were performed using a combination of Simulink® and PLECS® so as to confirm that the design criteria were met. Once the design was verified in the simulation model the required hardware setup of the DC microgrid was designed

Results and Achievements

Experimental and simulation results were obtained to verify the operation of the individual regulated converters and of the complete DC microgrid. The cascaded control loop was seen to match the simulation results for different voltage set-points. In addition, due to the droop control loop a compromise between the microgrid voltage regulation and the load current sharing was achieved after the DC microgrid voltage was established.

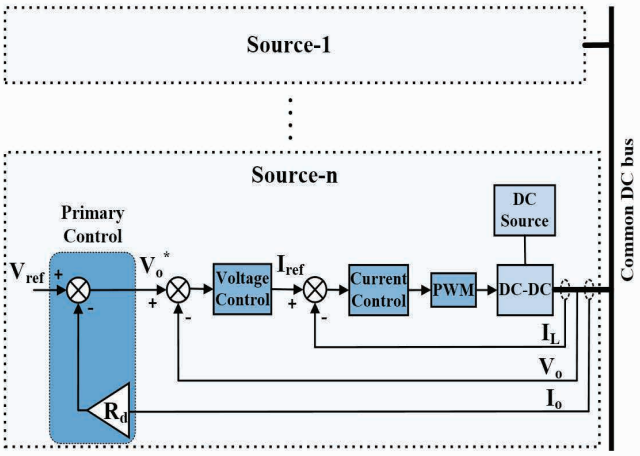

Figure 1: Primary Control of DC Microgrids

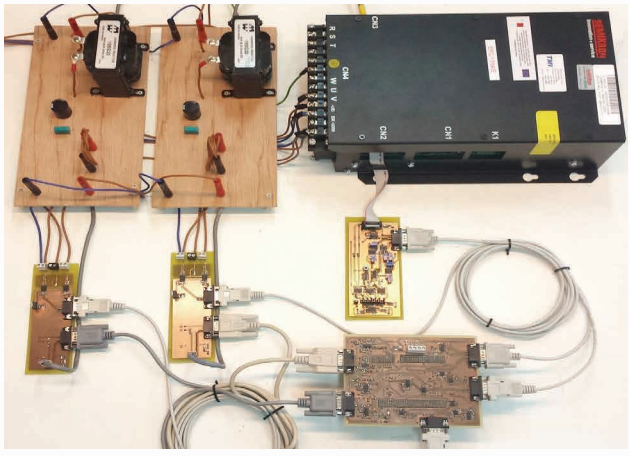

Figure 2: The Constructed 24V DC Microgrid

Digital Isolated Voltage Measurement With ADC

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

Introduction

Power electronics defines the procedure of processing and controlling of electric power flow by supplying voltages and currents in a way that is fitting for user loads [1]. These voltages and currents are needed to be measured for their control. A microcontroller, a digital programmable device can be used to read the analogue data in the digital domain. Galvanic isolation is included in the digital data transmission from the ADC to the microcontroller.

Project Objectives

The scope of this dissertation is to build demo boards that uses an external ADC to measure the high voltage directly non-isolated by means of a simple voltage divider and high current using current transformers. The demo boards are tested to see the maximum sampling rate reached.

Project Methodologies

Each board has three channels, equipped with high voltage protection by means of varistors [2], in order to measure and analyse three phase voltages. The external ADC is of Successive Approximation Register Topology with parallel digital interface, capable of a maximum sample rate of 4 million samples per second. The microcontroller reads the ADC and temporarily stores the samples in external memory to increase the sample rate. A Bluetooth communication link is used for the transfer of data between the demo board and the data acquisition PC. The voltage and current waveforms are then plotted in a LabVIEW GUI on the data acquisition PC

Results and Achievements

The final sampling frequency achieved is approximately 19 kHz, an acceptable sampling frequency for accurately measuring and analysing 50 Hz AC signals as are used in the European power system. A LeCroy oscilloscope having 8 bit vertical resolution, 600MHz bandwidth at 50 ohms and a 50 GS/s sample rate was used to compare its operation with that of the demonstration board. Despite the slight error between the two systems, both results output similar frequency conclusions on the waveforms applied to both systems. The error between the two systems' results is due to measurement tolerances present in both systems, different sampling methodologies, different hardware capabilities and different software techniques.

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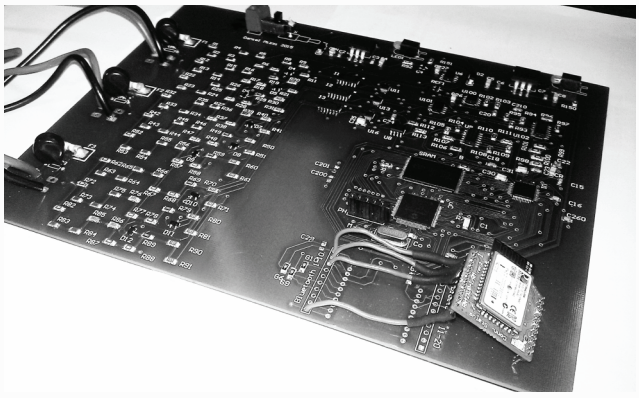

Figure 1: Demonstration Board

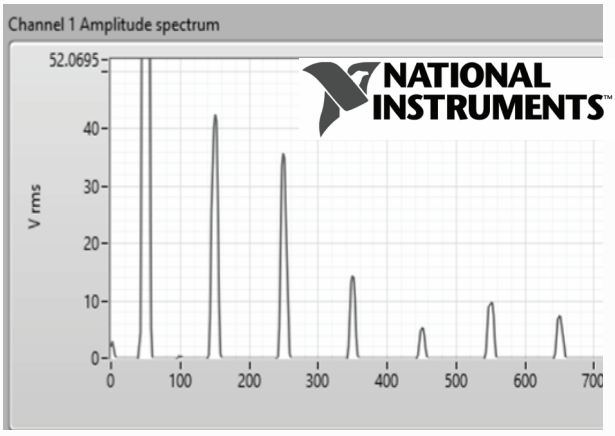

Figure 2: LabVIEW GUI Amplitude Spectrum

Investigation of Large-Scale Integration of Electric Vehicles on the Power Network in the Maltese Islands

Student: Melchior Pace / Supervisor: Dr Ing. John Licari / Co-Supervisor: Dr Cedric Caruana

Introduction

One of the main sources contributing to CO_2 emissions is the transportation sector, amounting to around 25% of the total European Union (EU) emissions [1]. Several measures are placed from the EU in order to reduce these emissions. One of the measures imposed from EU is the introduction of Electric Vehicles (EVs). Including a total of 5000 EVs by the year 2020 [2].

Project Objectives

The objective of this project is to model and investigate the EV charging effect on the national Maltese power network. This leads to an approximation of the possible number of EVs that can be connected to the existing power network infrastructure.

Project Methodologies

Three different EVs were tested in order to extract their driving range and the required data for modeling their on-board EV charger. Further to this, four low voltage feeders were selected from four different locations around the Maltese islands and later modeled in PSCAD.

Real data including individual household load profiles, total system load profile and various technical data was obtained through Enemalta in order to have the most realistic scenarios possible.

Figure 1: Residential Mode 2 Charging Electric Vehicle [3]

Results and Achievements

Four different electric vehicle penetration levels are considered ranging from 2% to 60%. Results show that the only limitation of the low voltage feeders was the maximum current capacity of the cable. Electric vehicle penetration level for the uncontrolled charging scheme reaches an average of 38.25%. While an average of 43.75% penetration level is achieved for the off-peak charging scheme. Further simulations were carried out having the aim to improve the maximum allowed electric vehicle penetration levels without reinforcement action on the low voltage power network are conducted. Results show that balancing the EVs shows noticeable improvement when sharp peaks occur. The controlled charging current scheme gives an average of 55.5% electric vehicle penetration level.

References

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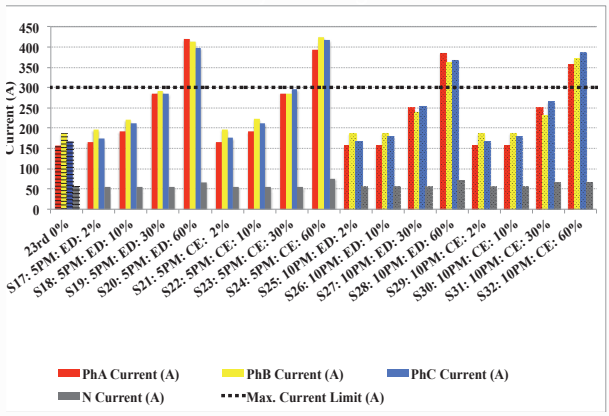

Figure 2: Maximum Phase and Neutral Current from Simulated Scenarios

A Magnetic Levitation Vehicle with Autonomous Control

Student: Brandon Spiteri / Supervisor: Dr Ing. Maurice Apap / Co-Supervisor: Prof. Joseph Cilia

Introduction

Magnetic levitation transport technology is being considered as the stepping stone towards the dynamic improvement in the transportation sector. A magnetically levitated train floats on electromagnetic waves and uses a non-contact magnetic propulsion system to overcome the limitations of the wheel-on-rail technology by drastically reducing the vehicle to track frictional losses.

Project Objectives

The aim of this project was to design and develop a magnetic levitation vehicle with integrated closed loop speed control and to study a possible alternative technique that can be used to achieve a high level of linear forward propulsion at the lowest possible on-board power requirement.

Project Methodologies

The permanent magnet's repulsive effect was used to achieve passive vehicle levitation whilst ensuring failsafe suspension. The proposed propulsion methodology was derived from linearizing the three phase brushless DC motor in which propulsion permanent magnets were fixed in the guideway whilst the vehicle was equipped with three electromagnets which were displaced from each other by 240 ° with respect to the guideway permanent magnets.

Vehicle position sensing was achieved by fixing Hall-effect sensors in phase with each electromagnet and this enabled the microcontroller unit to switch the electromagnet current, hence synchronizing the vehicle's electromagnets with the guideway's permanent magnets in the process. A prototype track had to be set up in order to determine the optimum guideway permanent magnetic separation whilst steel yokes were fixed within the guideway to reduce magnetic fringing.

Position sensing was used to determine the vehicle's speed and a root locus based and intuitive PI controllers were designed to force the vehicle to track a reference speed.

Results and Achievements

A 40mm and 60mm propulsion permanent magnets separation tracks were built and the resulting propulsion force exerted by the vehicle when one electromagnet is switch on was analyzed. An average propulsion force of 1372N was achieved using the 40mm separation track which fared better and much more linear than the 654N obtained from the 60mm separation track.

Both the root locus and intuitively based PI controllers managed to force the vehicle to track the desired speed. The developed 1.5kg vehicle reached a maximum speed of 1.41 km/h in the 1 metre track with 12W applied on-board power. This system also succeeded in overcoming the inertia forces from rest position using only magnetic propulsion without the need of external forces.

Figure 1: The Japanese MLX MAGLEV Train which Reached a Speed Record of 600km/h

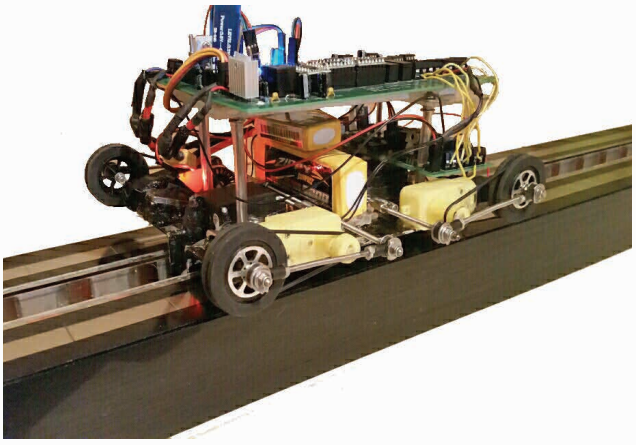

Figure 2: Vehicle Model in Magnetic Levitation Mode

Home Energy Management System

Student: Ryan Valentino / Supervisor: Prof. Ing. Cyril Spiteri Staines

Introduction

Nowadays, the use of electrical energy is continuously being questioned within the context of sustainable environment. Within the domestic sector a significant portion of energy is not being used efficiently. This can be attributed to lack of awareness and information. The effectiveness of displaying energy consumption resulted in average reduction of 9% as indicated in pilot project [1].

Project Objectives

The objective of this work was to design and implement a low cost wireless system capable of monitoring and controlling the power consumption of home appliances. The data gathered is sent over the internet and illustrated on a user friendly

Project Methodologies

The methodology followed in this project could be divided into three sections. Firstly, the design and implementation of an intelligent socket node (Figure 1) with sensing circuitry and firmware, so as to compute the power consumption of a connected appliance. Secondly, the design and implementation of a central node (Figure 2) capable of wirelessly communicating with a number of intelligent socket nodes and transmitting the information to an internet enabled device. Finally, the development of a website with the capabilities of controlling and monitoring power usage through the central node.

Figure 1: Intelligent Socket Node

Results and Achievements

The aim of this work was the design and implementation of a low cost energy management system for home use. The product is innovative because although other products are available in the market that generally target industrial and commercial buildings, this product targets the domestic sector by providing a low cost solution. The product provides a valuable contribution to society as it can be used as an educational tool to identify appliances that are consuming power unnecessarily. This added awareness should in the long run safeguard the environment, by reducing the daily energy consumption and demand.

The final result consists of a central node device and four intelligent socket nodes. The system allows the user to monitor the load parameters remotely via internet and also control the ON/OFF state of particular socket outlets.

References

[1] R. I. O. S. K. T. Tsuyoshi Ueno, "Effectivnes of displaying energy consumption data in a resisdential house," pp. 1289-1299, 2005.

Figure 2: Central Node

Music Tutor: An Evaluation Tool for Music Performance

Student: Luke Camilleri / Supervisor: Ms Alexandra Bonnici

Introduction

Whilst learning to play a musical instrument, beginner music students may struggle to read the written music and play the correct notes at the same time. This prototype tool aims to help the students by identifying pitch and rhythm mistakes in their performance, and aids the students in correcting their own mistakes using an interactive interface.

Project Objectives

The objectives of this dissertation are two-fold: to find signal processing algorithms capable of extracting musically related information from music signals, and to design a prototype learning tool using these algorithms and knowledge of the student-teacher relationship.

Project Methodologies

The prototype tool was designed specifically to work on piano performances. The tool compares the student's performance with a ground-truth performance, such as that played by the teacher. The comparison is done in both the pitch and the rhythm aspects of music.

The student's music signal is first processed to find the points in time where the notes are played. These are then used by the pitch detection algorithm to find the corresponding pitches, using Non-Negative Matrix Factorisation [1]. The sequence of pitches played by the student is then aligned with the sequence of pitches played by the teacher, using Dynamic Time Warping [2], in order to detect any wrong, extra or skipped notes in the student's performance. The bars associated with these notes are then found and shown on the interface, where the student is asked to repeat said bars. When the student has corrected all the pitch related errors, the note onsets are used to evaluate the student's rhythmical performance. The bars corresponding to notes which are out of tempo are found and output on the interface, where the student is again asked to repeat said bars.

The interface is designed to help the student if he\she repeatedly plays an incorrect bar, by asking the student to type in the notes present in the bar when the error is in pitch, and playing the rhythm of the notes in the bar when the error is a rhythmical one.

Results and Achievements

The note onsets algorithm was tested using both staccato and legato articulation techniques, where the algorithm successfully detected all of the onsets within an acceptable range of error. The pitch detection algorithm was tested using both single notes and two-note intervals, across all the 88 pitches of a full range piano, returning a 96.6% classification rate.
The tool was tested as a working prototype with beginner music students, where it was observed that the students improved their knowledge and performance of the selected music with every iteration of playing the music piece as a whole.

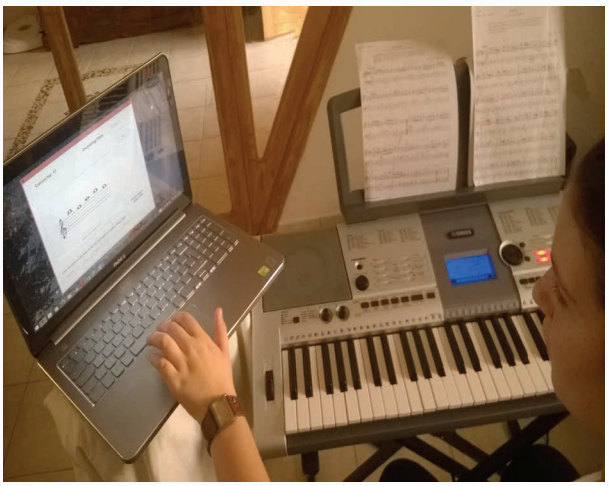

Figure 1: The prototype tool in use

References

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A Reaction Wheel Inverted Pendulum

Student: Matthew Camilleri / Supervisor: Prof. Ing. Simon G. Fabri

Introduction

The reaction wheel inverted pendulum system consists of a pendulum with a wheel attached to its body, which is allowed to spin freely about an axis parallel to the axis of rotation of the pendulum as shown in Figure 1. The wheel is driven directly by a DC motor, and controlled accelerations and decelerations are used to generate the right amount of torque in the wheel so that the reaction torque balances the pendulum in its upright inverted position. This system is interesting because the pivot point of the pendulum is fixed to the ground and therefore no direct physical force is being exerted on the pendulum pivot itself. This makes the reaction wheel pendulum attractive for real-life applications where no ground reaction is available such as attitude control in satellites.

Project Objectives

The main aim of this project was to design and implement a closed loop controller that is able to maintain the reaction wheel pendulum stabilized in its inverted position. This involved the design and implementation of the mechanical setup, the electronic hardware, derivation of the system's mathematical model, the design, simulation and coding of the control algorithms on the dSPACE DS1104 digital control board, and full testing and evaluation of the closed loop system performance

Project Methodologies

The pendulum was stabilized in its inverted position by using a Linear Quadratic Regulator (LQR) designed on the linearized state space model of the system. The system was then simulated and tested in Simulink, and subsequently implemented on the physical setup that was designed and built from scratch. The design of the physical system was done with the use of Autodesk AutoCAD. The interfacing involved all the electronic components, including a brushless dc motor controller used to actuate and sense the wheel speed, and a combination of inertial measurement units (IMU) to estimate the pendulum angle and velocity with the DS1104 control board. All the coding was implemented on Simulink using C-MEX S functions.

Results and Achievements

The results obtained verify that the system designed and implemented in this project was successful. The control task was completely satisfied since the controller stabilized the pendulum in its inverted position whilst keeping the wheel speed close to zero as shown in Figure 2. The controller is highly robust and manages to stabilize the pendulum from any initial condition in the range of ±9° and allows external disturbances in the range of ±4.5°. The controller also manages to keep the pendulum stabilized with an asymmetric offsetting mass added to one of the pendulum sides or even when the base of the setup is not placed horizontally.

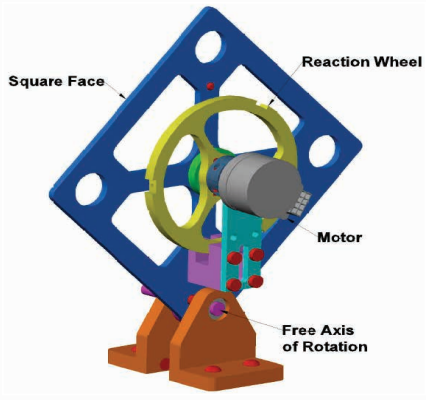

Figure 1: CAD Drawing of the Mechanical Setup

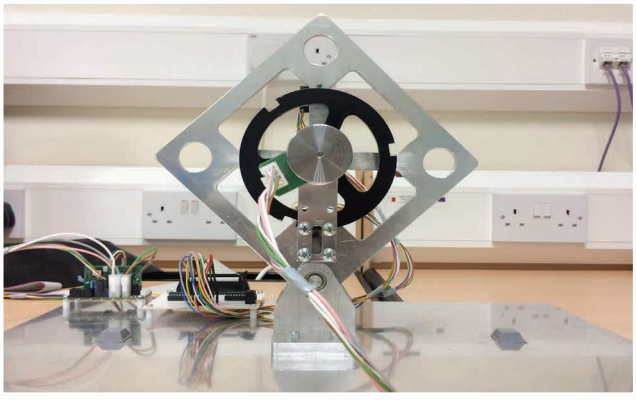

Figure 2: The Implemented Physical System

Neurofeedback Variation of SSVEP Stimuli in Brain-Computer Interfacing

Student: Charlene Chetcuti / Supervisor: Prof. Kenneth P. Camilleri

Introduction

Brain Computer Interfaces (BCI) provide a communication channel between the brain and the computer, without relying on the brain's normal output pathways. A Steady State Visual Evoked Potential (SSVEPs) is a neural response to a visual stimulus which is flashing with a regular pattern. A BCI may distinguish SSVEPs evoked by stimuli with different frequencies, where each stimulus is associated with a specific command [1].

Project Objectives

One of the main issues which has challenged the practical use of SSVEP-based BCIs is visual fatigue due to the flickering stimulus. Furthermore, the majority of present systems rely on the user to improve their performance by giving the user visual feedback. This project investigated the use of a neurofeedback protocol which provided feedback to the BCI system with the aim of reducing visual fatigue and improving classifier performance.

Project Methodologies

A novel protocol for the flickering stimuli was designed to exploit the opportunity for neurofeedback. This protocol allows the system to operate in a different modality during idle states, thus reducing visual fatigue, switching to a different modality when active and ensuring that the classification accuracy remains high. Experiments were designed to test the proposed feedback protocol against a standard protocol without modality switching. Parameters such as the length of data segment for SSVEP detection and the contrast of stimuli were also investigated.

Based on the parameters obtained through the preliminary experiments, an SSVEP-based BCI speller system was designed and tested both synchronously and asynchronously. The BCI speller was implemented and tested using both a standard protocol and the proposed neurofeedback protocol to allow a direct performance comparison.

Results and Achievements

Eight subjects participated in the study and tests were conducted which demonstrated a higher accuracy for the neurofeedback protocol. The mean Information Transfer Rate (ITR) of the synchronous system using a standard protocol was calculated to be 31.10±6.18bpm whilst the mean classification accuracy was calculated to be 82.88±6.19% compared to the neurofeedback protocol mean ITR of 26.05±4.10bpm and mean classification accuracy of 90.57±5.36%. When used asynchronously, the system implemented with the neurofeedback protocol obtained a mean efficiency - the ratio of minimum commands to actual commands - of 90.10±7.24% whilst the standard system obtained a mean efficiency of 63.60±3.22%. These experimental results are consistent with the theoretical models of these protocols.

It may be concluded that an SSVEP-based BCI would be expected to benefit from increased classification accuracy when using the neurofeedback protocol, at the cost of increased latency. Future research on faster signal processing algorithms could reduce the system latency.

Figure 1: Setup of the implemented BCI Speller Application

References

Journals:

[1] Y. Wang, X. Gao, B. Hong, C. Jia, and S. Gao, "Brain-computer interfaces based on visual evoked potentials.," IEEE Eng. Med. Biol. Mag., vol. 27, no. 5, pp. 64–71, 2008.

A Speech Interface for a Mobile Robot

Student: Gabriella Pizzuto / Supervisor: Prof. Ing. Simon G. Fabri / Co-Supervisor: Mr Mike Rosner

Introduction

Robotics is increasingly spanning every aspect of our lives, from domestic tasks to advanced military applications. Witnessing the potential of including robots in our everyday tasks, the benefits of using such technology are compelling to a great extent. This project addresses the challenges behind the design and implementation of speech recognition and speech synthesis in the context of human-robot interaction.

Project Objectives

The main objectives of this project comprise of the design and implementation of both the speech recognition interface and the software speech synthesiser, together with a communication platform to actuate and receive feedback from the Khepera III mobile robot depicted in the setup shown in Figure 1. One of the important goals of this project is to encompass natural language processing and natural human-robot interaction capabilities.

Project Methodologies

A robust speech recognition system, using the Julius decoder software [1] and the Hidden Markov Model Toolkit by Cambridge University [2] together with an intelligible speech synthesiser eSpeak [3], were developed and implemented on a Linux-based PC. Additionally, a communication platform was designed to allow communication between the speech recognition and speech synthesis modules, as well as with the mobile robot.

After gaining an insight into the operation of such a system, the speech interface was modified to include natural language processing techniques like text chunking and embrace a natural human-robot interaction approach by including command interruption and obstacle detection.

A typical implementation was presented and evaluated with respect to the ability of using the system for speaker independent applications aimed at manoeuvring the robot in cluttered environments.

Results and Achievements

The speech interface implemented proved to be a successful method to communicate verbally with the Khepera III mobile robot. A word correctness of 98 percent and a word accuracy of 94 percent for a well-trained voice sample, i.e. using 150 voice samples from the total of 550 voice samples used, were attained. In addition, for an untrained voice sample a word correctness and word accuracy of 81 percent and 76 percent respectively were achieved. This is evidenced by the graphs illustrated in Figure 2.

References

[1] Akinobu, L., The Julius Book, Kyoto, Japan: Lee Akinobu, 2010.

[2] Young, S., Evermann, G., Gales, M., Hain, T., Kershaw, D., Liu, X., Moore, G., Odell, J., Ollason, D., Povey, D., Valtchev, V., and Woodland, P., The HTK Book, Great Britain: Cambridge University Engineering Department, 2006.

[3] eSpeak, “eSpeak text to speech,” eSpeak, [Online]. Available: http://espeak.sourceforge.net/. [Accessed 26 February 2015].

Figure 1: The hardware and Khepera III mobile

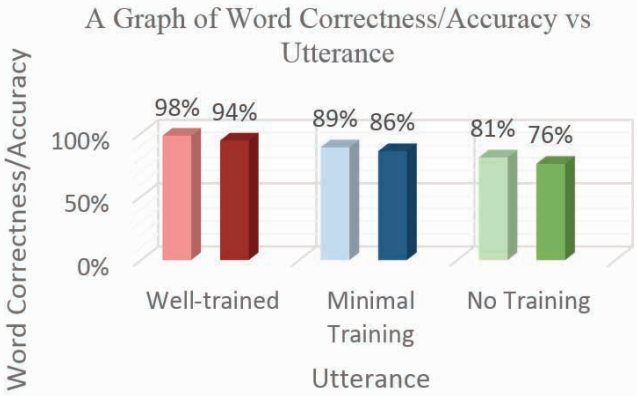

Figure 2: The results obtained in terms of word correctness and word accuracy

Object Search, Recognition and Following in a Cluttered Environment

Student: Christian Spiteri / Supervisor: Dr Ing. Marvin Bugeja

Introduction

The popularity of mobile robots is increasing and we are becoming more aware of how powerful and useful these machines can be. Autonomous mobile robots are even more attractive as these can complete jobs assigned to them without the need of any human intervention. Such robots should be capable of operating in cluttered environments so to avoid being damaged or put human beings in danger.

Project Objectives

This project aims to create a system where a mobile robot searches for a desired object using a vision system, and when the object is found, the robot should approach it, and avoid any obstacles cluttering its path. If the target moves, the robot should follow it.

Project Methodologies

A thorough literature review was carried out at the initial stages of the project. A solution to the 'search' task as defined in this project was not readily available in literature. For this reason, a novel algorithm was developed to accommodate for all the problem specifications, in light of a number of constraints related to the physical limitations of the robot used.
One the other hand, the "approach and follow" task, was addressed via the Dynamic Window Approach (DWA), originally proposed by Thrun *et al.* in [1].

The algorithm developed for the search task, was simulated on V-REP, a 3D simulator for robotics, where a 3D model of the Khepera III mobile robot, the same robot used for the physical experiments, was used. The whole system was implemented as an embedded system on the robot itself using the C programming language. The robot was equipped with a CMUcam5 (Pixy) vision system to recognize the desired target.

Finally, system testing was carried out to ensure that all the algorithms were functioning harmoniously together to achieve the wanted behavior.

Results and Achievements

The whole system was successfully implemented on a real Khepera III mobile robot. However, due to time constraints, the novel 'search' algorithm developed in this project was not implemented on the robot as an embedded system, and a random search algorithm was implemented instead. Yet, the novel fuzzy-based search algorithm was implemented and tested by a 3D robotics simulation with very positive results.

Further work on this project might include further testing, possible improvements, and implementation of the fuzzy search algorithm.
The camera is mounted on two servos which can also be used to increase the chances of detecting the target. These servos can be controlled directly from the robot through SPI. The camera can be made to rotate while the robot is moving, and then lock on the target once it is detected. This will enhance further the effect of the search action.

Figure 1: Typical path taken by the robot when approaching the target using DWA

References

[1] Fox D., Burgard W., and Thrun S., 'Controlling Synchro-drive Robots with the Dynamic Window Approach to Collision Avoidance', Proc. of the Intelligent Robots and Systems, Osaka, Japan, 1996.

A Writing and Sketching Robot

Student: Marlon Vella / Supervisor: Prof. Ing. Simon G. Fabri

Introduction

Robot manipulators have proven to be a very useful tool in a number of situations and have been suitably modified to cater for a multitude of applications. With the advancements in computational power and mechanical hardware technology, a growing body of interest in the development of robot manipulators to perform basic functions associated with the human arm has emerged. One such task is the ability to write or sketch.

Project Objectives

The main objective of this project is to implement on the *Thermo CRS Catalyst-5* robotic manipulator the necessary position and force control schemes in order to allow the manipulator to be able to write or sketch a given trajectory on a flat whiteboard surface using standard markers. Such a task preferably has to be completed whilst ensuring that the marker neither presses too hard nor leaves the writing

Project Methodologies

Initially, a literature review was carried out on position and force control schemes typically implemented on robotic manipulators. Following this, a kinematic and dynamic model [1] of the manipulator used in this project was established. Using these mathematical models a parallel position/force controller [2] was developed. Its performance was analyzed through a comprehensive series of simulation tests.

Prior to implementing the controller on the actual manipulator, the necessary hardware had to be properly set-up. A force/torque sensor was mounted to the tool-flange of the manipulator and a specialized end-effector was machined to hold the marker securely in place, as illustrated in Figure 1. Using an empirical approach the parallel position/force controller was then appropriately tuned to achieve the desired response. Finally a number of trajectories were supplied to the manipulator in order to evaluate the trajectory tracking performance as well as the force regulation capability of the implemented control strategy.

Results and Achievements

Implementation of a parallel position/force controller was completed successfully. The manipulator was able to accurately track a given trajectory whilst regulating the contact force between the marker and the writing surface to an average of the desired value of 0.5N. A procedure was implemented that allowed the manipulator to write the university initials, UOM. Apart from that, a simple continuous sketch through the use of a pen-tablet was able to be produced.

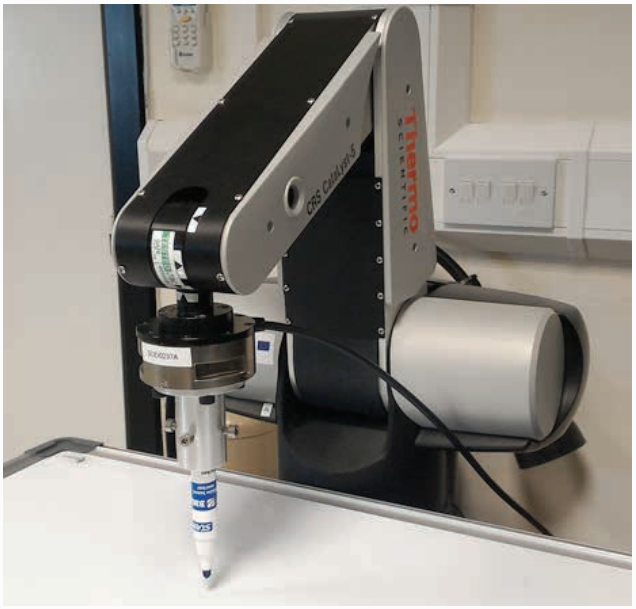

Figure 1: Robot manipulator in the writing position

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[2] S. Chiaverini, B. Siciliano and L. Villani, 'Force and position tracking: parallel control with stiffness adaptation', *IEEE Control Systems Magazine*, vol. 18, no. 1, pp. 27-33, 1998.

FINAL YEAR
ENGINEERING PROJECTS
MECHANICAL STREAM

Development of a Master Device for the Teleoperation of a Minimal Anthropomorphic Robotic Hand

Student: Robert Agius / Supervisor: Prof. Michael A. Saliba

Introduction

Since long ago, people have used tools to increase their manipulation capabilities. Teleoperation is the control of a device from a distance and dates back to the 1890s. With the evolution of technology, better robotic manipulators have been developed over the years, along with more demands on the respective master devices that control these manipulators.

Project Objectives

The objective of this project was to work towards the development of a new prototype glove master device for the teleoperation of the minimal anthropomorphic robotic hand (UM-MAR Hand) that was currently under development at University of Malta.

Project Methodologies

This project followed a systematic product design approach [1]. An evaluation of previous concept prototypes of the glove master device was carried out. This highlighted the limitations of the designs as well as what was needed from the new prototype design. Hence, this served as the problem definition stage of the design process.
Following this evaluation, was the conceptual design stage where various methods were employed to generate new possible concepts for each function that the glove master device was to have. These concepts were then weighed against each other in order to select the best one.
The components were then selected and the structure of the required programming was prepared.
In the detailed design stage, the design was amended such that it was more suitable for assembly and manufacturing. Additionally, an analysis on the various possible modes of failures was carried out to ensure that the design protects against them. Detailed drawings were drawn up and the programming was finalized.
The glove was then manufactured and interfaced with an existing robot hand for testing purposes. The project was finally concluded with the testing and evaluation of the new glove master device. The results obtained were then compared to those obtained from the evaluation of previous concepts in order to determine the resulting improvement.

Results and Achievements

A new glove master device was developed that utilizes bend sensors at the finger joints that change in resistance when the user moves his hand. This resistance was then used to measure the position of the index finger, middle finger, and thumb.
A touch feedback system was also introduced, using piezoceramic bi-morph actuators that are set to vibrate when the fingers of the robot hand reach a certain position. These are then interfaced with the robotic hand using an Arduino microcontroller.
The new glove master device results in a design with an improvement in readings of the measurement of the user's hand position.

Figure 1: Glove master device

References

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

Design of a Manufacturing Plant Layout for the Production of a Wind Turbine

Student: Katya Bezzina / Supervisor: Ing. Emmanuel Francalanza / Co-Supervisor: Ing. Paul Refalo

Introduction

In the light of the growing need for sustainable living, Econetique Ltd, the industrial partner for this project, is developing a new wind turbine. This project involves the design and planning of the processes, equipment and layout required to set up a manufacturing facility for this particular turbine.

Project Objectives

The project's objectives include the generation of a number of conceptual layouts based on investment versus cycle time, the process and machine selection, the establishment of human resources and the analysis of the factory's changeable aspect.

Project Methodologies

The methodology used to address the problem at hand was formulated by combining the Systematic Layout Planning approach used by Philips [1] and the Changeable Manufacturing System Design Approach developed by Francalanza [2].

The first part of the design process focuses entirely on determining the requirements of the system. This was done through the analysis of product design, production volume and space available. In a nutshell, the factory should incorporate the fabrication of aluminium components and the processing of carbon fibre blades.

In conjunction to the turbine's design, the required process plans, process times and material flows were established. During the Factory Design Synthesis stage, machine selection, departmental area allocation, closeness relationships and plant block layouts were developed in order to create a provisional facility design.

Consequently, the plant's process operations were modelled into Plant Simulation software and a number of experiments were carried out in order to identify bottlenecks and improve system efficiency. The results derived from the tested simulation model as well as the costs and investment considerations were evaluated to create a number of scenarios.

Results and Achievements

Based on the target production quantities, which vary along the first five years, this facility could be classified as a medium-sized production plant. Thus, a cellular or departmental layout with batch-type production was applied. An in-depth investigation on the optimal batch size was conducted to show the effect of increasing batch sizes with process times per turbine and per part. The number of lathe machines and blade mold tools required to reach throughput values were established and a recommendation was proposed for the plant to operate on a two 10-hour or three 7-hour shift basis.

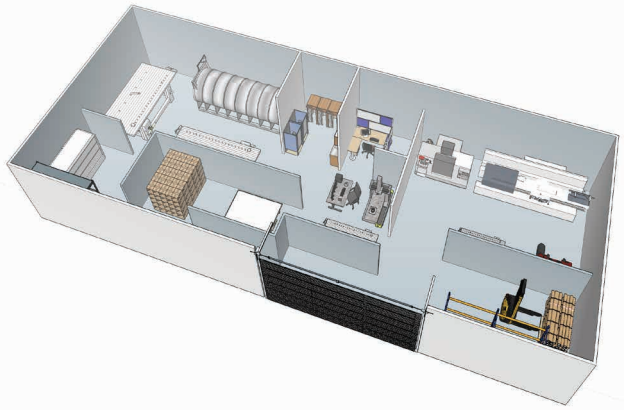

Figure 1: 3D Conceptual Layout

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[Journal:]
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Cost Effective Hermetic Lipstick

Student: Nicole Borg / Supervisor: Dr Ing. Arif Rochman

Introduction

A lipstick's chemical composition and long-lasting effect raise the need for the lipstick to be protected from the environment during storage and also during transportation. The need to have a lipstick which is more long lasting brought about technological advancements in the cosmetic industry. For such a lipstick to have a longer shelf life, a hermetic seal is required.

Project Objectives

The aim of this project is to analyze the hermetic sealing present on the market which can be applied to cosmetic packing and to have a hermetic sealed lipstick in the most cost effective way.

Project Methodologies

During the course of this project a product that has been designed and manufactured by Toly Products Ltd was thoroughly analyzed. This led to the familiarization with all the problems involved and thus introduces the hermeticity concept for lipstick packaging. With the aid of the various design tools, conceptual drawings were generated and thus a better idea was perceived of what the outcome should be. The three main functions of the product were always kept in mind during the design stage since the final lipstick should be functional, aesthetically pleasing and cost effective.

Figure 1: Prototype

Results and Achievements

In order to assess the hermeticity of the different concepts, a vacuum test was carried out. In this vacuum test, it is observed whether any water leaks out, when the prototypes are filled with water and subject to a vacuum. The results showed that only one concept did not fail the test, thus this concept was developed further. This concept included a base with a groove to host the seal and a cover. Upon closing the lipstick the cover squeezes the seal on the base and thus the parts seals together. This design was further analyzed through Design for Manufacture. Thus aided in analyzing whether the concept can be easily manufactured at the highest quality and was done with the aid of Moldflow Analysis. Through this analysis the amount of material required for each component, thus a costings analysis was briefly carried out.

Figure 2: Final Concept

Evaluation of Process Improvements in Rubber Diaphragm Moulding

Student: Savien Buhagiar / Supervisor: Dr Ing. Arif Rochman / Co-Supervisor: Dr Ing. Conrad Pace

Introduction

ProMinent Fluid Controls Ltd is a German company that comprises of several premises worldwide. The company is dedicated to the manufacturing of products relating to the handling of fluids and liquid media. Since its beginning in 1960, the company has always aimed to be a top class manufacturer of products in its range, delivering customer satisfaction through innovation and reliability [1].

Project Objectives

One of the main sectors within ProMinent deals with the production of rubber pump diaphragms. The process involved has been in use for quite a number of years; yet substantial variation in thickness is observed in the ultimate diaphragms manufactured. In simple terms, the process involves two main operations, being the calendering of raw rubber into sheets, and the compression moulding of the membranes to produce the final diaphragm. The aim of this project was to analyse in depth the whole process involved, and identify in particular which are the factors that mostly contribute to the observed variation. The results obtained would then lead to an identification of potential improvements that could possibly mitigate such detrimental factors.

Project Methodologies

This dissertation was based on the Design of Experiment approach, interconnected to the DMAIC technique [2]. This has allowed the methodology to be divided in a number of sequential steps. Typically, the initial stages were those relating to problem definition and understanding, and this was merely done by a thorough observation of each and every step that is involved within the whole process. This has allowed the identification of a number of factors that have an impact on the process output. All this has then led to the planning of a series of experiments, through which the previously identified factors were altered sequentially. The data gathered through experimentation was analysed using both graphical and statistical means, providing enough information to conclude about which parameters are the most influential. Following this, several improvements were deduced, all of which could be of great help if properly applied and abided with.

Results and Achievements

During all the experiments carried out, significant dimensional variability has been observed throughout all the operations involved. It was not uncommon to find certain diaphragms whose thickness exceeded that specified by the tolerance limits. Thus, it stood evident that certain elements of the process must be altered such that the mean diaphragm thicknesses lie well within the specified limits, ensuring process capability as much as possible.

The calendering process itself, Figure 1, proved to be quite problematic in obtaining a uniform raw rubber sheet thickness. During compression moulding, the mass of the raw material inside the mould cavities, the moulding temperature and the pressure were the main three factors which have caused some of the highest variation in all the readings gathered. Regarding all this, the ideal combination of processing parameters was dictated, together with several other general improvements that could improve the overall procedure.

Figure 1: Initial raw material feeding in the calendering machine

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Design of a Proof-of-Concept Surgical Instrument for Pleurodesis

Student: Darryl Edward Calleja Stafrace / Supervisor: Dr Ing. Philip Farrugia / Co-Supervisor: Dr Aaron Casha

Introduction

When fluid gathers in a region near the lung, there is a disturbance in the natural pressure system. This inhibits breathing to an extent dependent on the amount of excess fluid, and in the worst case scenario can lead to death. *Talc Pleurodesis*, is an operation which can reduce the chances of fluid re-gathering in this region.

Project Objectives

This project aims at designing a novel instrument which can successfully achieve pleurodesis via talc insufflation. The instrument must be state-of-the-art, which implies it incorporates modern technology.

Project Methodologies

First and foremost, when designing any engineering product it is important to have a design plan to guide the designer. The basic design cycle [1] was used to execute the design tasks involved.

One of the project requirements was to generate an innovative solution. Hence, it was vital to review existing products on the markets, including patents. Customer Surveys in addition to the Quality Function Deployment were vital to incorporate the 'voice of the customer' into the list of specifications, and hence within the instrument itself.

To generate an innovative solution, a number of design tools were employed, including SCAMPER and synectics. Morphological charts were also utilised to explore the whole design solution space. Various means for each sub-function required in the surgical instrument, were considered. Once the design concept was selected, mathematical modelling was applied to understand the conditions the instrument would be exposed to and ensure a safe design. Following this, an in-depth material selection exercise was carried out for every part to select materials which were best suited.

Other design tools such as designing for manufacturing were carried out to improve the design. Finally, a physical prototype was generated (as shown in Figure 1) to represent the design and perform an evaluation exercise.

Results and Achievements

To this end, an evaluation of the instrument was carried out with surgeons, scrub nurses and sterilisation technicians, in order to asses and evaluate the designed instrument. The participants were first given an overview of the working principle of the prototype, followed by semi-structured interviews. Overall the feedback was positive. One surgeon even said:

> *"It would be great to have such an instrument, We could really use one of these."*

Nonetheless some limitations were identified. Namely the mode of actuation in combination with the handle design. This resulted in difficulty when selecting a different dispersal direction. It was not fool proof nor very efficient. Hence, future works and research will aim to simplify the mode of actuation and possibly eliminate the need for actuation altogether.

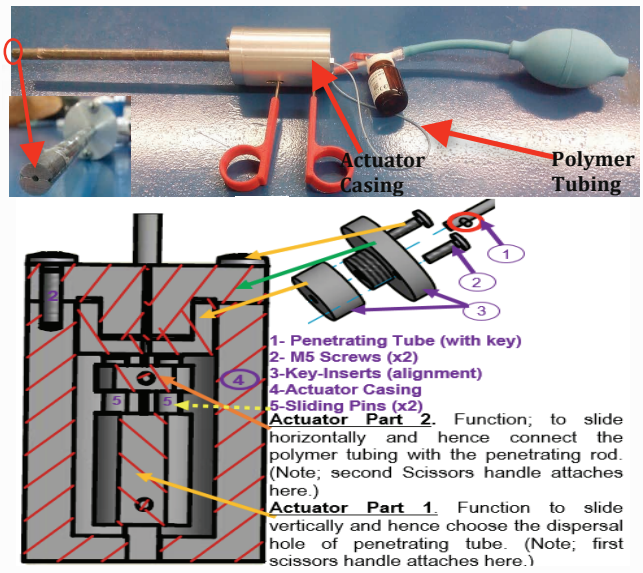

Figure 1: Top - Manufactured prototype with detail on dispersal Canals. Bottom – Section view of actuator Casing with labelled 'hidden' parts.

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Analysis and Simulation of Energy Consumption of CNC Machining Processes

Student: Julian Cefai / Supervisor: Ing. Paul Refalo / Co-Supervisor: Ing. Emmanuel Francalanza

Introduction

The demands on machining processes are ever growing, with demands for cheaper, quality products constantly on the rise. This rise in demand also means processes must become faster and more sustainable due to environmental concerns. This study aims to look at CNC machining processes in depth with the aim of making them more efficient and sustainable. This will be done specifically with regards five CNC machined components of *Econetique*'s wind turbine system. *Econetique* is a Gozitan company whose novel wind turbine design aims to increase the efficiency with which wind energy is harnessed.

Project Objectives

The primary objective of this study is to understand how a CNC machine uses energy when processing material, specifically when drilling, milling or filleting. The results of this analysis will then be used as a tool in a DfSM [Design for Sustainable Manufacturing] system. This system will then be applied to the aforementioned wind turbine components and the improvements estimated and recorded.

Project Methodologies

This study can be considered to have two main parts. Firstly in order to analyze the processes that would be employed to machine the turbine components a test part was developed (as seen in *Figure 1*). This test part made use of the primary processes involved in machining the components, these being milling, drilling and filleting. The power used when carrying out these processes was recorded using a data logging system. This system returns a power value every second. These power values will be used to relate the energy to process a feature of the component to the material removal rate used. This relation is then used to approximate the energy consumption for each turbine component.

The second part of this study is developing a system to improve upon this value as well as make the components more sustainable to produce. A system was developed which made use of guidelines compiled from literate. These guidelines have weightings assigned to them relating to how relative they are to the components and whether the components follow these guidelines, and to what degree. These weightings then give an urgency factor in order to prioritize improvements in the design. This process is intended to be general and iterative. That is to say the initial guidelines can be applied to multiple scenarios and by virtue of the weighting system become specific. This system should also be applied periodically to stimulate and record improvements in design.

Results and Achievements

The most relevant guidelines were: standardize components, features and materials and reduce material waste. Standardization of features was proposed. Material waste, and therefore energy waste, was reduced by machining the components from two blocks rather than one. An example of this can be seen below in figure 2.

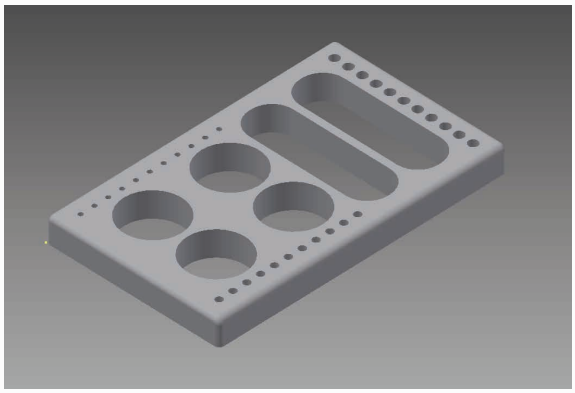

Figure 1: Test Part

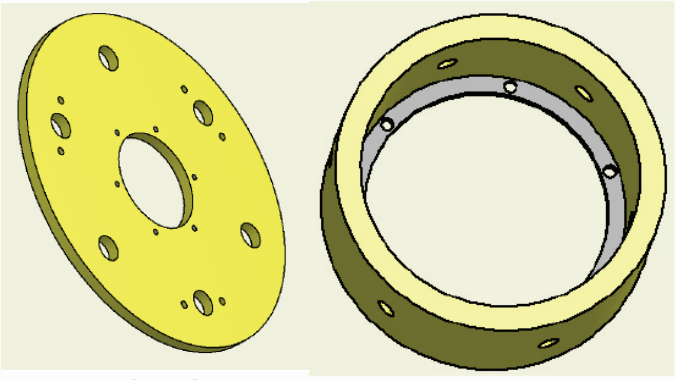

Figure 2: Split Component

A Kansei Engineering Approach For Designing Joyful Factory Operations

Student: Andrew Cremona / Supervisor: Prof. Ing. Jonathan C. Borg

Introduction

Factory operation workers are one of the building stones of a successful company. Having workers in a negative emotional state will suggest a loss in working performance. This is an undesirable factor when aspiring for excellence. In this respect, a foundation for the understanding and resolving of the issue transpiring around the factory worker was established.

Project Objectives

1) Identify major sources of stress within factory environments; 2) Analyze the effects of such stressors on the performance of factory workers; 3) Develop a means to alleviate factory work-related stress; 4) Evaluate the impact of the proposed Kansei Engineering approach.

Project Methodologies

Throughout this dissertation, negative emotional state sources were investigated profoundly through specific interviews and industry examination. Several volunteers took part of a study in which the subject will perform a manual assembly operation whilst his/her environmental conditions are constantly changing. This study is carried out to analyze the effects of stressors on the five senses. This analysis is quantified using Emocards and results are portrayed in five different radar charts (for each human sense) as shown in Figure 1. In Figure 1, a result of 8 depicts the most negative emotional state, whilst 1 depicts the most positive.

Figure 1: Experimentation Results of One of the Five Senses

Through the latter study, two parallel approaches were developed in order to expose such sources. These were termed *ACD-Based Kansei Approach* and *ACD-Based Kansei Reversed Approach*. Subsequently, a framework designated as *FEAS Kansei Engineering Framework,* as shown in Figure 2, was generated to restore neutral or, more importantly, positive emotional states to factory workers; hence 'Joyful Factory Operations'. FEAS Framework was founded on two techniques and numerous quality tools. The two techniques are termed *Predicting* Technique and *Backward Analysis Technique.* The former technique is utilized as a preventive method of creating negative emotional states; whilst the other technique is utilized as a stress source finder and solution solver.

Results and Achievements

A number of deliverables should give a clear idea of its worth to actual industries. The deliverables are as follows:

a) One, highly proficient engineer currently undergoing a Masters program in Business and Management and a well-experienced manager within local industries were presented with a run-through of FEAS Framework in order to attain feedback on the latter. These two individuals had constructive observations regarding the realization of the framework. b) The limitations of the framework were considered and comprehended thoroughly.

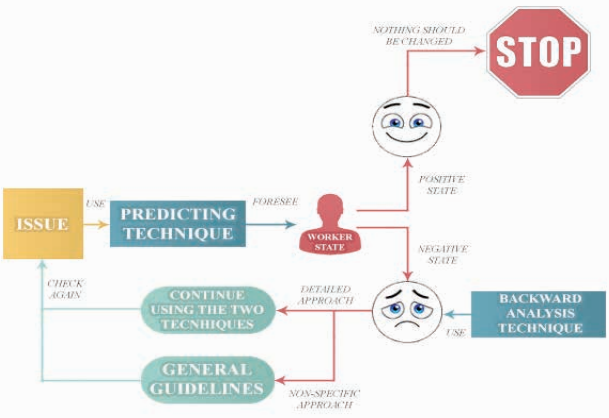

Figure 2: FEAS Kansei Engineering Framework

A Feasibility Study on Electron Beam Melting for the Manufacturing of Annuloplasty Rings

Student: James Falzon / Supervisor: Dr Ing. Philip Farrugia

Introduction

With the latest reports indicating a significant rise in cardiac surgeries for the next five years, mitral valve repair has become the general practice to treat valvular regurgitation. The surgery is characterised by an implantation of annuloplasty ring to restore the mitral valve shape and regain its structural integrity. Electron Beam Melting (EBM) an Additive Manufacturing technology has the ability to fabricate complex, and customised products in shorter lead times. [1]

Project Objectives

This research aims to successfully build annuloplasty rings, by altering critical process parameters. In addition, another aim was to perform a costings assessment between EBM and a competent conventional manufacturing process.

Project Methodologies

After different *Computer-Aided Design (CAD)* models of the annuloplasty rings were generated, a design of experiments based on the multi factorial design was adopted to systematically alter chosen parameters at different factorial levels. Factors chosen, namely include the *Standard Tessellation Language* (STL) file as a pre-process parameter and the beam focus offset as the process parameter. The tessellation file format, which is a language used to convert generated model into triangular meshes, was varied between low and high resolution. Together with this, the focus beam offset, which dictates the melt pool size during the process, was altered on two different levels.

Experiments were repeated with the addition of incorporating support structures within the models.

Annuloplasty rings produced by EBM were assessed by measuring critical dimensions specifically where the implant is to be anchored with the mitral valve. From the measurements recorded, dimensional accuracy was deduced. Figure 1 illustrates an annuloplasty ring produced by EBM, superimposed on the mitral valve.

For the costings assessment, a five axis CNC milling was opted to assess the feasibility of EBM, compared with the former, to produce such an implant. An absorption costing methodology was adopted and data was gathered according the fixed, overheads and variable costs.

Results and Achievements

Increasing the STL file resolution always resulted in higher dimensional accuracy. On the other hand, increasing the beam focus offset on parts characterised by overhanging features, resulted in the formation of warpage. In the second set of experiments, when support structures were incorporated, dimensions attained were improved drastically, irrespective of the factors altered.

From the costings assessment, based on the first year of production, EBM deemed to be more expensive as the depreciation cost, which is directly related to the machine cost, is more expensive than that for CNC milling. Even more so, it was concluded that for such a low unit production, EBM is not feasible, however it shortens the lead time when compared with the former.

When surgeons evaluated the rings produced, they remarked positive feedback on the quality of parts and advised directions for future work.

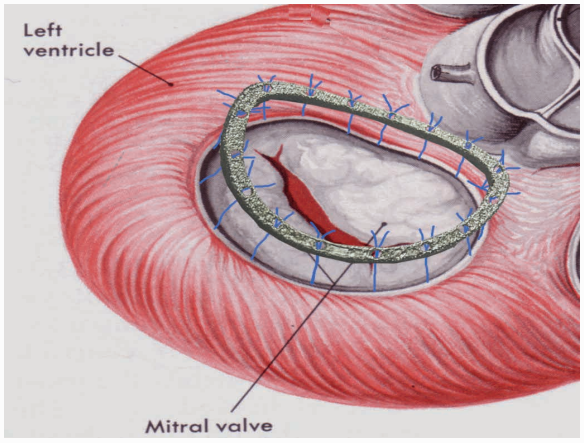

Figure 1: Superimposed Ring on the Mitral valve adapted from [2]

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An Experimental Test-bed for a Planar Underactuated Robot Hand

Student: Steven Grech / Supervisor: Prof. Ing. Michael A. Saliba

Introduction

Underactuated hands offer medium complexity end effectors for robots to grasp objects of varying shapes and sizes by adapting their configuration to wrap around the object. Advantage of this can be taken by implementing them in flexible industrial automation. This work is a continuation on research about their dynamic analysis and design optimization in [1].

Project Objectives

This project aims to design and develop a mechanism to switch a single actuator drive to subsequent gripper links together with a versatile and adaptive experimental test-bed for a planar underactuated robot hand.

Project Methodologies

Different mechanisms from literature and already implemented underactuated hands were scrutinized prior to engaging in the development of the new test-bed. In particular triggered mechanisms were considered as these adhere better to the work done in [1]. Triggered mechanisms feature mechanisms equivalent to or such as clutches in order to disengage motion from the first links of a gripper and to transfer motion to other links. The disengaged mechanisms may be also locked in place by means of non-backdrivable mechanisms such as worm and worm wheels. [2]

Triggered mechanisms for underactuated hands were not found to be common among literature and the most prominent were the ones found in [1] and [3]. Thus conceptual design of new mechanisms in order to strive for simpler ideas was performed.

Conceptual designs for the versatile test-bed were also generated after thoroughly considering the adaptabilities and parameters required in adherence to the work in [1].

Successively the conceptual designs generated for both areas independently were compared and a selection process was performed to strive for the best result of each while integrating both in a holistic system together with control and feedback.

Detailed design of the chosen concepts was then realized and optimized for manufacturing. The system was then manufactured and set up.

Results and Achievements

Through this project, the experimental test-bed in Figure 1 was developed and manufactured. It consists of a new underactuated switching mechanism, a versatile gripper and a control system. The switching mechanism switches a single actuator drive to subsequent gripper links in a sequential manner while certain parameters of the gripper can be varied depending on testing required. The control system controls the opening and closing of the gripper based on user inputs and feedback from force and position sensors. In addition, several conceptual designs of underactuated triggered mechanisms were presented which broaden the spectrum of designs in literature.

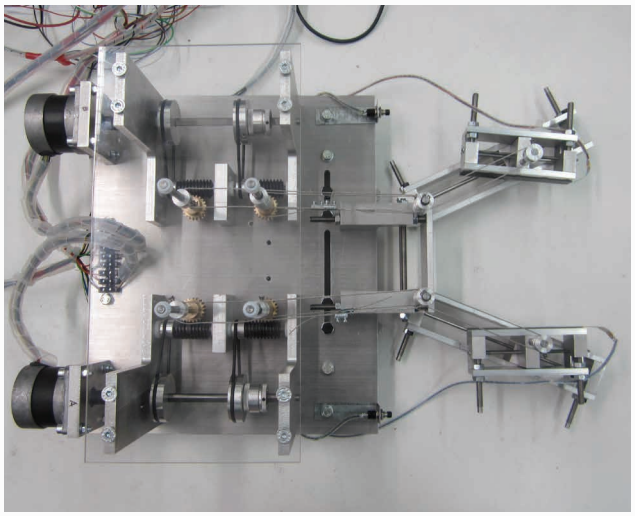

Figure 1: The Developed Test-bed

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Optimisation of an Automated Multi-Station Thermoforming Process for Packaging Production

Student: Julian Paul Scicluna / Supervisor: Dr Arif Rochman

Introduction

Playmobil Malta Ltd. is one of the leading companies which has been producing toy figures in Malta since 1972. This dissertation focused on two of the thermoforming production lines that are used by Playmobil Malta Ltd. to produce a packaging product for their toys. Analysis of the current processes, generation of improvements and implementation of the suggest solutions were carried out.

Project Objectives

The aim of this project was to understand and analyse the current thermoforming process by identifying the typical problems encountered during production. Recommendations methods in order to optimise the process were to be included.

Project Methodologies

As invented by Motorola, a DMAIC procedure: Define, Measure, Analyse, Improve and Control was used as the guideline for this project [1]. In the *Define* stage a case study was selected and observed so in order to familiarise with the process. Proper familiarisation with the process was needed to achieved positive results at the end of the project. The second stage was to *Measure* the current process. This was done by gathering as much data as possible through several tools. This data was useful so that a comparison between the current and the improved process can be done. A PFMEA together with a Pareto Chart were prepared to understand the current failure modes and their effect on the finished product. The next stage was the *Analyse* phase. Four main problems were identified. These were related to the formation of surface defects on the final product, the formation of chill marks around the sides of the container, the difference in material thickness and improper sealing. Suggested improvements were generated in the fourth stage of the DMAIC procedure, *Improve*, which included modification to the current mould where vacuum holes on the surface of the mould were shifted to the edge of the mould to reduce surface defects by 80%. Other improvements were considered by altering the current process itself and by altering the forming temperature. Finally in the *Control* stage ways of implementing the above suggestions was seen.

Results and Achievements

Some results can be shown as follows. Figure 1 shows the modification suggested to the current mould where vacuum which are circled in red were shifted from their old positions (Figure 1a) to their new position (Figure 1b). Upon testing of the new mould it was observed that surface defects where reduced by 80% whilst still having the desired quality and finish of the part.

In the case of altering the forming temperature, it was observed that a slight increase in the forming temperature resulted in a better wall thickness distribution of the container. In addition to that, a better seal to the container was seen.

Reducing the pre-blowing or pre-stretching rate of the thermoforming process resulted in a reduction in chill marks formation around the part. This would lead to higher customer satisfaction since with less chill marks the products packed in the container can be easily viewed.

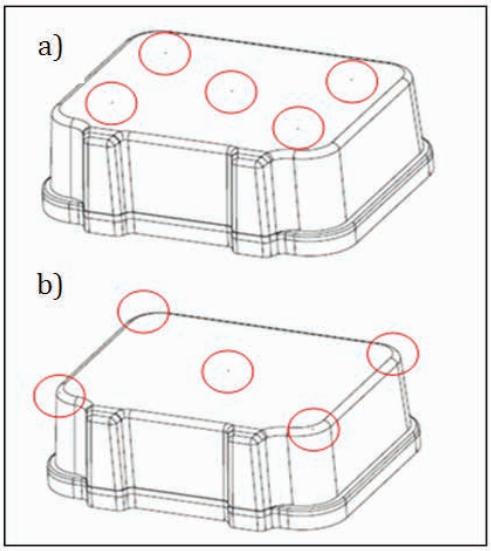

Figure 1: a) Current mould used at Playmobil Malta Ltd. b) New mould designed

References

[1] Dmaictools.com, 'Learn DMAIC in Five Minutes - Define, Analyze, Measure, Improve, Control', 2015. [Online]. Available: http://www.dmaictools.com/.

Design of a Hinged Hermetic Compact Case

Student: Elaine Zammit / Supervisor: Prof. Ing. Jonathan C. Borg / Co-supervisor: Mr Olaf Zahra

Introduction

Hermetic or air-tight sealing, is vital in the cosmetic industry especially now that water-based formulas are becoming more popular among customers. However, one of the downsides of such formulas is that these contain volatile substances that are prone to evaporate when stored or exposed to certain environments. Water in particular, which is present in large amounts dries up more quickly and thus this leads to drying and cracking of the formula.

Project Objectives

The aim of this project, carried out in conjunction with Toly Products Ltd was to design a compact case that is fully hermetic yet concurrently addresses aesthetics, performance, manufacturability and keeping costs low. The different concepts devised were then evaluated and prototyped in full.

Project Methodologies

The route taken to devise the solutions followed the 'Basic Design Cycle' [1]. This involves a number of steps that guide the designer throughout the design process. First, the case-study provided by Toly Products Ltd, a hinged compact case that lacked full hermeticity, was analyzed. Possible causes of its shortcomings were listed and concepts were generated that addressed the shortcomings. A decision matrix was used in order to rank the proposed solutions according to the criteria of aesthetics, manufacturability, ergonomics and hermeticity. To help the ranking process, information was obtained on the industrial and customer perspectives through a survey. Prototypes were then designed and built in order to test a compact case concept that provided the best hermeticity. Two tests were conducted. The first was a leakage test which involved filling the prototypes with a dye and placing them in a container full of water. These were then pressurized in order to find out if there was any leakage. The second test involved filling the prototypes with an actual water-based formula, sealing them, and placing them in a heating chamber. The prototypes were exposed to a temperature of 50°C for 21 days. The weight readings were recorded and tabulated for this period. The concept that provided the best hermeticity was then chosen for manufacturability analysis and finally established as a solution for the given case-study. Manufacturability analysis included considering the impact of the solution on tool design complexity and cost.

Results and Achievements

A hermetic solution was achieved by creating a novel powder pad which has a dual-function: one side of the pad serves the user as applicator; the other side serves as a sealing element to the formula when inserted in its designed cavity. The 3D virtual model of the solution generated is illustrated in Figure 1.

Based on the tests carried out, this solution is expected to increase the shelf-life of the cosmetic formula and prevent it from drying up or cracking prematurely. The proposed solution is a simple design which meets the defined criteria, namely, a product that is of low cost, aesthetically pleasing, easy to manufacture, and efficient to use. All this makes this compact case a must-have item with superior marketability when competing with other products of its genre.

Figure 1: Virtual Model of Solution

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Development and Performance Analysis of Injection Moulding Tools Fabricated Using Additive Manufacturing

Student: Robert Zammit / Supervisor: Dr Arif Rochman

Introduction

In injection moulding (IM), the product development time is greatly influenced by the tool manufacturing stage. When using rapid tooling (RT) to manufacture tools for a variety of production volumes, the tool development time is greatly improved, when compared to traditional manufacturing techniques. Furthermore, this will greatly reduce the product development time, which gives competitive advantage over other companies which do not use RT [1].

Project Objectives

The most important objectives set in this project are:

- To choose a RT technique to fabricate tool inserts.
- To choose a tool material, which gives the desired properties to the tool.
- To design a conformal cooling channel in the inserts and sliders.
- To test the cooling efficiency of the designed cooling channels.
- To manufacture the cavity inserts and the sliders.
- To test the designed cooling channels in an IM trial.

Project Methodologies

The solution development stage started by choosing the RT system to be used and the tool material. Both choices were done with great attention, as these will have a great effect on the final results. These choices were mainly based on the tooling requirements. The solution development stage was continued by designing the conformal cooling channels in each part of the IM tool. To translate the computer-aided design models into a manufactured tool, pre-processing and post-processing tasks were done. The pre-processing operations included tasks such as such as offsetting. While, post-processing operations included tasks such as machining. The IM tools were tested in an IM trial run.

Results and Achievements

From the simulation done to compare the cooling characteristics of the conformal inserts to the conventional inserts, it was found that the conformal inserts have better cooling characteristics. Therefore, the cooling time for the conformal inserts was decreased. When the parts were fabricated using selective laser melting (SLM), the different parts were measured, finding that the dimensional accuracy and the surface roughness do not vary significantly between different orientations. This means that the level of anisotropy, which is associated with additive manufactured parts, is reduced. This is mainly the effect of the pre-processing tasks which were carried out beforehand. The parts produced using SLM can be seen in Figure 1. In the IM trial, a high quality product was produced at a reduced cooling time. In fact, the cooling time was reduced from 60 s to 45 s. This reduction in the cooling time can be contributed to several changes. However, the choice of the tool material and the design of the cooling channels are considered to have a significant effect. Therefore, it was concluded that when using RT, having an optimal tool material and conformal cooling channels, can lead to a reduction in the cooling time.

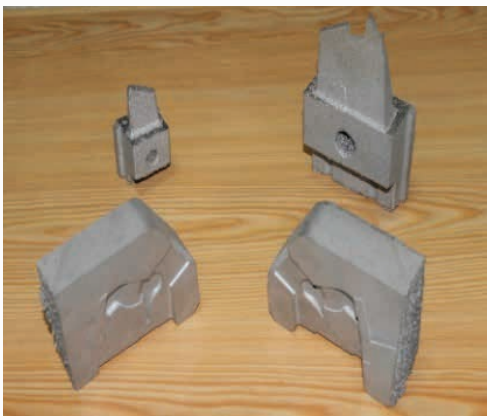

Figure 1: Two inserts and sliders fabricated using SLM

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Investigating the Performance of Offshore Floating Wind Turbines Under the Influence of Wind Shear and Turbine Yaw

Student: Marco Abela / Supervisor: Prof. Tonio Sant

Introduction

Advancements within the wind energy sector have pushed wind turbines to deeper waters. Floating Offshore Wind Turbines (FOWTs) use ballasting and mooring lines to support the turbine. This technology is relatively new, and the motivation of this study was to help investigate a specific 5 MW Tension Leg Platform (TLP) FOWT. By using wave conditions typical to the central Mediterranean, the 5 MW TLP FOWT output was investigated under changing wind shear and turbine yaw, with an underlying application for Maltese waters.

Project Objectives

The aims of the project were to analyze the generated power, rotor axial thrust, platform motions and resulting tower-top displacements. FOWT simulations used varying wind shear exponent and rotor yaw to investigate the effects under these conditions. Their combined effect was also analyzed, and comparison was given to simulations generated for a similar fixed land wind turbine. The project also aimed to investigate changes within the most probable Mediterranean wave conditions for the chosen wind.

Project Methodologies

Computer models for a 5 MW fixed land turbine and 5 MW TLP FOWT were created. Simulations were conducted for varying wind shear exponent from 0 to 0.25 and rotor yaw from 0° to 50°. Combinations of wind shear and yaw were also simulated, and two different aerodynamic models were implemented for each condition. This allowed for observation of the resultant effects from these differing models. Finally, changing wave heights and periods were considered. Their effect on the output represented the most probable wave effect for the applied rated wind speed of 11.4 m/s on the wind turbine models.

Results and Achievements

All the produced outputs were seen to fluctuate significantly for the TLP FOWT when compared to the fixed turbine. This was expected due to the imposed hydrodynamic conditions. Above this, mean generated power and rotor thrust were seen to decrease with increasing shear and yaw. Figure 1 shows the effect of shear on the general rotor thrust output. Figure 2 shows the effect of yaw on the mean generated power. Fluctuations within the output increased significantly, with a more notable effect produced under increasing yaw. The significant platform displacements were also observed. Under wind shear, platform surge was mainly affected, and a small reduction in mean value was coupled with increased oscillations. Under rotor yaw, platform motion increased, with all of the surge, sway, pitch and yaw seeing significant displacements and fluctuations. Finally, changing wave conditions caused no change in mean. However, increasing wave height (H_w) produced increased oscillations in results. Moreover, wave period (T_w) increased oscillations at the lower simulated value of 4.5 s, as this approached the TLP FOWT's natural frequency.

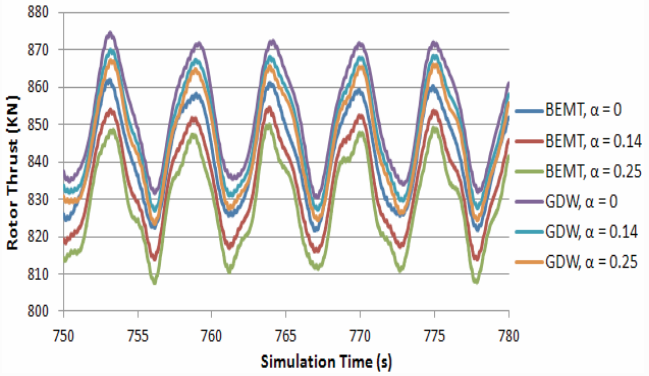

Figure 1: Graph of Rotor Axial Thrust (KN) Against Simulation Time (s) for the TLP FOWT. H_w = 1.5 m, T_w = 5.5 s

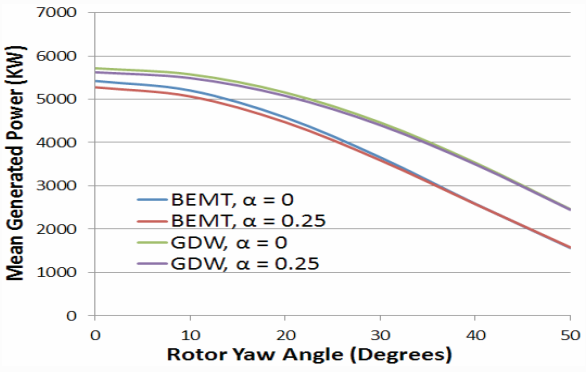

Figure 2: Graph of Mean Generated Power (KW) Against Rotor Yaw Angle (Degrees) for the TLP FOWT. H_w = 1.5 m, T_w = 5.5 s

Experimental and Analytical Analysis of an Industrial Cooling Tower

Student: Ismael Aquilina / Supervisor: Dr Ing. Mario Farrugia

Introduction

Evaporative coolers are designed to cool the process fluid as it passes through the tube bundle, by the inlet air passing through the bundle and deluge water sprayed over the tubes.

Project Objectives

Measure the evaporative cooler parameters, conduct a performance analysis and compare the dry and wet mode of operation using an analytical model present by Kroger.[1] Build an Accutube to measure the process fluid flow rate.

Project Methodologies

The performance of the evaporative cooler was analysed by varying the inlet air mass flow rate, by changing the inlet air area of the evaporative cooler with the use of a curtain, and rating its performance according to the Approach, Range and Effectiveness. The Vaisala HMT 120 temperature/humidity sensors, averaging Pitot (to measure process fluid flow rate), Pitot Static tube (to measure the inlet mass flow rate), flow meter (to measure loss in make-up water), and thermometers (to measure process fluid temperatures) gave the necessary measured parameters to analyse the evaporative cooler performance. An Averaging Pitot Static tube was also built specifically for this dissertation and was tested, calibrated and used to measure to inlet process fluid flow rate.

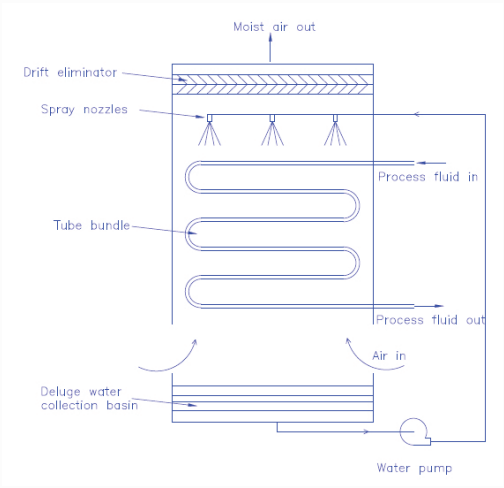

Figure 1: Closed Circuit Evaporative Cooler

Results and Achievements

Using the trends from the works of De Backer and Wurtz[2], the wet mode operation and dry mode operation were compared and the impracticality of the dry mode operation for this evaporative cooler was determined. The performance of the evaporative cooler was also rated according to three parameters. These are the Approach, Range and Effectiveness. By varying the air mass flow rate it was shown that the Approach decreases as the air mass flow rate increases, whilst Range and Effectiveness increases with an increase in air mass flow rate.

A discrepancy between the calculated evaporated water and the measured loss of makeup water was observed. It is believed that the reason behind this was that droplets of water, not mist, could be escaping from the evaporative cooler.

References

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

[2] L. De Backer and W. M. Wurtz, “Why every air-cooled steam condenser needs a cooling tower,” *CTI Report, TP03-01*, 2003.

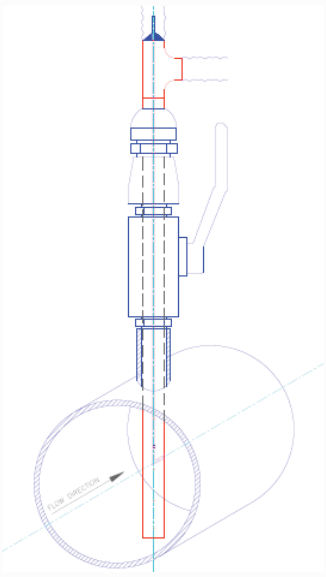

Figure 2: Accutube inserted in Test Pipe

Design, Test and Build of CAI Apparatus to Determine the Compressive Residual Strength of Marine Grade Laminate Panels

Student: Jan Bonello / Supervisor: Dr Ing. Claire De Marco

Introduction

During fabrication, machining and use, composite laminate panels are subject to a variety of impacts, one of which is simulated by quasi-static indentation (QSI). QSI can cause barely visible impact damage (BVID), influencing the residual properties of the composite material. The compressive residual properties of composite laminate panels are determined through compression after impact (CAI) tests.

Project Objectives

The main aim of this work is to design, test and build a CAI test fixture (based on ASTM D7137M [1]) for the determination of composite panel residual properties. Marine grade composite laminate panels shall be designed fabricated, indented according to ASTM D6264M [2] and tested in the CAI apparatus according to ASTM D7137M [1]. The results from the indentation tests will be used to characterize the contact behaviour of the composite laminates. Results from the CAI tests will be used to determine the residual properties of the laminates.

Project Methodologies

The composite laminate specimens, composed of E-glass fibres and a polyester resin matrix, were fabricated using the hand-layup technique. The specimens were then subject to QSI indentation, using a rigidly backed configuration. QSI was carried imparted using two different indenter geometries (hemispherical and cylindrical). Indentations were effected to two different indentation depths. The indented specimens were subsequently CAI tested in the fabricated apparatus. The CAI test fixture was aligned within the compression machine, and a compressive load was applied until the specimen failed.

Results and Achievements

Results from QSI testing indicated that more resistance was offered to the cylindrical indenter than the hemispherical indenter; due to the different indenter geometry. Additionally, the contact law governing hemispherical indentation was found to have an exponent index close to unity, as suggested in literature [3]. The damage areas imparted to each specimen were also manipulated statistically resulting, that for a given indentation depth, the cylindrical indenter imparts a larger damage area.

Additionally, the damage area for each indenter increases with indentation depth. Results from CAI tests indicated that overall the results involved a significant amount of scatter, indicating the test population was too small. Additionally, a number of specimens did not experience CAI failure at the indentation site. The compressive ultimate residual strength for all specimens lied within the same range, indicating that the results are representative of the ultimate compressive strength of the un-indented specimens. The effective compressive modulus is not directly influenced by the indentation damage and all specimen tests reaped similar results in this regard. The results also compared well to theoretical predictions of the mentioned properties corresponding to the un-indented material. The CAI specimen failure modes were also discussed in detail.

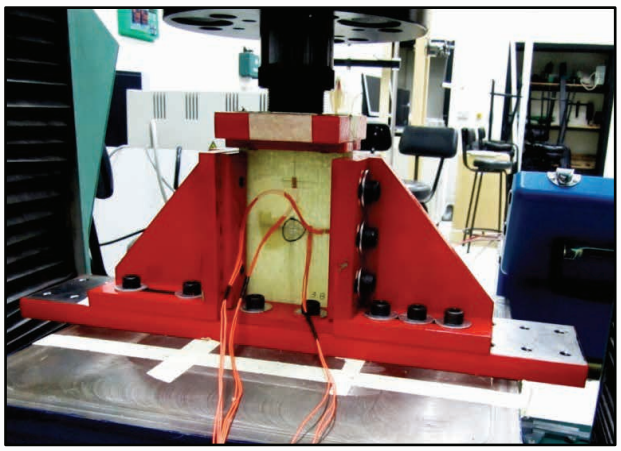

Figure 1: Photograph of the CAI experimental

References

[1] *ASTM Standard D7137M, 2007, "Standard Test Method for Compressive Residual Strength Properties of Damaged Polymer Matrix Composite Plates", ASTM International, West Conshohocken, PA, 2007, DOI: 10.1520/D7137_D7137M-07, www.astm.org.*

[2] *ASTM Standard D6264-98, 1998 (2004), "Standard Test Method for Measuring Damage Resistance of Fiber-Reinforced Polymer-Matrix Composite to Concentrated Quasi-Static Indentation Force", ASTM International.*, West Conshohocken, PA, 2004, DOI: 10.1520/D6264_D6264-98, www.astm.org.

[3] S. Abrate, "Contact Laws," in *Impact on Composite* Structures. Cambridge, United Kingdon: Cambridge University Press, 1998, ch. 2, pp. 6-25.

Investigation the Effect of Rotating and Stationary Ducts in Electrical Machines

Student: Adrian Borg / Supervisor: Dr Christopher Micallef

Introduction

As electrical machines became more powerful and more efficient, thermal management becomes more of a concern. The heat generation and dissipation is one of the largest limiting factors in electrical machine design. Various types of ventilation were developed to overcome this problem, including axial and radial ducts through the machines.

Project Objectives

The project aimed to investigate the effects of these ventilation systems through numerical modelling techniques (CFD). The effects of different setups on the flow through the radial ducts were investigated. Correlation between the different setups and flow through the radial ducts was developed.

Project Methodologies

Validation tests of the rotating reference frame technique was performed. A CFD model was setup to obtain results that could be compared to experimental results gathered in a concurrent project.

After validating the modelling technique, a total of five different radial duct alignments were modelled, ranging from in-line to a staggered duct. This involved generation of geometries, meshing for each of the setups, setup of boundary conditions and solving the numerical models using FLUENT®.

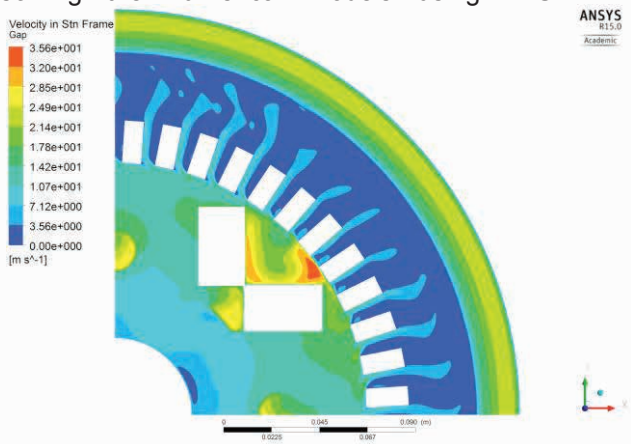

Figure 1: Velocity contour plot through the centre of the radial duct of the in-line model

inspected and comparisons between the various models was performed.

A final model with axial rotor ducts blocked at the far end was generated and simulated. This followed a similar process to that of the other models and was compared to the results of the original model.

Results and Achievements

The results of the validation tests were positive with the simulated model having a similar mass flow rate to that of the experiment, proving that the rotating reference frame technique is valid for this application.

The first motor model gave an initial understanding to the flow present through the radial duct, showing some air flowing into the stator duct (Figure 1). A number of significant results were realised. It was shown that the in-line setup experienced higher flow than the other setups. The difference in mass flow rate between the in-line and staggered model was as high as 25%. A steady decrease in the mass flow rate was observed through the results of each of the models as the radial ducts became more misaligned (Figure 2).

When the axial rotor duct was blocked at the far end, the mass flow rate through the radial duct increased to nearly twice that of the in-line model. This however also results in a lower flow through the axial duct itself.

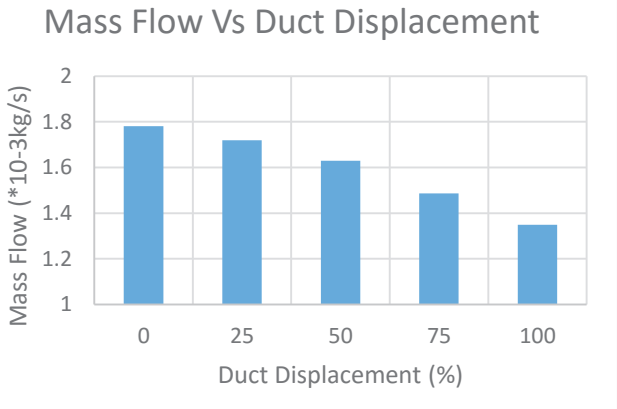

Figure 2: Mass flow rate variation in the models with different duct misalignments

An Experimental and Modelling Framework for Liquid-Cargo Sloshing in Marine Vessel Hulls

Student: Mitchell Gareth Borg / Supervisor: Dr Simon Mizzi

Introduction

Sloshing describes the induced dynamic motion of a free-surface liquid found to occur in various engineering applications; from cargo-tanks on LNG carriers, to propellant-tanks on air and spacecrafts.

Cargo-tanks undergoing violent ship-motions may drive a free-surface liquid to shift with enough excitation to create a strong sloshing flow, which may, ultimately, induce instability and structural damage. [1]

Project Objectives

Due to the detrimental nature of sloshing, the primary objective of the project was to determine and develop means with which this effect may be studied.

Once the setup was fabricated, the secondary objective was to apply suppression devices to hinder the liquid-sloshing dynamics. Upon success, these methods were to be then simulated on software to achieve numerical validation.

Project Methodologies

A pendulum-tank experimental setup was created to model the rolling effect of small-amplitude liquid-sloshing inside a partially-filled modified-rectangular cross-sectional tank.

The tank is initially displaced by a stipulated peak-angle, and allowed to freely oscillate until the tank came to rest. This method was then used for five distinct fill-levels, which have been considered to investigate the influence of the fill-level in a tank on the dynamic-slosh behavior.

This influence has been analysed with regards to three tank setups, which induce a degree of porosity within a partition placed in the line of symmetry of the tank cross-section. The setups consist of an open-bore tank (100% porosity), a partitioned tank (0% porosity) and a perforated-partitioned tank (50% porosity).

Results and Achievements

With regards to the experimentation, two specific quantitative aspects were derived to inspect the damping qualities of the internal structures applied; (i) the time elapsed for the tank to come to rest, (ii) the maximum increase/decrease in torque within a single oscillation.

The figures below depict the distinct tank setups at a 75% fill-volume. To put forward an example, the open-bore tank comes to rest within the least elapsed time. However, the setup also possesses a detrimental torque increase, inducing instability, as depicted in Figure 2. Upon comparison, it was concluded that the perforated-partitioned tank achieves the most ideal result.

Two-dimensional numerical models of the open-bore and partitioned tank physical models were created and undergone simulation at a 50% fill-volume, which achieved good agreement with the experimentation.

References

[1] R. A. Ibrahim, “Liquid Sloshing Dynamics: Theory and Applications,” Cambridge University Press, Cambridge, United Kingdom, 2005.

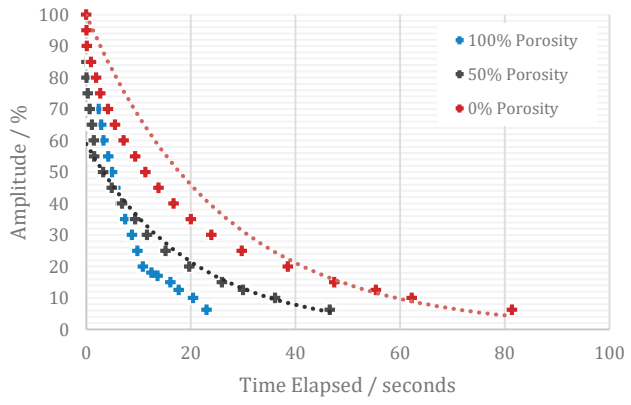

Figure 1: Decaying Time-Response of Initial Signal

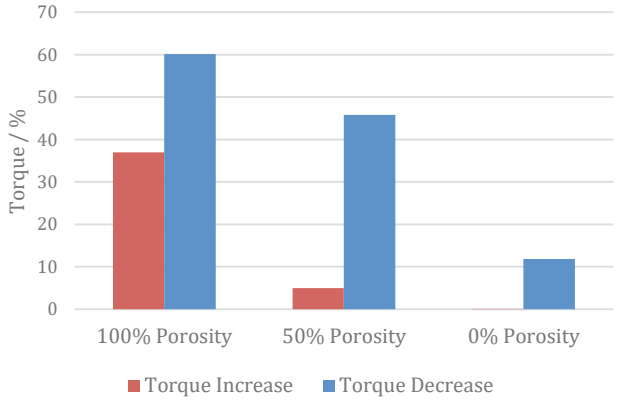

Figure 2: Maximum Load-Shift per Oscillation

Design of Structural Joints

Student: Dinah Brincat / Supervisor: Prof. Ing. Martin Muscat

Introduction

The main idea of this project was to verify and validate the methods for the design of structural connections focusing on bolted joints presented by EUROCODE EN1993 1-8: Design of Joints. [1] Different lap joints were subjected to a tensile load until the maximum load carrying capacity was found.

Project Objectives

The objectives of this project were to identify the design methods used by the standard EN1993 and to design different lap joints accordingly to this standard. Then, fabricate and test the designed bolted connections, perform finite element analysis to identify the maximum load carrying capacity and compare the results and identify if the standard used is conservative or not.

Project Methodologies

The sizing of the designed lap joints was influenced from standards EN1993 and MSA EN ISO 12996:2013. [2] A plate of 2mm with a yield strength of 343MPa, and tensile strength of 406.5MPa was drilled at the appropriate edge distance to create a bolted connection. The connections were assembled by an M3 x 12 bolt, having a yield strength of 578MPa and tensile strength of 946MPa. Figure 1 shows one of the designed lap joints having four bolts. Each bolted connection was fabricated and tested using a tensile testing machine, INSTRON 4206, at a speed rate of 10mm/min until the bolted connection failed.

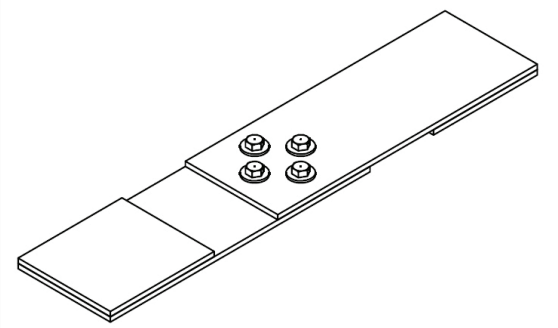

Figure 1: Four bolted lap connection

Finite element analysis (FEA) software ANSYS 14.0 was used to perform stress analysis on the lap joints by taking SHELL and BEAM elements to create the bolted connection and identify the maximum load carrying capacity.

Results and Achievements

Table 1 shows the results obtained from the FEA analysis by using an elastic perfectly plastic and multilinear material, the experiment, and the calculated allowed load from EN1993. A higher load carrying capacity of the bolted connections resulted when comparing the FEA and experimental approach to the EUROCODE 1993 calculated values. However, further testing and analysis is required for the eccentrically loaded lap joint as results did not compare well with the three methods of analysis.

The objectives of this project were met and it was concluded that the EUROCODE 1993 code of standards was in fact conservative FEA and experimental analysis clearly indicate that the lap joint would fail at a higher load.

References

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

[2] Malta Competition and Consumer Affairs Authority, Mechanical joining-destructive testing of joints MSA EN ISO 12996:2013

No. of Bolts	Numerical Computational Ultimate Load		Experiment Ultimate Load	Eurocode 1993 Allowed Load
	Elastic Perfectly Plastic Analysis (kN)	Multilinear Analysis (kN)	(kN)	(kN)
1	2.60	6.38	6.40	2.21
2	6.20	7.30	6.50	4.42
4	11.30	14.00	14.00	8.84
4 Eccentrically Loaded	2.80	4.00	2.49	9.16

Table 1: Ultimate Load Results found using EUROCODE 1993,FEA and Experimental Approach

Design, Simulation and Analysis of a Sailing Yacht Hull

Student: Antonio Camilleri / Supervisor: Dr Ing. Claire De Marco

Introduction

Creating a concept design of a sailing yacht consists of various stages. The initial stage requires designing a hull according to the desired shape from which further estimations and analysis can be carried out. A sailing yacht design considers both hydrodynamic and aerodynamic analysis. This project will focus mainly on hydrodynamic force analysis.

Project Objectives

The project objectives consisted of selecting the hull parameters for a 30m sailing yacht, creating the hull design, estimating the required engine power, estimating the sail area, mast and keel dimensions, ballast weight and analyzing stability criteria.

Project Methodologies

The hull design for a 30m sailing yacht is created from initial stages, thus generating the shape of a hull and obtaining the lines plans for the sailing yacht hull (Figure 1). Hydrostatic calculations are carried out, from which the shape of the hull is defined according to coefficients and parameters. The total hull resistance is estimated using standard series data for the NPL series and the Delft Systematic Yacht Hull Series. Software packages, *Maxsurf* [1] from *Bentley Systems* and *Wolfson Unit Software* [2] are used to cross check the resistance values obtained for the standard series methods used. A suitable engine is selected, thus determining the weight of the engine a required parameter used to locate the centre of gravity. All the lightweight and deadweight components of the yacht are estimated and thus the centre of gravity is located.

Weights of the mast and keel together with the required sail area are estimated using data from existing sailing yachts. Stability analysis is carried out using simulations, following the criteria from, *International Code on Intact Stability, 2008* [3] by the IMO, the standard *12217-2:2013* [4] by the ISO and the *Commercial Yacht Code* [5] by Transport Malta (TM). A velocity prediction program (VPP), *Span* [6] is used to simulate and predict velocities that the sailing yacht can attain at different wind speeds.

Results and Achievements

Results obtained for the total hull resistance from standard series data are used to estimate the required installed power and a suitable engine is selected. All the weights and compartments on the yacht are defined thus determining the lightweight and deadweight of the yacht thus the corresponding position of the centre of gravity is defined. The sail area, mast and boom dimensions and their corresponding weights are estimated from available data of existing sailing yachts. A simulation for stability analysis is carried using *Hydromax* [7] for a number of applicable criteria set by *IMO* [3], *ISO* [4] and *TM* [5]. A keel size was estimated from a model yacht used in a towing tank test and used for a velocity prediction simulation. At moderate wind speeds, the sailing yacht can reach the designed hull speeds.

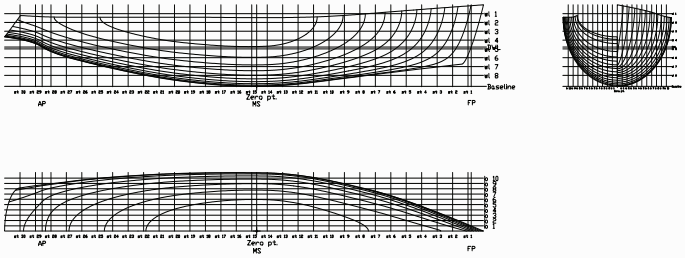

Figure 1: Lines plan for the designed hull

References

[1] Bentley Systems. *Maxsurf - Maxsurf Software Modules* 2014 .
[2] Wolfson Unit MTIA. *Power Prediction Program* 2015 http://www.wumtia.soton.ac.uk/software/power-prediction-program.
[3] IMO, *International Code on Intact Stability.* MSC. 267(85), London 2008.
[4] International Standards, "Small Craft - Stability and buoyancy assessment and categorization- ISO 12217-2:2013," 2013.
[5] Transport Malta and Merchant Shipping Directorate, *Commercial Yacht Code.* 2010.
[6] Bentley Systems. *Span - Maxsurf Software Modules* 2014 .
[7] Bentley Systems. *Hydromax - Maxsurf Software Modules* 2014 .

Velocity Measurements in Rotating Channels

Student: Daniela Camilleri / Supervisor: Dr Christopher Micallef

Introduction

Numerous applications in engineering systems, such as the combined radial and axial ventilation in alternators, involve flow in rotating channels. This type of flow is more complex than that in stationary ones and therefore this type of fluid flow was investigated.

Project Objectives

The aim of this project was to establish the most feasible instrumentation setup for measuring the airflow rate in rotating ducts. In order to simulate rotating ducts and the flow within them, a test rig was designed and constructed.

Project Methodologies

The test rig (figure 1) consisted of a pipe bent at 90° in order to simulate the axial and radial vents in an alternator. The pipe was rotated on its own axis by means of an electric motor. Alignment of the pipe with the motor shaft was achieved by means of an aligning fixture and a bearing at the end of the pipe.

The instrumentation chosen to measure the velocity of the airflow inside the pipe was hot wire anemometry. Hot-wire sensors operate by transmitting a voltage signal which is directly related to velocity of the airflow.

Two hot-wire sensors were placed inside the pipe, however different setups were used. A stationary single sensor was placed at the entry region, while another probe was constructed to rotate with the pipe and was placed at the fully developed region. In order to transmit the voltage signal, rotating hot-wire probes require the use of slip rings. This rotating sensor under such a setup was tested in order to ensure that the results obtained were reliable.

In order to determine a relationship between the output voltage of the anemometer and the velocity, the hot-wire probe had to be immersed in an airstream. Once calibration was carried out, the hot-wire sensor could therefore be used to determine the airflow velocity within the pipe.

Results and Achievements

Results from the tests carried out on the rotating hot-wire showed a time variation in resistance due to the contact of the rotating slip rings with the stationary brushes. Therefore, this setup would result in incorrect results as the electronic circuit would interpret this change in resistance as a change in velocity. Kirchoff and Struziak [1] showed that this issue can be overcome by using a printed circuit for the electronic circuit and rotating it with the probe. In this way, the only leads passing through the slip rings would be that of the power supply and the amplified signal out.

Therefore, the velocity of the airflow in the pipe was only analyzed by the sensor at the entry region. Results showed that by increasing the input frequency of the electric motor, the magnitude of the velocity increased, however the swirl component remained at a relatively constant value.

Figure 1: Setup of the Test Rig

References

[1] Kirchoff R.H. and Struziak R.M., 'Direct Measurement of the Mean Flow Velocity Vector' J. Fluids Eng, 1976, Vol. 98, No. 4, pp. 736-739

Validation of the Sternal Foam Model Results

Student: Justin Catania / Supervisor: Dr Ing. Zdenka Sant

Introduction

Median sternotomy is one of the most common surgical procedures, where an incision is performed on the patient's sternum such that the surgeon has access to the internal chest organs. After the sternotomy procedure the two sternal halves are approximated and are closed via suturing. Even though complications are not common but, when present this could lead to sternal dehiscence and mediastinisis, which have a high mortality and morbidity rate in the region of about 10 to 40 per cent.[1]

Project Objectives

The main objectives of this project were to verify the results from computational simulation and to identify the locations of the extreme strains as they develop on the surface of the sternal foam model, due to the applied load. Improvements on the existent testing frame were required to verify the stress strain distribution within the sternum.

Project Methodologies

Theoretical background enabled a better understanding of the subject and a better way to reach the aims of this project. Number of innovations on the already existent test frame were carried out to achieve better experimental results. All the improvements done were individually tested providing confirmation about the positive effect of all new developments. The foam model was attached to wire ropes via epoxy resin and mounted on the testing frame as shown in figure 1.

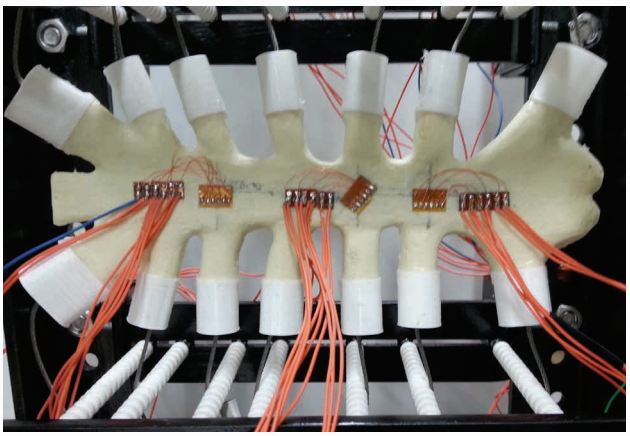

Figure 1: Sternum model mounted in testing frame

Since the model has seven wire ropes on each end 'E-cell' load cells were used on each wire to calculate the tension within each wire. All the wire ropes were connected to the Instron tensile testing machine such that testing could take place.

The testing was conducted with the load increasing gradually and at each load step the strain measurements from E-cells and strain gauge rosettes were recorded. The E-cell measurements converted into loads via a conversion equation obtained from calibration, were applied to FE model to simulate the experiment. The principle strain magnitudes and directions were then calculated from the strain gauge rosette measurements.

Results and Achievements

The comparison of results obtained from finite element simulation and the experimental testing was carried out between the principle strain magnitudes and directions. This comparison study verified the computational model. Figure 2 shows the first principle strain distribution for the finite element model with labelled rosette locations.

References

[1] A. R. Casha, A. Manché, M. Gauci, M.-T. Camilleri-Podesta, P. Schembri-Wismayer, Z. Sant, R. Gatt, and J. N. Grima, "Placement of trans-sternal wires according to an ellipsoid pressure vessel model of sternal forces," Interactive Cardiovascular and Thoracic Surgery, vol. 14, no. 3, pp. 283–287, 2011.

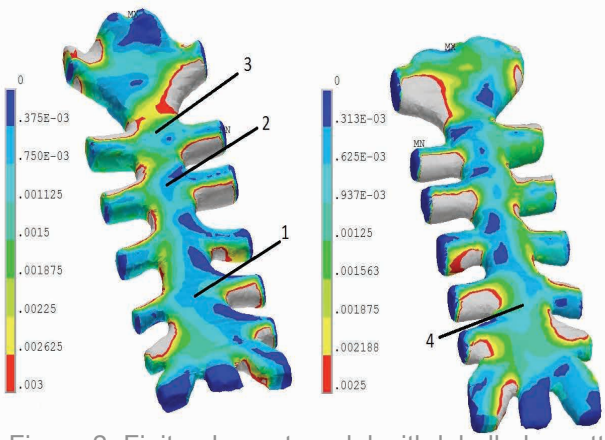

Figure 2: Finite element model with labelled rosette locations: left – front, right - Back

Easy Stand-up with Aid

Student: Karen Chase / Supervisor: Dr Ing. Zdenka Sant

Introduction

Rising to stand from a seated position is a fundamental activity in the daily lives of independent human beings [1]. However, when a person's lower limb muscles weaken, for whatever reason, their ability to rise from a seated position suffers greatly, as large amount of muscle force are required. The inability to stand up easily induces a sedentary life, despite the possibility that the person is still able to perform other activities. This causes muscle atrophy, and further reductions in muscle strength. It is therefore important to provide people who have weak lower limb muscles with rising aids, enabling them to rise from a seated position unassisted, and thus, continue with an active lifestyle.

Project Objectives

- Design an aid to reduce the muscular forces required to stand up, and the reaction forces and moments at the joints, which must be overcome.
- Analyse the transfer of forces in the lower legs while rising to stand.

Project Methodologies

Sit-to-Stand (STS) tests, using motion capture technology and surface electromyography (sEMG), were carried out in order to determine the attributes of STS with healthy muscles. Six large, superficial muscles mainly contributing towards STS, were tested and analysed. Muscle activity was measured and a relationship between muscular activity and muscular force was developed. Static equilibrium models were developed in order to calculate the forces and moments at the joints, first excluding and then including muscle forces. The results were used in order to design and fabricate an aid. It was decided that the aid would be dynamic, moved using torsion springs. The tests were carried out once more, using the aid.

Results and Achievements

The relationships between muscle activity and muscle force developed were satisfactory and in tandem with literature on the subject.

The model developed for calculating the forces and moments at the joints was deemed inaccurate as the equations used did not take into account dynamics. The STS aid was unable to commence movement with the added weight of a person seated on it, due to parallel reaction forces. The addition of an activator spring could be added in order to create a non-collinear force.

At its initial static position, the aid was raised upwards and anteriorly, which caused the forces in three of the examined muscles to lessen. However, the other three muscles displayed an increase in the muscular forces required to complete the STS movement. The muscular forces during the STS movement were compliant with literature and the body movement.

Reaction forces and moments at the test subject's joints also increased, apart from the vertical forces, which decreased (also due to the static position of the aid).

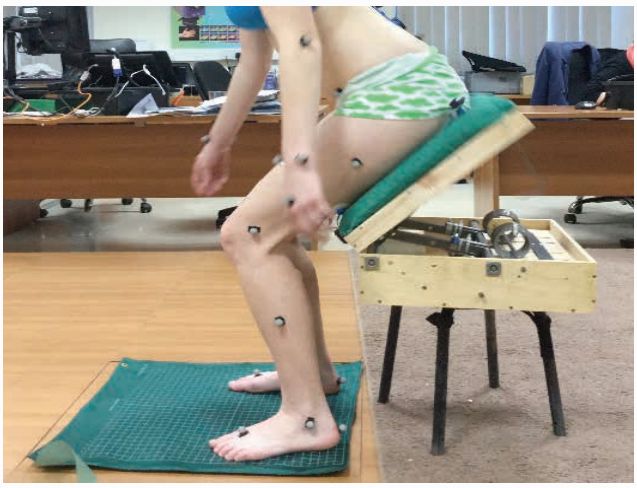

Figure 1: Aid in use during testing

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Modeling and Analysis of an Offshore Wind Turbine Coupled to a Positive Displacement Sea Water Pump

Student: Denis Dalli / Supervisor: Prof. Ing. Tonio Sant / Co-Supervisor: Ing. Daniel Buhagiar

Introduction

Recent trends in the Offshore Wind Energy sector have been shifting from the standard gearbox and electrical generator assemblies to a more reliable hydraulic transmission system. Part of this system includes a variable displacement digital displacement pump. This pump could also use sea water as a hydraulic fluid, which would be highly beneficial for offshore projects, due to its unlimited availability.

Project Objectives

The main objective of this project was to develop a mathematical model for a digital displacement sea water pump, and then model it using a Matlab software package such as Simulink. This computational model was to be coupled to a similar model of the wind rotor, already available.

Project Methodologies

The mathematical model derived for the pump included both mechanical and hydraulic modeling. First the overall pump mechanics were considered, followed by similar modeling of individual pistons in the pump. This involved both kinematic and kinetic relations between the different pump components. The mechanics of these pistons was then combined with their hydraulic models which had also been derived. These models were then implemented in Simulink using standard modeling blocks which were adapted to suit the exact relations derived in the mathematical models. Simulations were tested out for the entire pump under full loading and partial loading conditions. Further tests were done to simulate pump operation under greater hydraulic pressure operation.

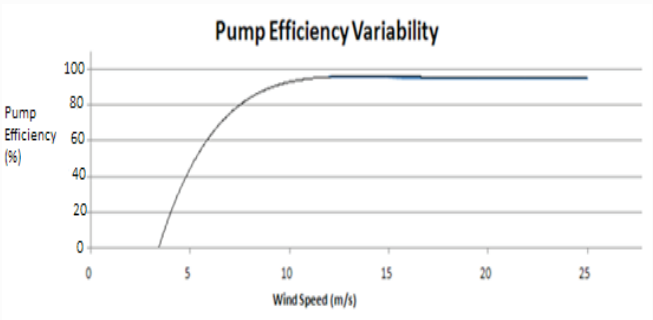

Figure 1: Pump Efficiency Curve

Results and Achievements

Results were obtained both on an individual cylinder model and also on the complete pump model. Plots for piston positions and forces were some of the results obtained, together with the volumetric outputs of pressurized fluid and torques generated on the pump shaft. Comparisons were made between the three main operating conditions used. These comparisons managed to identify the main source of pump efficiency losses under part loading conditions. This was found to be the force used up by the piston when pushing unpressurized fluid back out of the low pressure valve of the cylinder. The results of the individual cylinders agreed with the expected results, and gave good insight into operation at part loading conditions. Similar tests were performed for the complete pump. Individual pistons would generate flow output and torque intermittently due to the two distinct portions of cyclic operation of a piston, the filling and discharging strokes. With the 256 pistons of the pump operating in an assortment of 64 phase differences, the ripple which would have been experienced in volumetric output and pump torque became almost unnoticeable. This was another positive result which could be viewed from the Simulink models.

References

[1] N. DIEPEVEEN, 'On the Application of Fluid Power Transmission in Offshore Wind Turbines', Ph.D, Delft University, 2013.

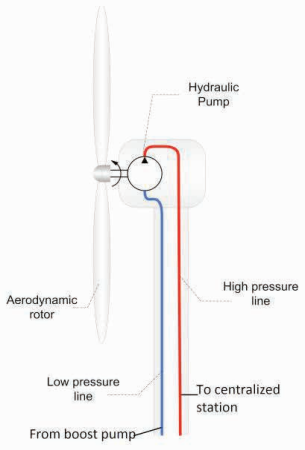

Figure 2: Overall System Schematic [1]

Continuation on Common Rail Diesel Engine Testing

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

Introduction

Common Rail fuel injection system provides a flexible fuel injection system for a DI-Diesel engine. This type of system gives the ability to control various parameters within the injection system such as the start of injection, fuel quantity, injection pressure and the rate of injection.

Project Objectives

The main objectives of this dissertation were to continue to understand the principles behind the common rail diesel injection system, together with the implementation of an aftermarket programmable ECU on the diesel engine.

Project Methodologies

The Peugeot HDi Diesel Engine, which was also used in previous dissertations by Seychell and Camilleri [1] [2], was set up on the Stuska Dynamometer in the Thermodynamics Laboratory. Since the Stuska Dynamometer setup had no frequency output but only voltage outputs, a voltage to frequency circuit had to be constructed. This was used mainly to simulate the wheel speed sensor during the stock ECU testing. LabVIEW was used for the data acquisition from the stock ECU

Results and Achievements

An important achievement in this dissertation was the understanding of the principles behind the control of the high pressure within the rail and the delivery of the high pressure fuel pump. Careful observations done on the two solenoids found on the high pressure pump of the common rail system helped the understanding of the operational principles. With this knowledge in hand and with the aid of a prototype Diesel programmable ECU developed by Reata, pressure control was tested on an injector test bench.

Apart from controlling pressures, the test bench was also utilized for injector flow tests. During the study done by Camilleri [1], an injector driver electronic circuit was constructed which was further developed for this dissertation with the aim of being capable of driving all the four injectors consecutively. This circuit was tested on the injector flow bench and modifications on the holding current were done with the aim of improving its performance and getting the desired flow results.

Finally the programmable prototype Reata ECU was implemented on the HDi Peugeot Engine. Engine timing was performed so that injection quantities and injection events happen at the desired time. To validate the proper control of the injector setup, the engine was started and set to idle with the appropriate engine mapping.

References

[1] S. Camilleri, “Investigation of common rail Diesel engine,” University of Malta, Msida, 2011.

[2] C. Seychell, “Investigation on a Diesel engine with a common rail injector system,” University of Malta, Msida, 2010.

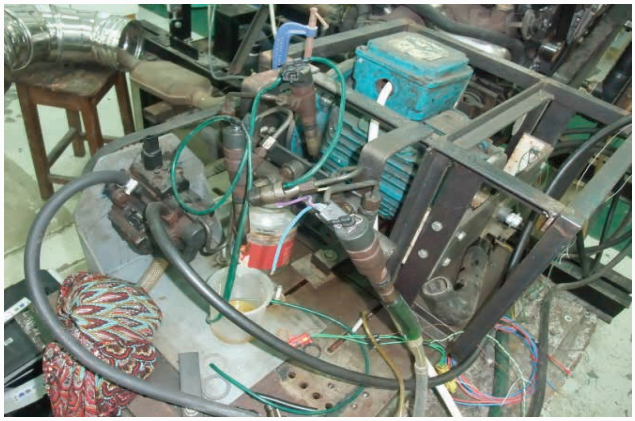

Figure 1: Injector flow test bench

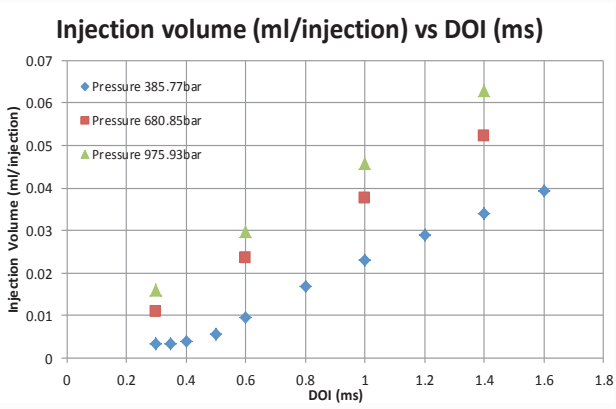

Figure 2: Injection volumes at different pressures

Flow Visualisation of High Lift Devices using Experimental and Numerical Techniques

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

Introduction

High-Lift Devices are components auxiliary to an aircraft's wing with the purpose of increasing lift during certain phases or conditions of flight. They have been developed and extensively used in the aviation industry throughout the last century and are still widely adopted in modern aircrafts.

Project Objectives

The aim of the project is to investigate the effects of High-Lift Devices on a NACA 2412 aerofoil through flow visualisation using experimental techniques and computational modelling. The high-lift devices being investigated include: a Plain Flap, a Split Flap, a Slotted Flap, a Fowler Flap and a Leading-Edge Slat.

Project Methodologies

The two-dimensional flow field around the aerofoil setups was obtained experimentally using a Smoke Wind Tunnel. The experimental conditions were recreated with Computational Fluid Dynamics (CFD) modelling using ANSYS® Fluent™. The Reynolds Averaged Navier-Stokes (RANS) method with the Realizable k-ε turbulence model and the Enhanced Wall Treatment technique were used to model the turbulence and effects of the boundary layer forming on the aerofoil walls. The computational models were validated by comparing lift coefficient plots with published literature [1] [2]. Velocity Streamlines were used to visualise the flow field. These were compared to the experimental images.

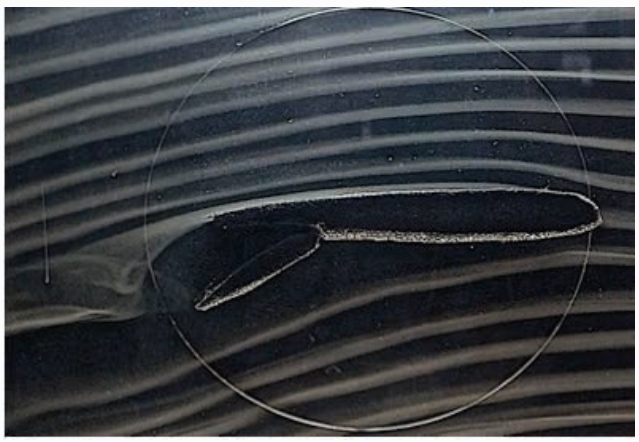

Figure 1: Experimental Flow Visualisation of a NACA 2412 aerofoil with a Split Flap at 0°

Results and Achievements

The computational lift coefficient plots models were in qualitative agreement with published literature [1] [2]. The flow visualisation results obtained using the Smoke Wind Tunnel [Figure 1] and the computational models [Figure 2] showed a good qualitative agreement. However, the computational models tended to predict smaller regions of flow separation.

The effects of the high-lift devices on the NACA 2412 were investigated by comparing the flow visualisation results and lift coefficient plots, underlining differences in lift coefficients, the stall angle and regions of separated flow and flow reversal. The differences observed were in agreement with typical effects of these devices highlighted in published literature [3] [4].

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[2] Galea R.P., 'The Investigation of Slats and Flaps on an Aerofoil' B.Eng.(Hons.) dissertation, Department of Mechanical Engineering, University of Malta, Msida, 2014.

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[3] Smith A.M.O., 'High-Lift Aerodynamics', Journal of Aircraft, 1975 Vol. 12, No. 6.

[Technical Report:]
[4] Young A.D., 'The Aerodynamic Characteristics of Flap' [R&M No. 2622], Aeronautical Research Council, 1953

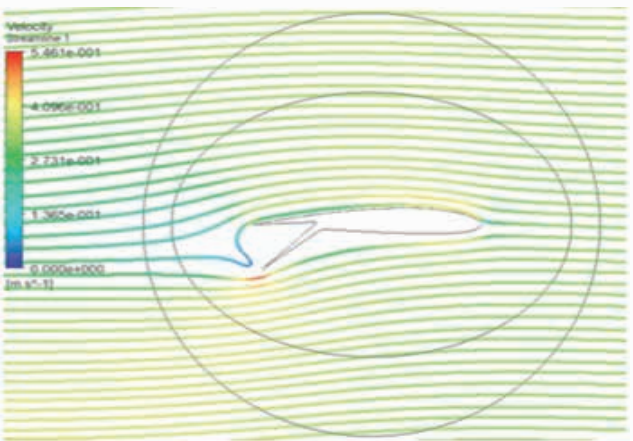

Figure 2: Computational Flow Visualisation of a NACA 2412 aerofoil with a Split Flap at 0°

Ship Resistance, Propeller and Rudder Interaction and Optimisation in the Preliminary Design of Commercial Vessels

Student: Ian Hubbard / Supervisor: Dr. Ing. Claire De Marco

Introduction

For commercial vessels, two of the most economic driving forces for ship owners are fuel cost and most recently, environmental emissions. These play huge roles in the viability to both, an existing ship or ship still under design, as fuel prices are steadily increasing. Another issue is that regulating bodies such as the International Maritime Organisation (IMO) are enforcing stricter emission controls and legislations. With this in mind, it is important to investigate and optimise efficiencies of such aspects of a vessel including its propulsion system and appendage resistances [1].

Project Objectives

The objectives of the project were to develop MATLAB programs in order to analyse and solve for the resistance characteristics of displacement hull forms and to establish an optimised design for both a suitable propeller and rudder of highest efficiency and least possible drag characteristics for preliminary ship and propulsion design.

Project Methodologies

Analysis and optimization were achieved through multiple MATLAB codes and solvers written to carry out each step in the project. Analysis of hull resistance at various speeds was performed using suitable resistance techniques, namely the Holtrop & Mennen [2] and Hollenbach [3] methods. The propeller design was established using the Wageningen [4] propeller series. Optimisation was achieved through the program's selection algorithm for the propeller producing the highest open water efficiency, obtained from a large computed set of data based on propeller revolutions and cavitation avoidance. The rudder design was then investigated for lowest possible induced hydrodynamic drag with respect to the influence of a propeller slipstream. Optimisation was carried out through parametric variation of the taper ratio and the rudder's longitudinal distance from the propeller. Numerical analysis of the rudder and its interaction with the upstream propeller were achieved through a written solver utilizing and implementing the blade element-momentum theory and the lifting line theory.

Results and Achievements

With respect to hull resistance, it was found that reduction of the design speed of 14.8kts to 14kts would decrease resistance by 87.1kN accounting for a 14% reduction in fuel consumption. Propeller optimisation results yielded a maximum propeller efficiency of 50.7%, which was found to be quite low, however this was due to the propeller diameter of 5.56m, which was not ideal for such a large ship (189.9m) and significant propulsive gains could have been achieved if the stern frame were to be altered to accommodate a larger propeller. The rudder design and optimization with respect to the propeller influence showed more promising results. Moving the rudder closer to the propeller from its original position by 46% produced a 2.7% gain in propulsive efficiency and with taper reduction by 30% reduced overall rudder drag by 16%.

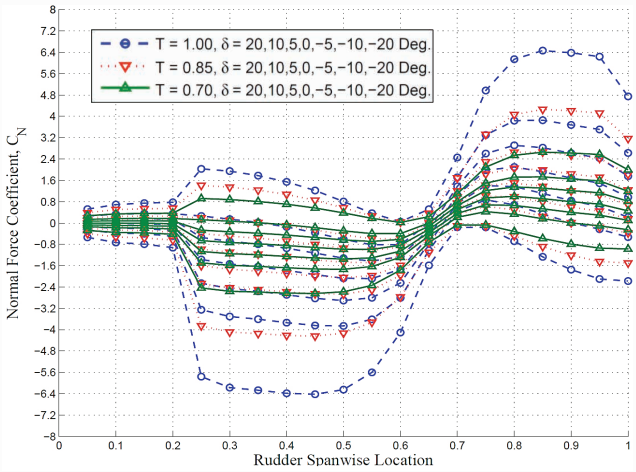

Figure 2: Force coefficient, C_N across the rudder span for *X/D = 0.35*.

References

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[3] K.U Hollenbach, "Estimating resistance and propulsion for single-screw and twin-screw ships", *Ship Technology Research*, Vol. 45, Part 2, pp. 72–76, 1998

[4] L. Troost, "Open water test series with modern propeller forms", in *Transactions of NECIES*, Vol.54, 1938

Design of a Towfish

Student: Martina Khan / Supervisor: Prof. Ing. Martin Muscat

Introduction

The project aims at designing an underwater vehicle for monitoring jellyfish population at various sea depths. The depth of dive is varied using hydroplanes. It needs to be designed to dive to a maximum depth of 50m below sea level and needs to be positively buoyant so that when it is not being towed it rises to the surface of the sea.

Project Objectives

The main objectives of the project was to decide on the modifications to be made on the latest towfish design and to review available codes of standards in order to re design the towfish incorporating the necessary modifications.

Project Methodologies

The towfish was considered as a pressure vessel and consisted of three main geometries: cylinder, cone and hemisphere. Two cylindrical arms were also attached in order to house the two main cameras required.

The material chosen for the towfish was the mild steel type plate - P344N since it has good mechanical properties, good yield and tensile strength.

The design and size of the towfish was carried out according to the EN 13445-3:2009 'Unfired Pressure Vessel' European Standard. Design by Rule was first used to calculate some of the various dimensions and thicknesses of the main components of the towfish. This was mainly used to prevent buckling.

Design by Analysis was then carried out using ANSYS Mechanical to check for the structural integrity of the towfish. In order to induce buckling in the model, the force and moment loads found in DBR were used.

Results and Achievements

From the results achieved, the edges of the cone with the cylinder and the cylinder with the hemisphere were no more plastically deformed. This is because the flanges which were creating excessive deformation were removed. The 3 main geometries will be welded together in order to avoid deformation.

Hence, the two main modifications done on the towfish which are the removal of the flanges and the opening in the cylindrical shell to access any equipment in its main compartment were done and the required results were achieved.

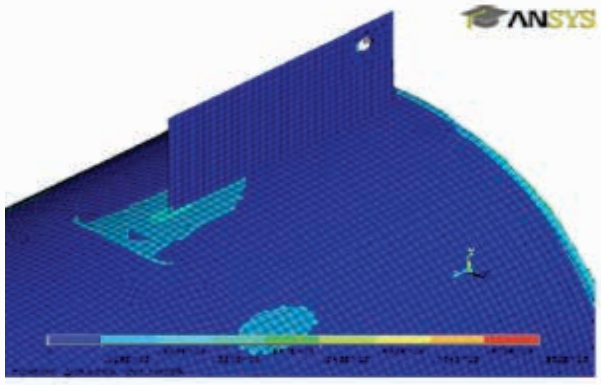

Figure 1: FE model of main cylindrical shell and towlug

Modelling Energy Performance of Buildings

Student: Bernice Magro / Supervisor: Prof. Robert Ghirlando

Introduction

Buildings are a major cause of energy consumption, more than 25% of the energy produced is consumed by buildings. The EU issued a directive so that the energy performance on new and old buildings would be improved. Minimum energy performance standards had to be established by all the state members. In this dissertation the energy performance of the Wine Research Centre at Buskett was modeled with the intention of finding ways on how to reduce the energy consumption of the wine industry.

Project Objectives

- To undertake a literature review on the various methods which can be utilized to reduce the energy consumption of buildings.
- To learn how the TRNSYS software works and use it to model the energy performance of the Wine Research Centre at Buskett.
- To understand how this building performs in practice and determine how the energy consumption of this building can be reduced.

Project Methodologies

An extensive Literature Review was carried out to determine what is the newest technology available to reduce the energy consumption within a building. Initially Google SketchUp was utilized to create a graphical model of the building as shown in Figure1.

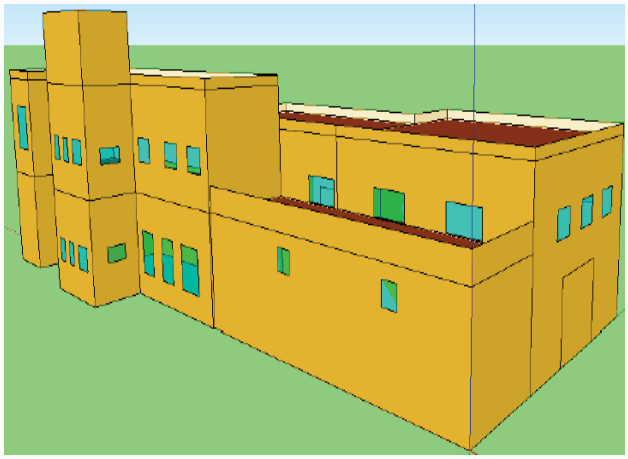

Figure 1: The SketchUp model of the Wine Research Centre

The model produced was then transferred to TRNBuild. Within TRNBuild details of the building had to be specified, such as the materials used to create walls, windows and doors. Then TRNSYS Simulation Studio was used to carry out several simulations to decide what the main elements that affect the energy performance of this building are. The results obtained were analysed to determine a way in which one can reduce the energy consumption of this building. One of the techniques utilized was shading and its effect on the energy demand was investigated.

Results and Achievements

From the simulations carried out the temperature of each room was calculated. A sample of this data is presented in Figure 2. Since this is an old building in some parts a double leaf wall was used, therefore another simulation was carried out to determine whether the filler used had an impact on the temperature within the room. In this case air, soil and polystyrene were compared and small temperature differences were discovered.

A simulation was carried out to determine to what extent the overhangs affected the building. When comparing results a lower temperature was noted when overhangs were added to the model during the Summer. The results obtained showed that there was a reduction in the heating demand and in the cooling demand as well.

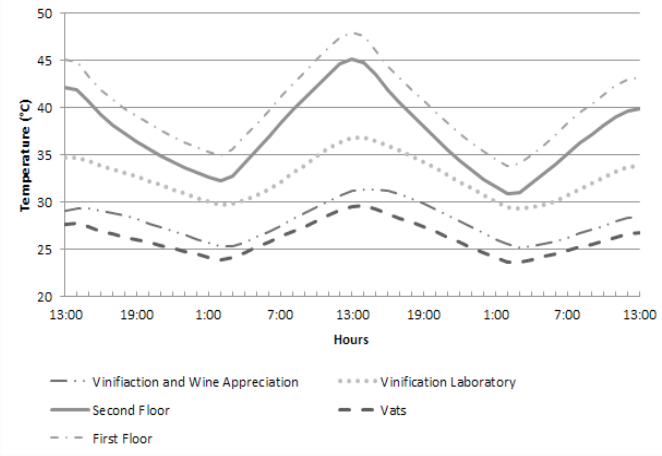

Figure 2: Temperature in different zones

Fatigue Life Prediction of a Wind Turbine Nacelle

Student: Ryan Mahoney / Supervisor: Prof. Ing. Martin Muscat

Introduction

In 2007, the University of Malta initiated a project which would see an old Chicago-Type Wind Pump in Ghammieri converted into a turbine with a concept consisting of a new rotor design. Our island is known to be subjected to a variety of fluctuating magnitudes of wind speeds throughout the year. Therefore, a fatigue life prediction of the nacelle structure was recommended to be carried out.

Project Objectives

The main aim of this project was to predict the fatigue life of the wind turbine based solely on the raw wind data available over the past year and a half.

Project Methodologies

The wind data used was that collected via two anemometers which are situated at the site where the wind turbine will be set up. The equations to calculate the fatigue loads experienced by the nacelle due to the wind, were obtained from standards [1]. The wind speeds criteria for the various operating regions of the wind turbine were clearly defined and established (idle/standstill, normal operation and furling). In doing so, specifications of the generator and inverted to be used, were also considered to ensure no damage would be sustained by any component, both mechanically and electronically. The criteria was then applied to the wind data collected for a clear picture of how the turbine would be expected to operate.

The nacelle structure was modelled using Finite Element Software and the locations which are most likely to experience fatigue were established (as seen in Figure 1). After translating all wind data into stresses, the stresses at these locations were used to obtain stress-range histories.

S-N curves for the respective locations under observation were plotted according to Eurocode 3 [2]. These curves relate the number of allowable cycle before fatigue for each stress range. Finally, Miner's Rule calculates the total damage fraction over the total period of time being analysed. This result was then used to predict the fatigue life.

Results and Achievements

From the four locations which were selected for the fatigue life prediction, only one location failed to reach the 20-year benchmark which is normally set by standards [1]. This location has an unclassified type of weld. A slight modification to this weld, for example, using a standard weld as found documented in Eurocode 3 [2], may increase the fatigue strength which will see its fatigue life go beyond 20 years.

From the stress-range histories obtained, it was concluded that at no point were either the allowable design strength or yield stress of the nacelle's material exceeded.

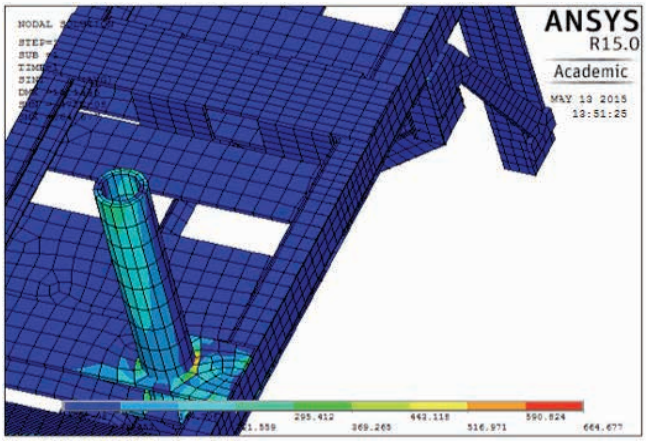

Figure 1: Stresses Experienced by the Nacelle Structure and Yaw Shaft during Normal Operation (Bottom View)

References

[1] EN 61400-2:2006 – "Wind Turbines – Part 2: Design requirements for small wind turbines", International Electrotechnical Commission.

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[3] ASTM E 104.9-85 (2005), Standard Practices for Cycle Counting in Fatigue Analysis

Modelling the Wake Losses from Offshore Wind Farms with Varying Hub Heights

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

Introduction

Offshore wind farms are becoming increasingly important for the power sector in Europe. However, wake losses due to interfering wind turbines reduce their energy production significantly and turbine spacing is limited by practical constraints. Wind turbine wakes can be visualised in Figure 1.

Project Objectives

- To devise a number of configurations in order to investigate the effect of varying rotor hub heights;
- To model these configurations and compare the wake loss predictions for offshore wind farms with fixed rotor hub heights with wind farms having varying rotor hub heights;
- To evaluate the discrepancies, if any, between the wake model predictions at different conditions.

Project Methodologies

A literature review in the field of offshore wake modelling was conducted to better understand the development of wind turbine wakes and how these can be modelled. Previous investigations on offshore wake modelling and studies on wake model validation were explored. The theoretical background related to wake models and atmospheric characteristics was analysed.

All wake modelling and energy calculations were done in WindPRO, a software suite that is specifically designed for wind energy projects. Three wake models implemented in this software were used to model the wake losses under various conditions. Initially, two wind turbines were modelled to analyse single wake behaviour. The number of turbines was increased to six, in a straight line parallel to the wind direction, to study the effect of multiple wake interaction. Lastly, an array consisting of four rows with three turbines each was modelled to investigate the wake interaction from neighbouring turbines. All configurations were tested with various hub height variations at varying wind speeds and turbine spacing.
Further investigations were carried out on the influence of ambient turbulence intensity, the wind

Results and Achievements

The results showed that staggered height configurations, such as the one shown in Figure 2, were effective in mitigating wake losses and contributed to higher energy production. Higher gains in park efficiency were observed as the number of wind turbines increased. Moreover, the greatest mitigation of wake losses occurred when there was the highest variation between the hub heights.

It was concluded that height staggering is most effective at conditions that favour wake losses, such as, lower wind speeds and thus, higher thrust coefficient values, and close turbine spacing. Moreover, the most efficient wind farm layout shifts according to wind speed.

Figure 1: Wind turbine wake [1]

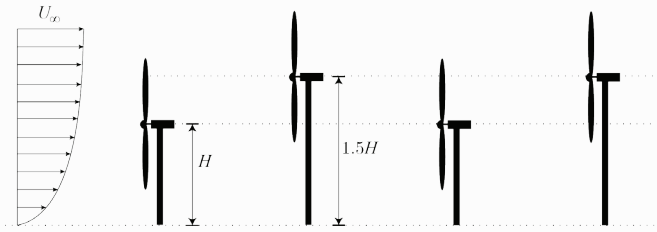

Figure 2: Staggered height configuration

References

[1] Hasager C., Rasmussen L., Jensen L. and Réthoré P., 'Wind farm wake: The horns rev photo case' *Energies*, 2013, Vol. 6, No. 2, pp.696-716

Low Velocity Impact (LVI) Response on Marine Sandwich Hulls

Student: Karl Mizzi / Supervisor: Dr Ing. Claire De Marco

Introduction

The project presented an experimental and analytical study on LVI response on marine sandwich panels. The panels comprise of a DIVINYCELL® H100 closed cell linear PVC foam core and face laminates skins comprising of POLYLITE® 440-M850 resin with either copped strand matt or woven E-glass.

Project Objectives

To determine relationships among the indentation depth, force histories, peak contact force, and the extent of surface damage to the diameter of the hemispherical indenters dependent on the properties and thickness of the sandwich panels. To compare the results obtained from the physical testing of the sandwich panels with the analytical results.

Project Methodologies

The marine grade sandwich panels were designed in accordance with BS EN ISO 12215-5:2008 [1] by using a wet lay-up and cured under vacuum pressure.
Impact damage followed the ASTM D7136/D7136M-05 [2], in which a force sensor recorded the contact force history. The sandwich panels were subjected to LVI with hemispherical indenters of different diameters. Destructive sectioning methods were used to assess the damage on the sandwich panels after impact and the roles of the face skins and the foam core during impact.
Analytical models were employed to evaluate the impact force and time periods when the sandwich panels were subjected to different indenter. Two analytical models were considered; the energy balance model and the spring mass model. The dependence of the peak force and contact force history on the structural parameters and the indenter diameters were analysed.

Results and Achievements

The surface and indentation damage were observed to be dependent and the indenter diameter as illustrated in figures 1 and 2. The time periods were observed to decrease with increasing the indenter diameter and core thickness for the same initial impact energy. The peak force increased with increasing the indenter diameter and panel thickness.
The results obtained from the analytical models were compared to the experimental results. An improved relationship between the peak force and the indenter diameter was obtained for the energy balance model. The spring mass model tended to over-estimate the peak force since the models do not take into account damage initiation and propagation, and neglected the effect of membrane stiffness. An improved analytical spring mass model with the inclusion of displacement and velocity dampers should be investigated.

References

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

[2] ASTM Standard, “Standard Test Method Resistance of a Fibre-Reinforced Polymer Matrix Composite to a Drop-Weight Impact Event, ASTM D 7136/D 7136M - 05.”

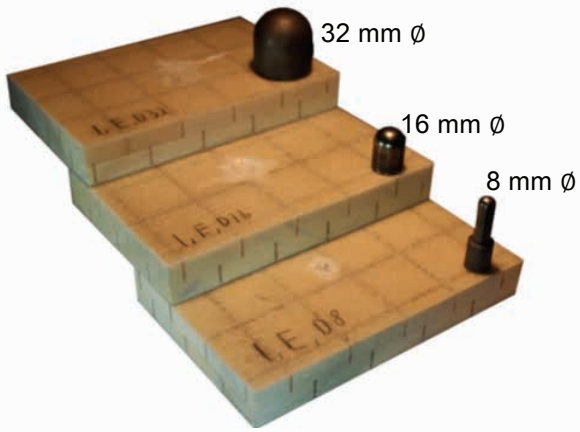

Figure 1: Sandwich specimen showing surface damage

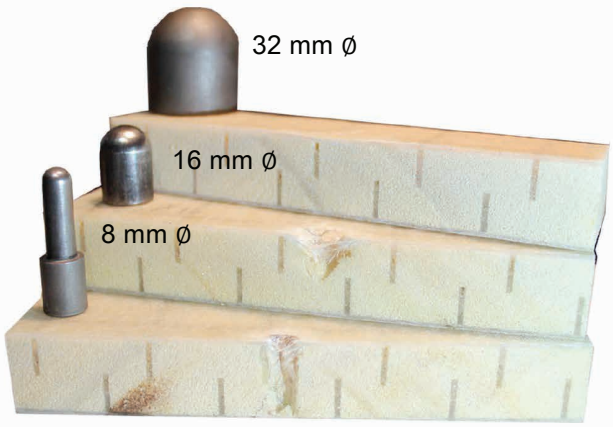

Figure 2: Sectioned sandwich specimen illustrating indentation

Preliminary Design of a High Speed Craft

Student: Abigail Muscat / Supervisor: Dr Ing. Claire De Marco

Introduction

High speed leisure crafts are high in demand in the market as these marine vessels provide the luxury of exploring bays and enjoying the sea in great comfort and safety. Thus designers have to be able to combine comfort, luxury and speed in the design.

Project Objectives

The aim of the project is to create a new concept design of a high speed recreational planing hull and to study in depth some of the design stages required in the first design spiral. The objectives are to design the new hull, determine the resistances acting, find the respective power and propulsion system required, establish a structural design and implement a structural analysis to ensure safety and perform intact stability tests to assure conformity with the required standards.

Design of a New Hull:

Based on the design statement and a study of similar vessels, the dimensions and target speeds of the concept hull were determined. The new planing hull was modelled by using Maxsurf [1] and ratios were evaluated on the hydrostatic results obtained to ensure that the hull classified as a planing one.

Project Methodology

Once the design was established, the Savitsky [2]; Blount and Fox [3]; and Savitsky and Brown's [4] methods were used to determine resistances. Hullspeed [5] was used to evaluate the resistances with the same methods and the results were compared. Blount and Fox's method was chosen as it was suitable for non-prismatic hulls. Power calculations were performed to determine the propulsive power required to create a thrust large enough to exceed all resistances. The propulsion system was thus chosen.

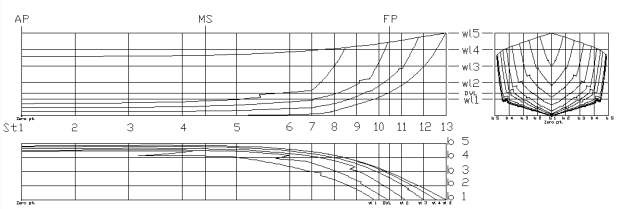

Figure 1: Lines plan of the new hull design

The structural based design of the craft was established on Gerr's [6] scantling rules and results were checked to ascertain the compliance with BS EN ISO 12215 [7]. Corresponding materials were also chosen. The general layout was then asserted and intact stability tests were performed.

Results and Achievements

The results obtained met the applicable regulations imposed by BS EN ISO 12217 [8] and the HSC code [9]. A new hull concept was thus achieved and studies required in the first design spiral of the preliminary design stage were performed. The new hull met all the regulations required up to this stage and therefore it was assured that it would be a good foundation for the next design spiral.

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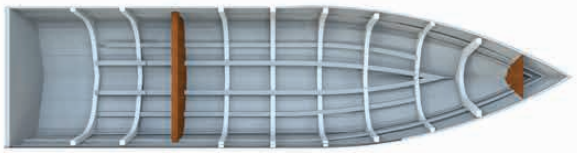

Figure 2: Top view of interior structural design

Numerical Modelling of Mild Steel Friction Stir Welded Assemblies used in the Ship Building Industry

Student: Clarissa Saliba / Supervisor: Prof. Ing. Duncan Camilleri

Introduction

The use of steel in industry is increasing with welding being the most popular type of joining process, but the high temperatures lead to plate distortion and residual stresses which can induce failure. Friction Stir Welding (FSW) is a relatively new process which joins the material without reaching melting temperatures, hence less residual stresses are present in the material. FSW is very successful on aluminium and research is constantly being made to successfully apply this process to harder metals such as steel.

Project Objectives

The aim of this study was to adapt the CFD model based in [1] to make it suitable for modelling mild steel. Experimental results were used to calibrate the model and investigate the effects of several parameters. An analytical solution was carried out to compute the longitudinal contraction forces and distortion angles. A simple linear FEA model was used to determine the critical buckling load which would determine the success of the FSW process.

Project Methodologies

The CFD program ANSYS® FLUENT™ was used to create a rigid visco-plastic model simulating FSW where a fully sticking model was assumed. This means that heat generation is solely due to plastic shearing of the material, and friction between tool and workpiece is ignored. The tool pin is made of PcBN which is a hard tooling material suitable for FSW on steel. The workpiece material is mild steel having temperature dependent properties such as viscosity, specific heat capacity and thermal conduction. The tool shank, which is inserted into the chuck of the FSW machine, was water cooled. Heat loss due to the effect of a backing plate was calibrated with experimental results and applied to the bottom surface of the plate. Different parameters such as pin penetration depth, heat loss profiles, welding speed and tool rotational speed were applied to analyse their effect on plate temperatures and stir zone shape. An analytic solution based on the theory in [2] was applied to calculate the contraction force and distortion angle. A linear eigenvalue buckling analysis was carried out using FEA where diffe rent sizes were applied to a simply supported plate.

Results and Achievements

From the CFD study it was concluded that water cooling on the tool does not have a great effect on plate temperatures, but only serves to reduce tool temperatures, hence increasing tool life. It was also concluded that increased pin penetration depth leads to higher maximum plate temperatures as well as wider stir zone shapes. A faster welding speed increases cooling rates leading to lower temperatures. The opposite is noted for faster rotational tool speeds, where the increased speed creates more shearing and heat generation. From the different heat loss profiles applied to the bottom surface, it was also concluded that the heat extracted by the backing plate can be improved in order to increase heat loss and reduce temperatures.
The results from the analytical solution show that the higher the temperatures, the larger is the longitudinal contraction force while the smaller is the distortion angle. From the FEA analysis it is clear that different plate sizes have a great effect on the maximum critical load which induces failure due to buckling.

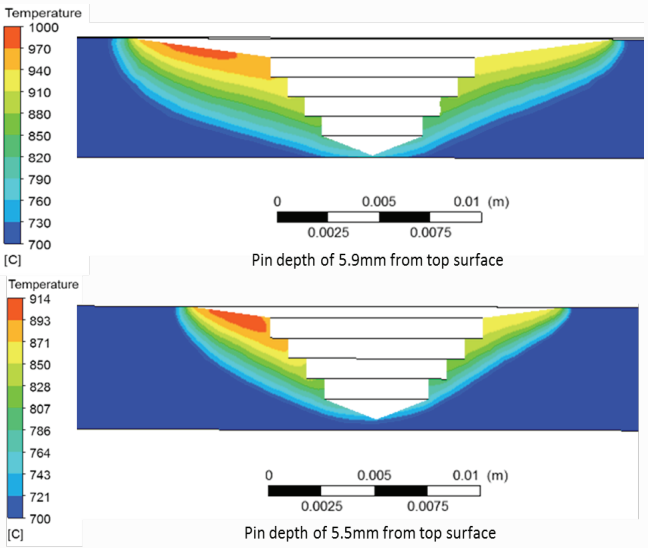

Figure 1: Effect of pin penetration depth

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Characterising the Performance of a Wound Coil Heat Exchanger

Student: Adrian Saliba Vella / Supervisor: Dr Ing. Christopher Micallef

Introduction

A wound heat exchanger is used as a condenser in a number of air conditioning units manufactured by Seifert Systems Limited. This consists of a copper tube wound around an aluminium core. As part of a cost reduction excercise, the core design was modified to the design shown in Figure 1. This study analyses the performance of this new design.

Project Objectives

The aims of this project were to:

- find the optimum thermocouple attachment in a forced convection scenario.
- understand the heat transfer field taking place during operation of the heat exchanger.
- establish whether the pitch of the copper windings has notable effect on the heat exchanger's performance.
- suggest design modifications to enhance the performance of the heat exchanger.

Project Methodologies

An aluminium plate with different thermocouple surface attachments methods was placed in an air-conditioning laboratory unit. The plate was heated using a heater and then cooled suddenly using a stream of cold air. The temperatures recorded by the surface mounted thermocouples were compared to the readings from thermocouples embedded in the plate using silver adhesive.

To characterise the performance of the wound heat exchanger, a total of 142 thermocouples were attached using a single method of attachment, both in axial and radial directions. The thermocouple ends were welded using a thermocouple welder to obtain a single, identifiable data logging point. The wound condenser was placed in the air-conditioning laboratory unit, water was circulated through the wound copper tube and the temperatures were recorded. After the necessary tests were carried out, the aluminium core was unwound and rewound with copper tube at half the previous pitch. The same tests were then carried out on the newly wound condenser.

Results and Achievements

After several tests, it was found that epoxy resin was not an adequate thermocouple attachment method in a forced convection scenario whilst aluminium tape alone performed well.

The heat exchanger performance analysis results revealed that the wavy fins were very effective at drawing away heat from the copper coils however the convective heat transfer coefficients were not large enough to dissipate away the heat effectively. Results also showed that at the middle section, heat transfer was presumably taking place radially outwards, from the aluminium to the copper, instead of the other way round.

Air temperatures within the different sectors of the core recorded significantly different temperatures.

The counterflow arrangement was the most effective for copper wound at the narrow pitch, whilst for the wide pitch the parallel flow configuration displayed slightly better performance.

The relationship between the number of copper windings and performance is not linear and in fact a 95% increase in copper length transpired in only a 17% improvement in effectiveness.

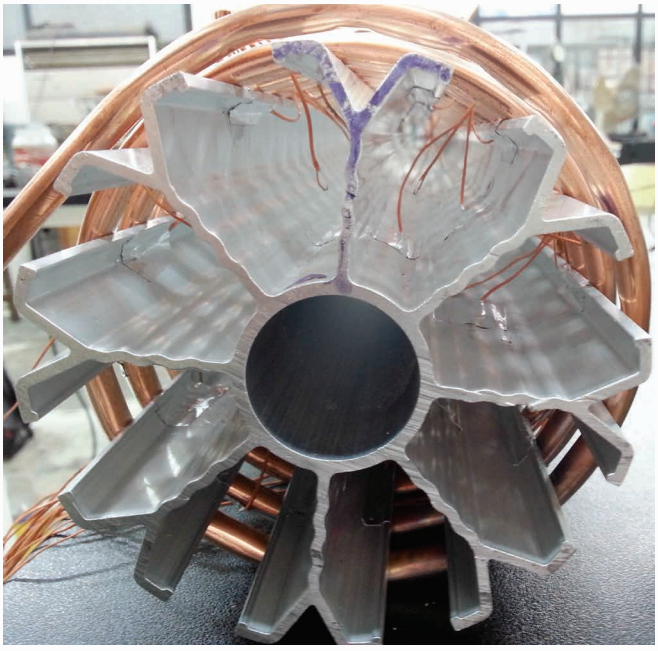

Figure 1: The aluminium core with thermocouples attached, wound with copper tube

Stress-Strain Analysis at the Bone-Implant Interface

Student: Mariella Schembri / Supervisor: Dr Ing. Zdenka Sant

Introduction

Degenerative spine disease and trauma are major causes of disability in the adult working population [1]. These conditions can be characterised by the compromised stability of the spinal column. This represents a life threatening situation and must be corrected. For this purpose various fixation device are developed to provide stability and allow load transfer from one vertebra to another.

Project Objectives

Simulate fixation of the L3-L4 vertebral segment by means of a dynamical system composed of pedicle screws and rods.

Carry out a stress-strain analysis for the implant as well as for the bone tissue.

Project Methodologies

Screws were placed at the vertebral pedicles converging at an angle between ten and fifteen degrees as suggested by leading AO surgeons [2]. Rods were passed through the screw heads to allow sliding of the vertebrae along these rods. A firm connection between the screws and the rods was ensured by using sleeves and nuts.

The vertebral bodies were meshed using 2mm tetrahedral elements. Shell181 elements were used to mesh the outer shell of the vertebrae to represent cortical bone tissue. Solid186 elements were used to mesh the inner volume of the vertebrae to represent trabecular bone tissue. For the implant, the axisymmetric areas of the lower part of the screw and the nut were meshed with quadrilateral elements and then rotated about the centre line.

Boundary conditions were applied to the inferior end of the L4 vertebral body allowing only some movement along the vertical z-axis. A load representing the weight of the body was applied to a pilot node which was created at the centre of the L2-L3 intervertebral disc (Figure 1).

Contact elements were used between the nut and the sleeve and between the rod and the screw and sleeve surfaces to ensure transfer of loads between the two contacting surfaces. Initially, sliding along the rods was not permitted to ensure that the computational model is free from errors. Once proved that the model at this condition behaves as expected, the standard contact between screws, sleeves and rods was set.

Results and Achievements

The maximum principal and von Mises stress and strain for each component was analysed. With initial prohibition of the relative motion between screws and rods large stress values were obtained at the contacting regions.

Setting the contact between the rods, screws and sleeves to *Standard condition* the sliding along the rods is allowed but the convergence of the system is more time consuming due to fine tuning of the contact stiffness parameters. At this time the computation is still underway..

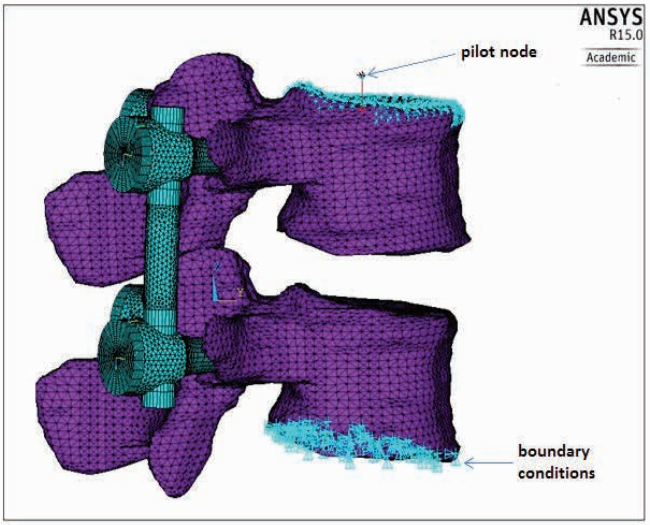

Figure 1: Loads and boundary conditons imposed on the meshed assembly

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Free-Piston Engine

Student: Ron Schembri / Supervisor: Prof. Ing. Robert Ghirlando

Introduction

The automotive industry has come a long way since the introduction of the internal combustion engine in the 1880s. Today, a large amount of research is dedicated to developing new alternative engines that are ideally more environmentally friendly, by increasing fuel efficiency as well as decreasing emissions. Such an area of interest includes *Free-Piston Engines*. The idea behind such an engine has been around for some time, however its high demand for a high level of control deemed it unfeasible at the time. With today's advancements in systems and control engineering, such a concept is attainable. Current developments include merging free-piston engines with Homogenous Charge Compression Ignition (a form of internal combustion where the mixture, generally fuel and air, is compressed up to the auto-ignition point).

Project Objectives

As a continuation to work carried out previously, it was vitally important to analyse the engine in order to grasp a very good understanding of the working principles of the *free-piston engine*. The main objective of this project was to completely redesign all engine components in order to achieve a fully aligned engine. Once completed, other objectives included reassembling the engine, whilst ensuring significant improvements to alignment, testing of the electrical circuit designed to provide a spark at the right moment during operation, and finally perform various tests on the engine with the implemented engine modifications.

Project Methodologies

This dissertation included the manufacturing of new components as well as other manufacturing processes on existing parts of the engine. Due to the little attention given to alignment while building the engine, exactly 75 per cent of all engine components required manufacturing in order to obtain perfect alignment between two assembled components. Such manufacturing processes include facing or stepping of components, as may be seen in the step details between pairing components in Figure 1 and Figure 2 below. The section views show how the components were altered so that a perfectly aligned position can be held between paired components before fastening. Prior to manufacturing, various geometrical tests were performed in order to ensure that manufacturing datums were taken correctly.

Results and Achievements

Upon finalising all engine modifications, numerous trial runs were carried out. A significant improvement regarding an initial drawback in the design of the engine was definitely achieved. The ease of shaft movement improved drastically due to the alignment modifications carried out. This result was noted after supplying air through the compressor cylinder sides alternatively. Once all the necessary equipment was connected to the engine, trial runs for a successful start on fuel were also carried out. Although multiple attempts were made to start the engine on fuel, due to numerous factors it did not experience a perfect start as desired, however, many improvements were made on the engine throughout the dissertation.

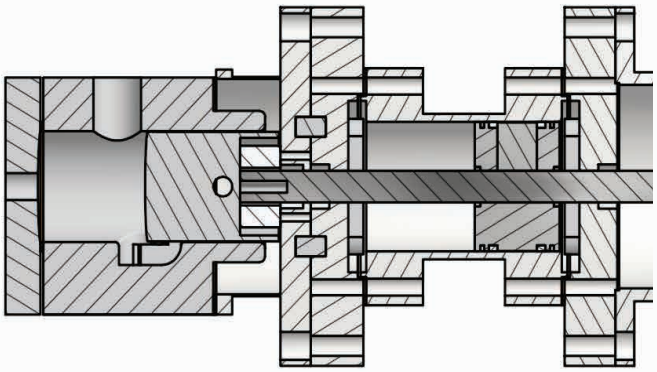

Figure 1: Left Section View of the Free-Piston Engine

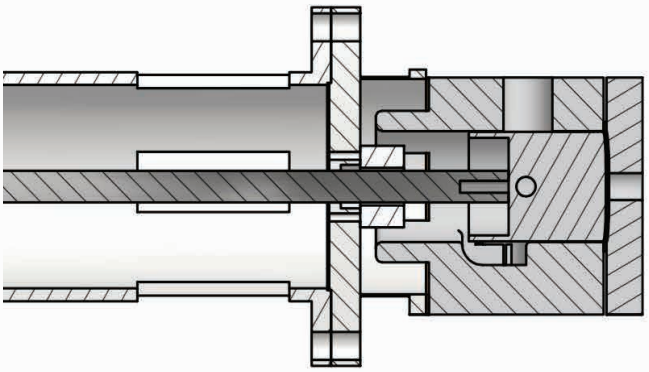

Figure 2: Right Section View of the Free-Piston

Performance Analysis of a Multi-Bladed Wind Turbine Rotor

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

Introduction

The use of clean sources of energy production is becoming increasingly sought after in the face of growing concerns regarding the use of fossil fuels as the world's major source of energy. In the Maltese Islands, the 'Chicago Wind Mill' (CWM) was a popular means of drawing water from the water table for irrigation purposes. A project has been undertaken by the University of Malta to convert an existing CWM into a wind turbine that is capable of generating clean electricity into the Maltese grid.

Project Objectives

The first major objective was the prediction of the wind turbine's performance using analytical models. The second objective was the design and construction of a Data Acquisition System (DAS). Its aim is to monitor and record the meteorological conditions and the corresponding turbine's power output. Thus, the results obtained analytically can be compared with the turbine's actual performance.

Project Methodologies

Two analytical models were implemented to analyse the turbine's performance – Blade Element Momentum (BEM) and a Free Wake Model (FWM). BEM is simple and computationally inexpensive, and results obtained are only preliminary. Vortex models provide a more accurate representation of the flow field than BEM for a wider range of loading conditions. However, the computational cost required is more significant. The DAS consists of a data logging device and interfacing electrical circuits. The data required was sampled and processed as required by regulations. This data was then stored, allowing further analysis

Results and Achievements

An experiment was carried out to calibrate and test out the data acquisition system. The results obtained from this system were compared with those obtained from general measuring instruments. The results agreed and the errors observed were low.

The analytical models were used to obtain values for the turbine's efficiency (known as the power coefficient) and the thrust force for a range of rotor rotational speeds, which can be expressed in terms of the tip speed ratio. A comparison of the results obtained from the two analytical methods is illustrated in Figure 2. The effect of various loading conditions, such as the misalignment of the turbine from the wind direction, was observed to play a significant effect on the turbine's efficiency. An analysis of wind data measurements spanning a year was carried out. This allowed for an approximation of the expected energy yield once the turbine is operational. The location under investigation is sheltered and the wind speeds observed were low, meaning that the expected energy yield is not high. However, upon comparison with other similar small wind turbines, results showed that the turbine's performance is similar.

Figure 1: New Rotor Design

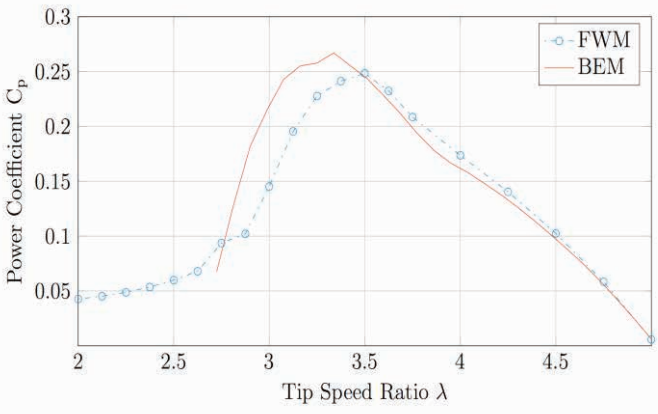

Figure 2: Theoretical Turbine Efficiency

Finite Element Analysis of Friction Stir Welding

Student: Daniel Scicluna Calleja / Supervisor: Dr Ing. Pierluigi Mollicone

Introduction

Friction Stir Welding (FSW) involves the joining of similar or dissimilar materials by placing a rotating tool in contact with the material whilst heating and softening it to ~85% of its melting temperature. A recent development has made it possible for lap joint dissimilar materials to be joint using the Friction Melt Bonding technique [1]. Such processes come at the cost of unwanted residual stresses in the materials.

Project Objectives

To simulate (using finite element analysis (FEA)) a complete FSW process of a lap joint of dissimilar materials. This includes initial inspection and validation of a FSW draft model to carry out thermal calibration, the simulation of welding up to cooling and the design of a number of unclamping modeling techniques.

Project Methodologies

The project consists of a simulation, using FEA software, Ansys, representing the FSW process, whereby a steel plate lies on an aluminum plate both 250 mm in length, in a lap joint manner. These two materials are then clamped down on a bed surface, friction stir welded, allowed to cool to a set room temperature and then unclamped. For the purpose of this study, due to symmetry, only one half of the plates is considered. Also, validation of the simulation code available had to be done along with corrections, where necessary. Following this, the model was thermally calibrated with experimental work by project partner - Université Catholique de Louvain [2]. A number of different models were then made in order to design and analyse different unclamping mechanisms. Some models differ in geometry, whilst others differ by the material type used. As much as possible each model was simulated at different tool traverse speeds since this is an influential factor to the FSW process. A mesh study for errors of the model was also done.

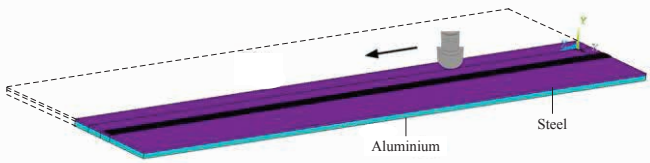

Figure 1: Half the geometry of the model. FSW tool advancing in the direction of the arrow

Results and Achievements

Most results achieved were considered realistic and plausible. As can be seen in figure 2, some stress results compared very well to similar experimental work [3].

Some other models experienced unclamping problems resulting in unconverged solutions. The reasons for these were inferred to be related to residual stress build-ups inside the models, inducing buckling or excessive bending of the plates and coarseness in the mesh.

In conclusion, most results were promising and helped build a base for further studies in the area of friction stir welding simulations. Given more computer power, all models could be improved.

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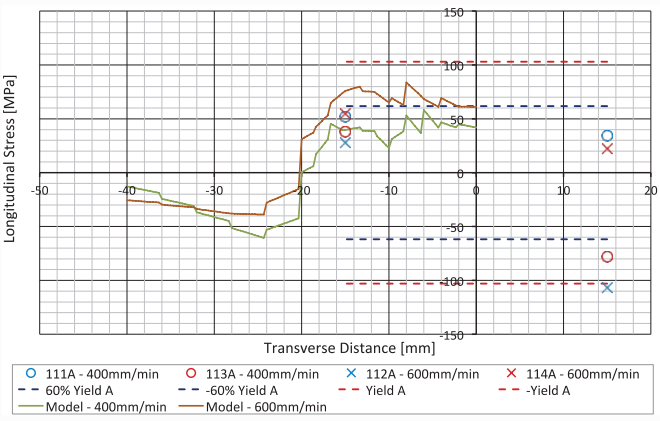

Figure 2: Longitudinal Stress (MPa) vs. transverse distance (mm) for Al 1050-H14, welded to ultra low carbon steel; experimental values by [2]

Creation of a Virtual Model from CT Scans

Student: Kenneth Shaw / Supervisor: Dr Ing. Zdenka Sant

Introduction

Finite element (FE) modelling is particularly useful within the clinical sector in predicting the mechanical behaviour of bone [1]. Although the mechanical properties of bone tissue have been extensively studied and recorded, the implementation of this knowledge in creating accurate FE models still poses a challenge [2].

Project Objectives

The objectives of this study were twofold. The first was to create a geometrical model of bone imaged using a CT scanner. The material properties of the bone were then to be mapped onto this geometrical model.

Project Methodologies

The CT images provided were first processed so as to isolate the bone from the background anatomical features. By defining eight vertices around each remaining pixel centroid, a voxel model was created. A total of three different voxel models, of varying fineness, were created. The average pixel grey value (GV) was then measured and assigned to each voxel. This value was used within a relation so as to calculate the bone density. Furthermore, the elastic modulus of the voxel was then calculated using a constitutive equation. The mechanical properties were then assigned to each voxel, and the models were created and imported into ANSYS.

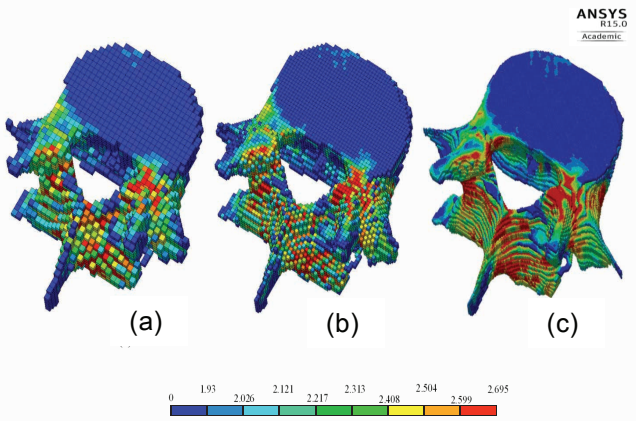

Figure 1: Stiffness distribution in the lumbar vertebrae voxel models in GPa. Fineness ranges from least in (a) to finest in (c)

Results and Achievements

The results presented in Figure 1 for the stiffness distribution show that the right side is stiffer than the left. Also, it can be noted that the finest model produced a more natural looking distribution than the other two. Furthermore, the finest model also predicted higher maximum stresses, however, the three models produced similar stress distributions at lower stress magnitudes as seen in Figure 2.

This study shows that the creation of a FE model containing material properties derived from CT scans is effective in diagnosing bone disease and is a useful tool in prescribing treatment and surgery rehabilitation.

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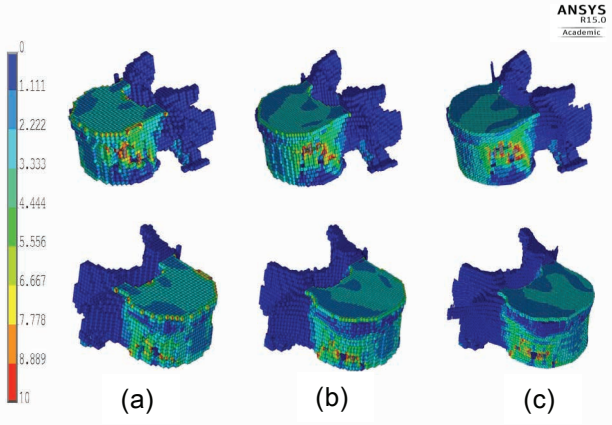


Figure 2: von Mises stress distribution on application of a 2000 N force on the vertebral body of the 3x3, (a) Heterogeneous; (b) Alternative Equation; (c) Homogeneous model. Scale is given

Characterization of a Kaplan Turbine using Computational Fluid Dynamics

Student: Roberta Vella / Supervisor: Dr Simon Mizzi

Introduction

Globally, hydro power plants using Kaplan turbines have an essential role in the sustainable production of electricity. These axial flow reaction turbines can be operated under fluctuating conditions thus allowing the use in various environments. By varying the pitch, fluid rotates the turbine generating electricity.

Project Objectives

The aim of the dissertation was to investigate the flow field and pressure distribution along a Kaplan Turbine using CFD. The main objectives were to:

- Restore an existing apparatus to a functioning status and calibration of existing instrumentation.
- Experimentation on the original apparatus to map out the pressure distribution along the Kaplan turbine.
- Apply CFD modelling techniques to carry out simulations on the Kaplan Turbine.

Project Methodologies

The flow meter outputs a frequency based on the amount of fluid passing through the impeller. Upon its restoration, a setup for calibration of the flow meter was built to simulate the actual flow through the original apparatus. The equipment was designed to allow the flow meter to be calibrated across a range of flow rates.

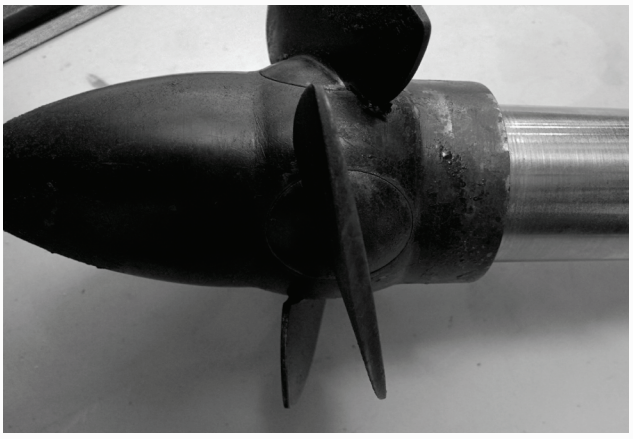


Figure 1: Model of Kaplan Turbine

The original apparatus was then restored to working condition. Experimentation on the Kaplan turbine was carried out by varying the rotational velocity across two blade pitch angles being 0˚ and 30˚.

Using CMM, the geometrical model based on the Kaplan turbine shown in figure 1 was generated. The flow domain was based on the distribution of pressure taps found in the equipment. ANSYS™ FLUENT® was used to simulate the flow across the turbine domain. Numerous turbulence modelling techniques and boundary conditions were applied on the geometrical domain to simulate the flow and pressure distribution along the Kaplan turbine.

Results and Achievements

The data sets attained from the calibration of the flow meter resulted that the flow meter exhibited linearity and a degree of proportionality as illustrated in figure 2. The parameters varied were the blade pitch angle and rotational velocity. Upon using pressure inlet and outlet boundary conditions, the resulting mass flow rate was underestimated. FLUENT® defines total pressure at the inlet which differed from the static pressure read from experimentation. Further simulations were carried out using velocity inlet and pressure outlet as boundary conditions. Since in actuality, several losses are incurred from the interaction with the fluid, the resulting pressure was also an underestimation. On the other hand, the mass flow rate achieved for the various rotational velocities compared well with those obtained from experimentation.

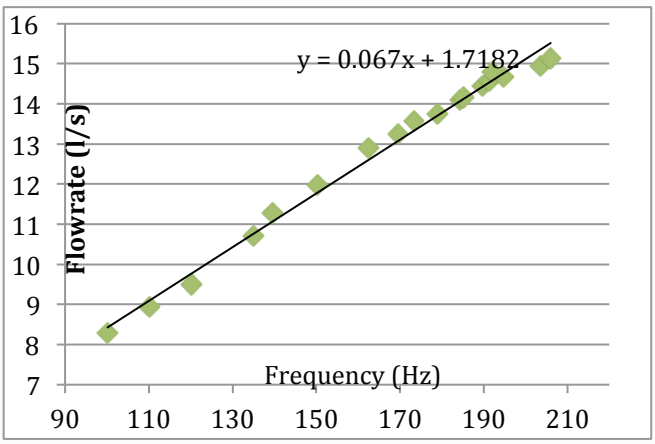


Figure 2: Graph of Flowrate (l/s) vs Frequency (Hz)

Analysis of Diesel Particulate Filter Blockage Problem in Malta and Heat Cleaning Procedure

Student: Emilio Xuereb / Supervisor: Dr Ing. Mario Farrugia

Introduction

The untreated harmful exhaust gases produced by the combustion of diesel fuel in the combustion chamber are the main culprits of the major air pollution problem. This lead to various exhaust gas treatments to be developed throughout the years to reduce as much as possible the negative effects of these by-products in the diesel engine. In 2000, in the light of more stringent emission regulations regarding diesel particular matter (DPM), Peugeot introduced the first diesel particulate filter (DPF) to reduce the particulate matter (PM) by 99%.

Project Objectives

The objectives for this project are to:

- Analyse an alternative solution by using of a furnace to oxidise the accumulated soot in order to simulate the regeneration process.
- Perform a literature search in order to gain knowledge about the DPF working principles and DPF blockage problem
- Carry out the primary and secondary research to get a better understanding of the local DPF problem.
- Test an alternative and a more efficient method from existing methods to solve the DPF blockage problem by using a furnace to reach soot oxidising temperatures to clean the DPF.
- Raise awareness on the lack of knowledge and information available regarding this problem.

Project Methodologies

A study was conducted in the form of a questionnaire that was distributed to drivers having their vehicles manufactured from 2007 onwards.

This was done in order to obtain more information about the local DPF blockage problem from the public point of view. Two interviews were also conducted to analyse the problem from a more technical point of view.

A blocked DPF was obtained from a 1.5L engine vehicle. Mass air flow rate was measured on this DPF but it was totally blocked. To oxidise the accumulated soot that blocked this DPF, a heat procedure was performed using a temperature controlled furnace. The heat procedure consisted of several temperature ramps to heat the DPF to a temperature high enough to oxidise the accumulated soot. After the heat procedure, mass flow rates were performed to calculate several parameters that indicate the degree of blockage. The pressure difference, discharge coefficient, blockage coefficient, average air velocity and mass flow rate were the parameters used to quantify the degree of blockage.

Results and Achievements

From the interviews and questionnaire it was concluded that lack of education regarding the DPF technology is the main culprit that the DPF blockage problem is increasing locally.

The heat procedure proved to be successful since the blocked DPF was back to its original state. This was reflected in the results obtained from the air flow measurements carried out. During these measurements the difference in pressure across the DPF decreased by more than 50%. Also the discharge coefficient increased significantly while the blockage coefficient decreased.

Figure 1: DPF Section in the Furnace

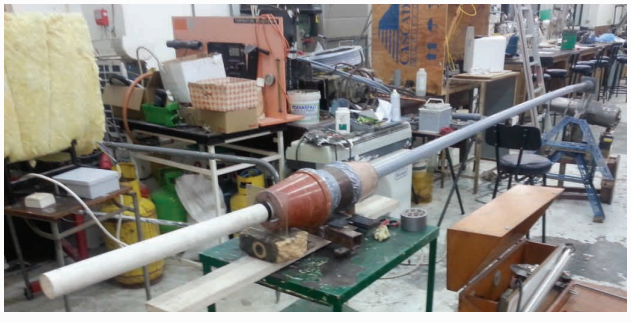


Figure 2: Air Flow Setup for DPF Section

Improved Methods for Cleaning Reverse Osmosis Membranes

Student: Timothy Zammit / Supervisor: Prof. Robert Ghirlando / Co-Supervisor: Prof. Maurice Grech

Introduction

This project was carried out with the Water Services Corporation as industrial partner. It involved numerous tests with a number of different chemicals for the cleaning of fouled Reverse Osmosis membranes.
This was made possible through the use of a Flat Sheet Membrane Test Rig located at the industrial partner's Reverse Osmosis Plant in Pembroke.

Project Objectives

Membrane life is dependent on how well it is maintained and cleaned; therefore, the main aims of this project were:

- To modify, repair and maintain the Flat Sheet Membrane Test Rig
- To test various chemicals for the cleaning of Reverse Osmosis membranes
- To analyse the fouled and cleaned samples using spectroscopic techniques

Project Methodologies

A number of tests were performed, consisting of:

- Seawater tests on the fouled membrane
- Chemical cleaning of the fouled membrane with commodity chemicals, followed by a seawater test
- Chemical cleaning of the fouled membrane with proprietary chemicals, followed by a seawater test

In order for the chemical cleaning tests to be performed, a new reservoir tank had to be designed, constructed and connected to the current test rig. Following this, all cleaning tests were performed under the same conditions for temperature and time, varying only the weight percentage of chemical used. Three samples were cleaned and tested simultaneously and all samples for all tests were selected from the same membrane module displaying the same degree of fouling to ensure fair results.
Fouled and Cleaned membrane Samples were then taken to the University of Malta's Engineering Department of Metallurgy and Materials Laboratory and examined under a Scanning Electron Microscope for further results.

Results and Achievements

It was determined through test results, Scanning Electron Micrographs and Energy Dispersive X-ray results on all tested samples, that the most effective cleaning method was indeed that currently employed by the Water Services Corporation.
This cleaning procedure made use of two commodity chemicals, one being an alkaline solution, and the other an acidic solution, which were used alternately during the process.
The results for this test showed an increase in water flux of 25%, a Salt Rejection of 97.4%, as well as more effective removal of metal oxide, colloidal and particulate fouling than any other test performed. In fact, Calcium and Potassium were completely removed as well as a significant reduction in Magnesium was observed.

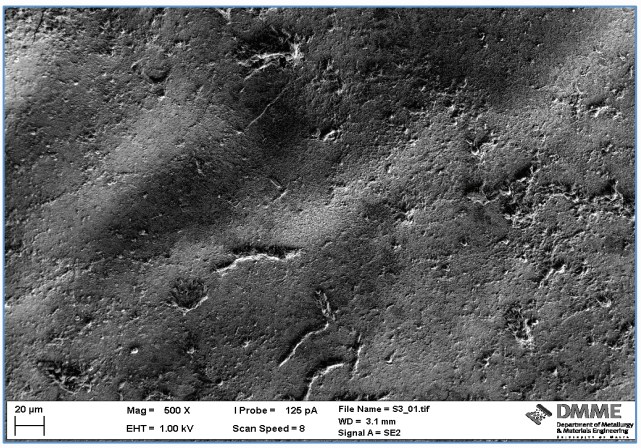
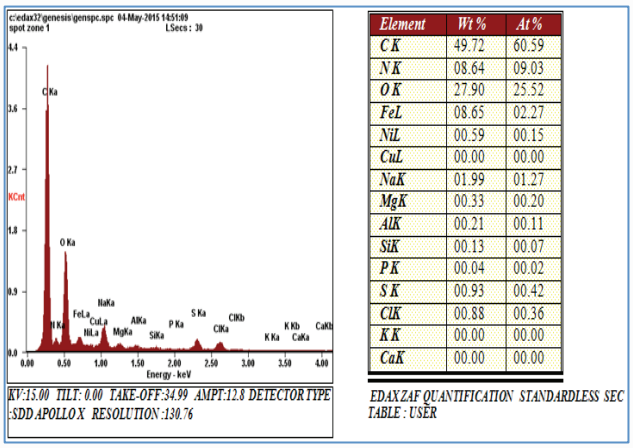


Figure 1: Scanning Electron Micrograph of a Membrane Cleaned with the standard WSC cleaning procedure at 500X



Element	Wt %	At %
C K	49.72	60.59
N K	08.64	09.03
O K	27.90	25.52
Fe L	08.65	02.27
Ni L	00.59	00.15
Cu L	00.00	00.00
Na K	01.99	01.27
Mg K	00.33	00.20
Al K	00.21	00.11
Si K	00.13	00.07
P K	00.04	00.02
S K	00.93	00.42
Cl K	00.88	00.36
K K	00.00	00.00
Ca K	00.00	00.00

Figure 2: EDS Analysis of Membrane Cleaned with the standard WSC procedure, at 200X

Development of Test Stand for Automotive Turbocharger Testing and Performance Mapping

Student: Miao Zhang / Supervisor: Dr Ing. Mario Farrugia

Introduction

Turbocharging plays a very important role in modern automotive industry, as it is a very effective way to improve engine performance. The turbocharger uses a turbine to extract energy from the hot exhaust gas of the engine, and use it to compress air to a pressure above the ambient pre entering the engine. By doing so, the turbocharger would increase the volumetric efficiency and so the power density of the engine. The operational characteristics of the turbocharger are described through the performance maps. The maps present the steady operational ranges of the turbocharger by plotting constant speed lines and isentropic efficiency islands over axis of pressure ratio against air mass flow rate

Project Objectives

The main objective of this work was to design and construct a test stand, which can be used to test turbochargers and collect the necessary data for performance maps generation.

Project Methodologies

The test stand constructed was a 2-loop [1] hot gas stand, where the turbocharger was driven by passing hot air through its turbine. The air was supplied by the use of a roots type supercharger, which was driven by a 15KW motor and speed controlled by an inverter. The supplied air was then heated by combusting it with gas fuel through a tubular type combustion chamber, as shown in figure 1. The combustion chamber consists of a flame tube which has three regions: the primary, secondary and tertiary. The combustion was designed to occur within the primary region, while air came in from the secondary and tertiary regions would be used for dilution purposes. A swirling motion was also created as air enters the combustion chamber, this swirling motion protects the flame tube from overheating. The combustion chamber was able to maintain a steady flame through a wide temperature range between 500 and 1000 ℃ and even higher. This provided further control to the energy supplied to the system. The flow on the compressor side was controlled by installing an adjustable valve at the compressor outlet.

Results and Achievements

The instrumentations used were rather simple, but good enough to test the functionality of the setup. The experiment data points gathered were plotted over the maps provided by the manufacturer. The comparison of the data points showed a good functionality of the test stand, but better instrumentation would be required for more accurate results.

References

[1] SAE, 'Turbocharger Gas Stand Test Code' Standard SAE J1826, 1995

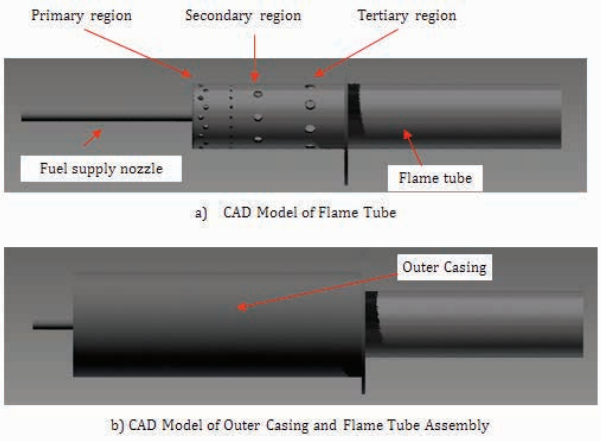


Figure 1: CAD Model of Combustion Chamber Assembly

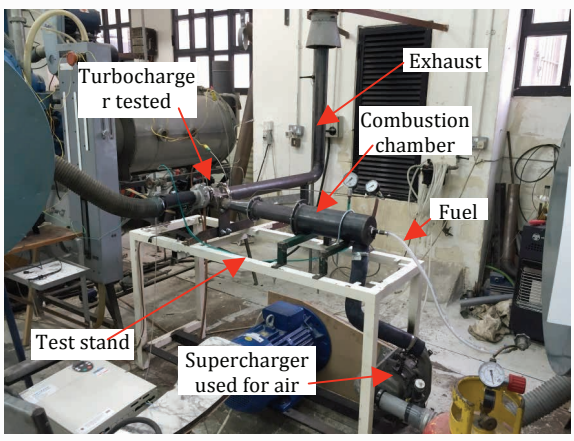


Figure 2: Test Stand Constructed

A Study on the Efficacy of Ammonium Dihydrogen Phosphate as a Consolidant Material for Globigerina Limestone

Student: Adrian Abdilla / Supervisor: Dr Daniel Vella

Introduction

Globigerina Limestone is the main building stone in Malta and examples of building and monuments can be found dating back to antiquity. Airborne pollutants and salt deterioration through rising damp phenomenon is a major cause of damage to historical buildings. Consolidation treatments are employed to safeguard the stone from further deterioration. Consolidation is a process through which a material is made to penetrate the deteriorated stone in order to cement the weathered material with the non-weathered material of the stone [1].

Project Objectives

In this study ammonium dihydrogen phosphate was evaluated as a potential new consolidant for Globigerina Limestone. .The consolidant treatment was tested on limestone blocks prepared to simulate different conditions in the field.

Project Methodologies

The consolidant ADHP was applied as a 1 Molar aqueous solution to three differently processed franka-type Globigerina Limestone samples by capillary absorption method. Globigerina Limestone test samples were as follows: (1) as-quarried, desalinated test blocks, (2) quarried, artificially aged, desalinated test blocks, (3) quarried, artificially aged – salt loaded test blocks.

Consolidant treatment time (by capillary absorption) was fixed to 48 hours. Artificial ageing of the test blocks was carried out by two sodium sulfate salt crystallization cycles as per standard BS EN 12370:1999 [2]. Artificial ageing was carried out to better approach the situation in naturally weathered limestone. Artificially aged salt loaded stone blocks were produced to simulate naturally deteriorated limestone contaminated by salt.
Changes to the stone's physical and microstructural properties after consolidation were assessed by a number of characterization including X-ray diffraction, scanning electron microscopy and Mercury Intrusion Porosimetry. A resistance to drilling test was used to evaluate improvements to the mechanical properties of the deteriorated stone after consolidation treatment.

Results and Achievements

Results showed that after consolidation treatment with ammonium dihydrogen phosphate, the stones' mechanical properties were improved. This improvement was due to the precipitation of the calcium phosphate mineral Brushite. The mineral is a precursor to the more complex hydroxyapatite (HAP). It is interesting to note that when the consolidant was applied to artificially aged salt (NaCl) loaded limestone test samples, the resulting precipitated consolidant involved a mixture of both brushite and hydroxyapatite. This result strongly suggests that HAP formation is promoted in limestone contaminated with salts.

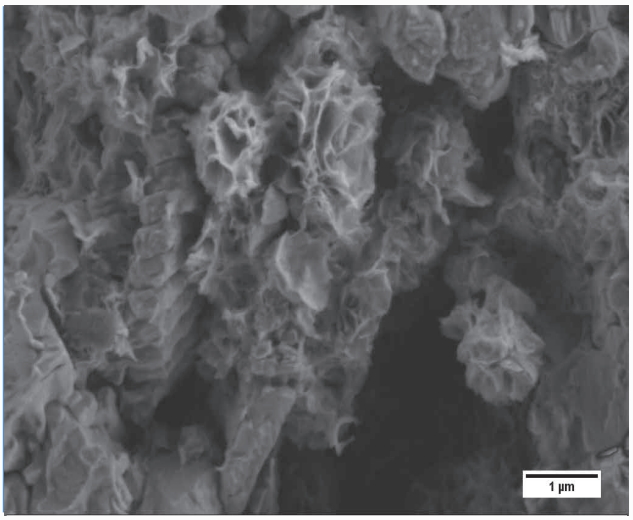


Figure 1: Electron micrograph of the deposited calcium phosphate rich mineral onto clean limestone

References

[1] E. Doehne and C. Price, Stone conservation. Los Angeles, Calif.: Getty Conservation Institute, 2010.

[2] Natural stone test methods - Determination of resistance to salt crystallization, BS EN 12370:1999

Scuffing Resistance of Laser Surface Modified Austempered Ductile Iron

Student: Roberta Apap / Supervisor: Dr Ing. Ann Zammit

Introduction

Scuffing can occur during start-up of automotive gear operation when there is not enough lubrication between the gear teeth. Austempered ductile iron (ADI) has recently emerged as a material with improved scuffing resistance owing to its combination of mechanical properties. The wear resistance of ADI can be further improved by different surface treatments such as laser surface modification.

Project Objectives

Considering that scuffing leads to the catastrophic failure of gears, this study attempts to determine the effectiveness of laser surface processing in enhancing the properties of ADI.

Project Methodologies

Literature on scuffing behaviour of as-treated and laser surface modified ADI was reviewed to understand better the wear mechanisms that take place during scuffing. ADI discs were fabricated from raw ductile iron material. The samples were austenitised at 900°C for two hours and austempered at 360°C for one hour. The unique ausferritic microstructure imparts high strength, toughness and ductility to the material [1]. After establishing the laser processing parameters that yield maximum hardness and high case depth, ADI discs were laser treated with adjacent spots as shown in Figure 1. Scuffing tests were carried out with a pin-on-disc machine on as-treated and laser surface processed ADI discs, using a hardened steel ball as the counter face.

Figure 1: Pattern of laser spots on the surface of ADI

Results and Achievements

The chosen optimal laser processing parameters were characterised by laser melting, creating dimples on the surface. The as-treated and laser surface treated ADI discs failed after approximately the same number of cycles (Figure 2). The scuffing resistance of ADI was attributed to the change in microstructure from the soft retained-austenite to hard strain-induced martensite during testing. This increase in hardness of ADI was comparable to that of laser processed samples. On the other hand, the wear rate of laser processed ADI discs was reduced due to the high hardness following laser melting and the retention of oil in the laser dimpled surface.

References

[1] Han J. M., Zou Q., Bardber G. C., Nasir T., Northwood D. O., Sun X. C. and Seaton P. 'Study of the Effects of Austempering Temperature and Time on Scuffing Behaviour of Austempered Ni-Mo-Cu Ductile iron', Wear, pp. 83-90, 2004

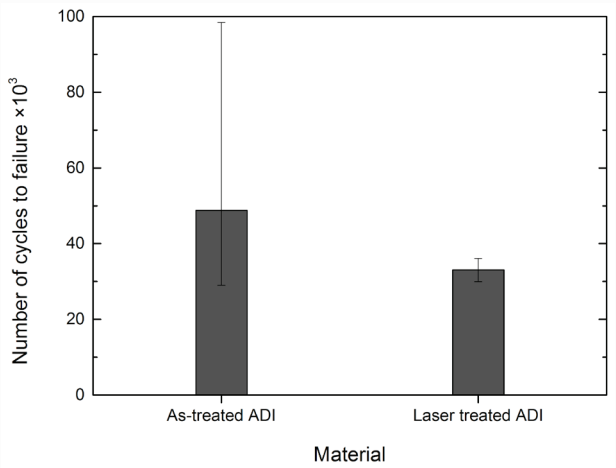


Figure 2: Scuffing Tests Results

Austempered Ductile Iron for Automotive Gears

Student: Matthew Bonnici / Supervisor: Dr Ing. Ann Zammit

Introduction

Automotive engineers are constantly seeking to obtain better efficiency and economy in the production sector while continually trying to reduce the carbon footprint of their vehicles. Austempered ductile iron (ADI) gears offer optimum benefits to suite these criteria, however their contact fatigue resistance is poor [1].

Project Objectives

The main aim of this project was to implement a harder surface on ADI in order to amplify the required surface properties in gear usage.

Project Methodologies

A number of ductile iron gears were produced (figure 1) and subsequently heat treated to transform to ADI. Half of the ADI gears underwent a shot peening process in order to increase the hardness of the outside case with the intent to make them more fatigue resistant. Multiple fatigue tests were performed on both as-treated ADI and shot peened ADI gears utilising a gear testing rig until all the gears reached a stipulated wear area. Analysis on the wear areas were then performed on all the gears.

Carburised steel gears, which are presently widely used in the automotive industry were used as a bench mark in order to compare the results to those obtained by the as-treated ADI and shot peened ADI gears.

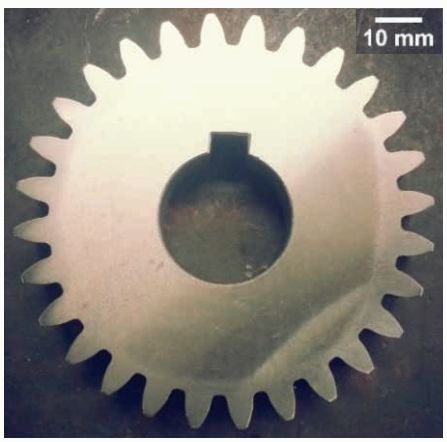


Figure 1: Ductile iron gear.

Results and Achievements

The shot peening process which was performed on the ADI gears significantly increased the hardness of the gears, thus creating a hard case which surrounded a relatively softer bulk material. This increase in hardness is obtained by a change in phase from austenite to martensite, which is a relatively harder phase, due to the work imposed on the surface while enabling compressive stresses to eliminate any tensile stresses present which give rise to crack initiation and propagation. However, a significant degree of roughness was imposed on the surface of these gears which did not aid in gear meshing.

Being capable of changing the phase structure the as-treated ADI gears performed better than the shot peened ADI gears. This was attributed to phase transformation from the soft austenite phase to the harder martensite phase and also to a better finish which enabled less surface interaction.

The carburised gears, having a higher degree of case hardness and an optimum surface finish exhibited the best performance and were capable to endure longer number of cycles (figure 2).

References

[1] Dommarco R. C., Bastias P. C., Dall H. A., Hahn G. T., Rubin C. A., 'Rolling Contact Fatigue (RCF) Resistance of Austempered Ductile Iron (AD)' Wear, 1998, Vol. 221, pp. 69-74

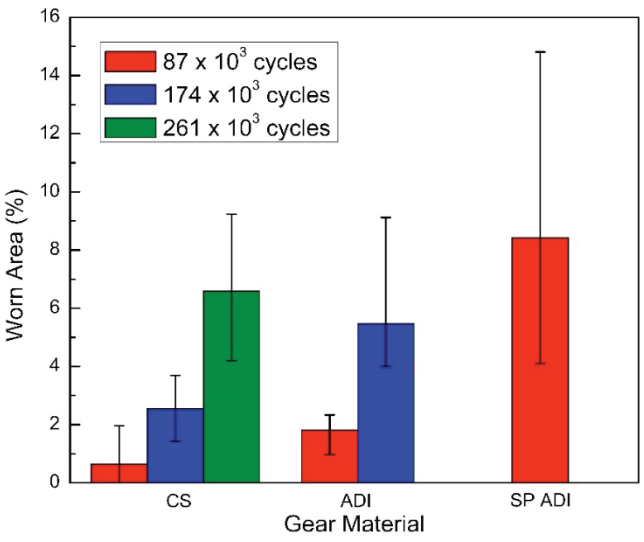


Figure 2: Percentage worn area of gear teeth for the different tested materials.

Surface Engineering Techniques to Assist Mould Release in Compression Moulding

Student: Mark Borg / Supervisor: Prof. Maurice Grech / Co-Supervisor: Dr Ing. Stephen Abela

Introduction

Mould release properties are of major importance in compression moulding because during the extraction process, the article has to be removed in order to allow material to be loaded for the next cycle. In the rubber moulding industry, this stage proves to be difficult to perform successfully, regardless of the moulding process [1]. The intrinsic chemical nature of some rubbers render them susceptible to adhere to the mould, resulting in mould fouling which has to be removed before carrying out further moulding. This fouling impairs the efficiency of production and the quality of the product. Trelleborg Sealing Solutions Malta Ltd. use compression moulding to produce fluorocarbon and hydrogenated nitrile butadiene rubber O-rings. They acknowledge that they can greatly benefit from improvements in the de-moulding stage as these two polymers are particularly difficult to de-mould.

Project Objectives

The aim of this project is to evaluate several surface engineering techniques which could improve the de-moulding of fluorocarbon and hydrogenated nitrile butadiene rubber formulation O-rings.

Project Methodologies

The surface engineering technologies were assessed using laboratory tests as well as field tests.

The surface engineering techniques were characterised at the Department of Metallurgy and Materials Engineering using: energy dispersive spectroscopy to determine the chemical composition; X-ray diffraction to determine the crystallinity and/or phases present; and scanning electron microscopic imaging to study the structure and the coating thickness. Nano-indentation testing was carried out to obtain the Young's Modulus and the nano-hardness properties.

During this project a de-moulding test was set up to compare the de-moulding attributes of the surface engineering techniques applied. The mould used in the test had six segments each treated with a different surface engineering technique and is shown in Figure 1. The surface engineering techniques investigated were hard chromium, diamond-like carbon, ion implanted electroless nickel, electroless nickel and PTFE composite, and ion implanted chromium nitride. The tests were performed at Trelleborg Sealing Solutions Malta Ltd. who have generously sponsored this research project. The coatings were assessed and compared according to their ease of de-moulding.

Results and Achievements

It was found out that some surface engineering techniques applied improved de-moulding considerably, yet not sufficiently for cost effective production of these very demanding proprietary rubber formulations. In fact a second treatment was required.

In the case of fluorocarbon O-ring production the recommended solution is the use of a hard chromium coating followed with an application of an external semi-permanent mould release agent. For hydrogenated nitrile butadiene rubber it is recommended to use hard chromium coating together with the application of an external semi-permanent mould release agent, as well as a sacrificial mould release agent applied at the beginning of each cycle. This significantly reduced the de-moulding time and improved the efficiency of production.

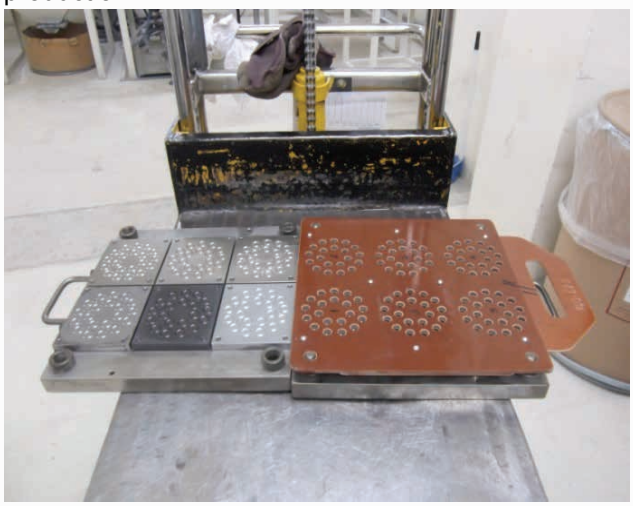


Figure 1: The segmented mould used in the in-field testing

References

[1] Strizke B, 'Custom Molding of Thermoset Elastomers' Hanser Publishers, Munich, 2009.

Effect of EBM on the Microstructure and Mechanical Properties of Titanium Alloy

Student: Jacob Paul Bruno / Supervisor: Dr Ing. Glenn Cassar / Co-Supervisor: Dr Ing. Arif Rochman

Introduction

The EBM process is an additive manufacturing technique that constructs 3D components layer by layer from Ti-6Al-4V powder. It allows great flexibility in the geometric design and produces little waste material, but may unforunately have repeatability issues. The effects of build orientation are currently not fully understood.

Project Objectives

The aims of this project include (i) the fabrication of EBM and wrought Ti-6Al-4V tensile and impact specimens, the latter servicing as benchmark for comparision and (ii) to vary process parameters such as lay orientation and in turn observe their effects on microstructure and mechanical performance.

Project Methodologies

XRD and SEM/EDS analysis revealed that use of new and recycled Ti-6Al-4V ELI (Grade 23) powder has no significant effect on the chemical composition and component size accuracy. Tensile and Izod impact specimens were designed according to ASTM E8/8M [1] and E23 [2] standards respectively and ground for improved surface finish. Wrought specimens were machined by wire-EDM.

The various lay orientations considered in this study are seen in Figure 1. Furthermore one specimen group was also built using two preheating cycles instead of the typical one cycle. Vickers microindentation was conducted, along with materical characterisation and fractographic analysis via optical microscopy and stereomicroscopy/SEM.

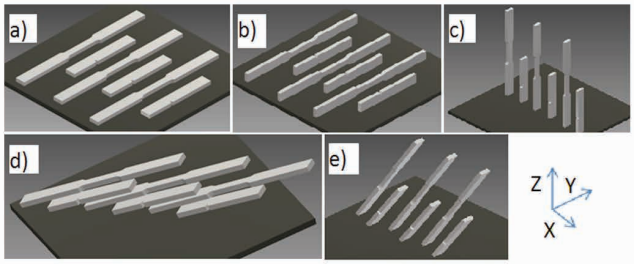


Figure 1: Different lay orientations studied – a) XY b) ZX c) ZY d) 30° to XY plane e) 60° to XY plane

Results and Achievements

Specimens inclined at 30° to the base plate experienced warping. Columnar prior-β grains develop along the build direction, as they follow thermal gradients, and contain a very fine acicular microstructure, as in Figure 2. Horizontal orientations produced highly refined microstructures due to higher thermal transfer. Variation in degree of grain refinement also occurs within individual specimen along the build direction.

Tensile strength is comparable to Arcam AB®'s data [3], which states that typically, EBM Ti-6Al-4V ELI has a yield strength of 930 MPa and ultimate tensile strength of 970 MPa. Refined microstructures resulted in higher impact forces and microhardness. Large defects in horizontal tensile specimens reduced their tensile properties while smaller prior-β grains reduce impact resistance. Wrought Ti-6Al-4V has slightly higher tensile properties but lower fracture toughness.

References

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[3] Arcam AB, 'Ti6Al4V Titanium Alloy', Arcam AB. [Online]. Available: http://www.arcam.com/wp-content/uploads/Arcam-Ti6Al4V-ELI-Titanium-Alloy.pdf.

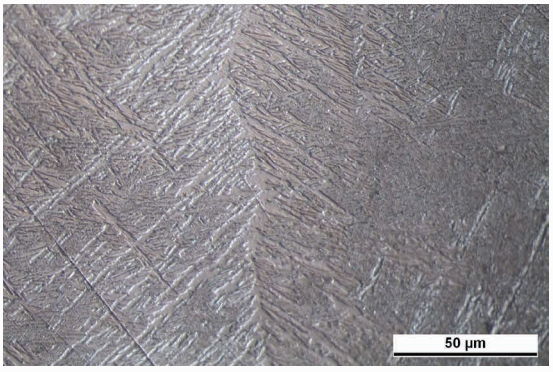

Figure 2: Typical acicular microstructure within prior-β grains

Tribocorrosion Behaviour of PVD CrN-Coated Low Temperature Carburised Implant Grade 316LVM

Student: Imer Cardona / Supervisor: Dr Ing. Bertram Mallia / Co-Supervisor: Dr Ing. Joseph Buhagiar

Introduction

There are twenty five percent of all adults that require hip or knee replacements, with obesity being one of the leading sources for these surgeries [1].
Tribocorrosion combines the synergistic effects of corrosion and mechanical wear and it affects greatly the biomedical industry, resulting in major expenses and revision surgeries of hip and knee implants, causing discomfort to the patient. This has led researchers to investigate ways how these effects can be mitigated [2].

One way how tribocorrosion processes can be mitigated is by the application of duplex surface engineering treatments. In this work, a thin, hard coating was deposited by Physical Vapour Deposition (PVD) on a low-temperature carburised 316LVM. The relatively thick carburised layer (≈ 40 µm) was meant to provide good load support to the thin (≈ 4 µm) PVD layer. The PVD treatments were carried out by Boride Services Ltd. (UK) and the carburising treatment by Bodycote Hardiff GmbH (Germany).

Project Objectives

The main objectives of this project were to investigate and compare the tribocorrosion response of untreated 316LVM, CrN and duplex CrN coatings in simulated body fluid conditions using reciprocating sliding configuration against an inert, alumina ball. The structural and mechanical surface properties of untreated, CrN and duplex CrN samples were also studied.

Project Methodologies

The hardness, adhesion and load-bearing capabilities of the coating with the substrate were examined by nano-indentation and nano-scratch tests.
Three different electrochemical conditions were used to study the effect of corrosion, wear and the synergism between the two. Reciprocating sliding tribocorrosion testing was carried out in simulated body fluid conditions in Ringer's Solution against an inert, Al_2O_3 ball.
Wear scar morphology obtained following tribocorrosion testing were further analysed using Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDS) and profilometry.

Results and Achievements

CrN and duplex CrN coatings displayed very high hardness compared to untreated 316LVM and the duplex CrN showed exceptional adhesion with the substrate.
Duplex CrN was found to have the highest wear resistance. However, CrN and duplex CrN failed catastrophically when corrosion attacked the substrate through micro-cracks that formed during tribocorrosion testing. This attacked the interface and triggered severe delamination and pitting at the surface, as shown in Figure 1. However, the low-temperature carburising treatment of the substrate was found to have prevented pitting at the surface from occurring.
A suggestion that could prevent this type of failure for CrN and duplex CrN is the use of a multi-layer system to prevent crack propagation to the surface layer. Another suggestion is to find ways how to mitigate corrosion reactions from occurring at the interface.

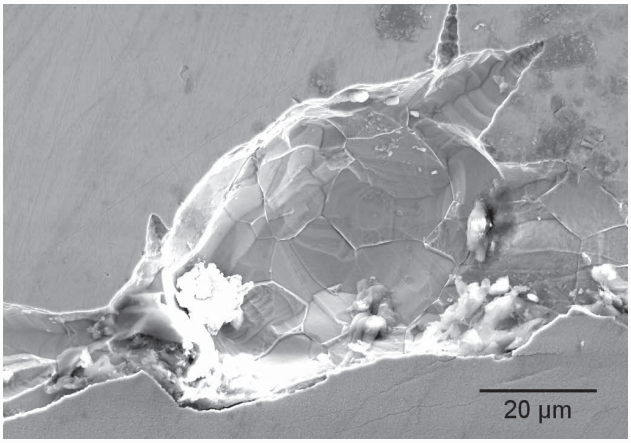

Figure 1: Pitting present in CrN coatings following tribocorrosion testing in Ringer's Solution against an inert alumina ball

References

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[2] Mathew M.T., Srinivasa Pai P., Pourzal R., Fischer A., and Wimmer M.A., 'Significance of Tribocorrosion in Biomedical Applications: Overview and Current Status', Advances in Tribology, 2009, Vol. 2009, pp. 1-12.

A Preliminary Study of the Effects of Multi-Wall Carbon Nanotubes on the Properties of Sol-gel Coatings

Student: Luke Cini / Supervisor: Dr Daniel Vella

Introduction

This study involved the preparation, deposition, characterization and testing of a sol-gel coating loaded with increasing concentration of carbon nanotubes (CNTs) for application onto mild steel susbtrate

Project Objectives

The objectives of this study were as following:

To characterize sol-gel coatings with increased loading of CNTs: coating thickness and microstructure.

To evaluate the effect of increasing the CNT concentration on the mechanical properties of the coatings deposited on mild steel.

To evaluate optical properties of the CNT-loaded coatings onto transparent glass substrate

To assess the anti-corrosion properties of CNT loaded sol-gel coatings deposited onto mild steel.

Experimental

A single sol gel coating was produced consisting of a 60:40 mole% ratio of the precursor materials tetraethyloxysilane (TEOS) and methyl triethoxysilane (MTES). The coating material was loaded with increasing concentrations of carboxyl-functionalised short multi-wall carbon nanotubes (SMWCNTs) in the range 0 to 0.01 percent by weight. Coatings were deposited by dip-coating technique using home-built dip-coater built for this study.

Coating optical properties were evaluated by UV-visible spectroscopy while chemical composition was investigated by Infra-Red spectroscopy. The uv-visible transmission spectra were also used to determine coating thickness. The hydrophobicity of the coatings was determined by contact angle measurements, while high magnification images of the coating surface were achieved a scanning electron microscope. Corrosion protection properties of the coatings were determined by subjecting the coated steel coupons to electrochemical potentiodynamic tests and a cyclic salt fog test. Nano-indentation was performed to evaluate mechanical properties, namely to determine the hardness and Young's Modulus of the coatings.

Results and Achievements

Preliminary results showed that the addition of low concentrations of carbon nanotubes (~ 0.01%) to the sol-gel coatings led to a slight improvement of the mechanical properties of the coatings as shown in Figure 1. Both coating hardness and Young's Modulus were marginally improved; this was in agreement with predictions from the rule of mixtures.

The optical properties, namely the % transmission of the coatings with increased loading of CNTs remained unaltered when compared to the coating without carbon nanotubes.

The contact angle increased with an increase in carbon nanotube loading, but this did not have the desired effect on the corrosion properties. Indeed no significant improvements or loss of protection were reported in corrosion tests.

Overall it seems that the inclusion of carbon nanotubes to sol-gel coatings improved the mechanical properties while leaving the optical properties unchanged. Further experimental work is required to confirm or otherwise trends observed and to shed more light on the effects on the corrosion properties.

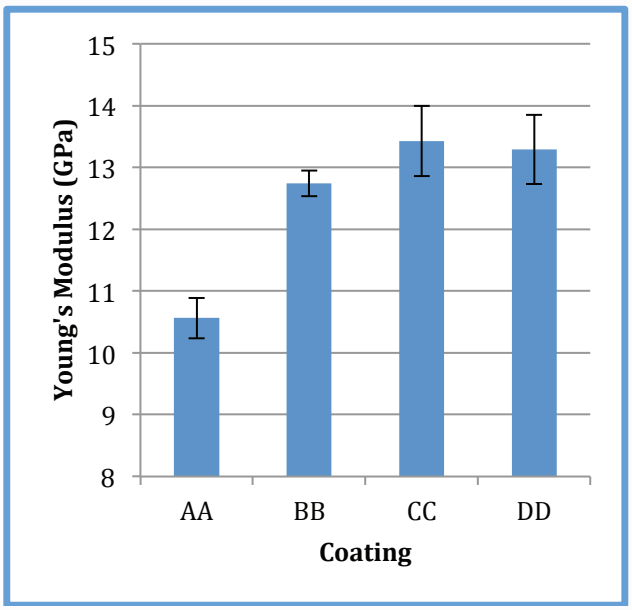

Figure 1: Young's Modulus in GPa for 60:40 mol% MTES:TEOS with (A) 0, (B) 0.001, (C) 0.005, and (D) 0.01% MWCNTs.

Transition Metal Carbon Coatings for Increased Longevity of Biomedical Implants

Student: Brenda Farrugia / Supervisor: Dr Ing. Bertram Mallia

Introduction

The joint action of corrosion and wear processes plays an important role in the degradation of the bearing surfaces of hip joint implants. A plausible solution to mitigate this problem would be to tailor their surface by using protective coatings on the bearing surfaces of the hip joint implant deposited by magnetron sputtering Physical vapour deposition (PVD) technique.

Project Objectives

The primary objective of this study is to characterise and investigate the corrosion and tribocorrosion response of Cr and Zr transition metal carbon coatings, deposited at Boride Services Ltd., for the surface protection of the bearing surface of medical grade austenitic stainless steel hip joint implant.

Project Methodologies

The novel Cr-C and Zr-C transition metal carbon coatings on biomedical grade stainless steel were characterised to determine their chemistry, structure, morphology, hardness and deformation behaviour.

Analysis of the static corrosion response of untreated and treated 316 LVM stainless steel in Ringer's solution, was performed using open circuit potential and potentiodynamic tests. A reciprocating sliding testing configuration was used to investigate the tribocorrosion response of the untreated and coated 316 LVM stainless steel. Sliding was done against a 7.94 mm inert alumina ball in Ringer's solution, to simulate body fluids, under a normal load of 1 N and 2 N. Three electrochemical conditions were used to determine the contribution of electrochemical and mechanical processes to the material volumetric loss of the untreated and treated 316 LVM stainless steel.

The resultant corrosion-wear scar morphology was further investigated using Scanning Electron Microscope (SEM), Energy Dispersive Spectroscopy (EDS), optical microscopy and contact profilometry.

Results and Achievements

The Zr-C coating comprised crystalline Zr and ZrC phases while the Cr-C coating was amorphous or nano-crystalline or a mixture of both [1]. The hardness of both coated specimens was substantially higher, Cr-C ~33GPa and Zr-C ~12GPa, than that of the untreated 316 LVM stainless steel substrate, ~3GPa.

The untreated and treated samples displayed a good corrosion resistance yet the Zr-C coated sample exhibited lower current densities indicating a better corrosion response under static potentiodynamic polarisation tests. From tribocorrosion tests, the untreated 316 LVM stainless steel showed frequent abrasion marks along the sliding direction indicating plastic deformation of the material. The Cr-C coating displayed minor polishing-wear while the Zr-C coating showed roughening of the corrosion-wear scar under all three electrochemical conditions when subjected to both 1 N and 2 N normal loads. Coating failure and severe roughening of the Zr-C corrosion-wear scar was observed when polarised anodically under a 1 N normal load.

Both coating materials were effective in reducing the overall material loss compared to the untreated 316 LVM stainless steel.

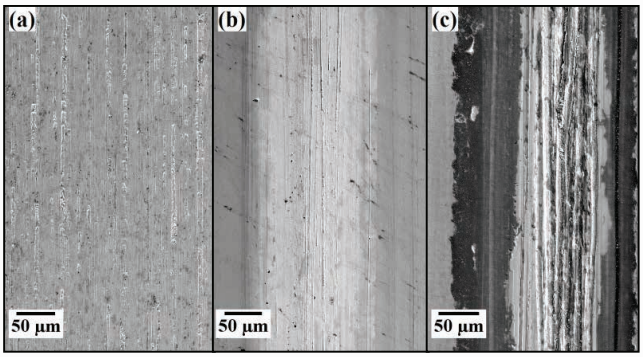

Figure 1: SEM image showing corrosion-wear scar morphology on (a) 316 LVM stainless steel, (b) Cr-C coating, (c) Zr-C coating, following tribocorrosion under 1 N load in Ringer's solution.

References

[1] Andersson M., Högström S, Urbonaite A., 'Deposition and characterisation of magnetron sputtered amorphous Cr-C films', Vacuum, 2012, Vol. 86, No. 9, pp.1408-1416.

Triode Intensified Plasma Treatments of Timetal 834 Titanium Alloy

Student: Joshuel Michael Grech / Supervisor: Dr Ing. Glenn Cassar

Introduction

Titanium alloys exhibit many attractive properties, such as low density, high corrosion resistance and excellent mechanical properties. They do however suffer from poor tribological properties. This work will be focused on improving the tribological properties of Timetal 834; a recently developed near-α titanium alloy, using triode plasma nitriding.

Project Objectives

To improve the tribological properties of Ti-5.8Al-4Sn-3.5Zr-0.7Nb-0.5Mo-0.35Si and assess changes in the surface properties and microstructure. The results were compared with similarly treated Ti-6Al-4V.

Project Methodologies

Ti-6Al-4V and Timetal 834 were diffusion treated by plasma nitriding using a dc-triode configuration supplement by additional plasma heating. TPN was carried out at 700°C and 800°C in a mixture of nitrogen and argon at a cathode voltage of -500V. The process duration varied between 1 and 2hrs.

Surface profilometry, nanoindentation hardness testing, Vickers micro-indentation surface analysis, scratch-adhesion testing, scanning electron microscopy (SEM), optical microscopy and X-ray diffraction data is presented to corroborate the effects of the plasma nitriding process.

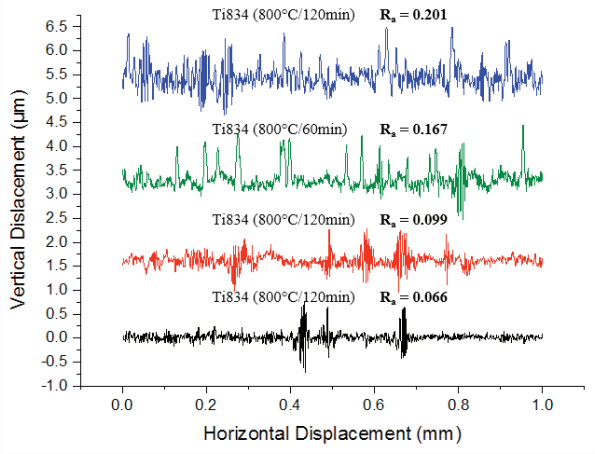

Figure 1: R_a values for untreated and TPN treated Ti834

Results and Achievements

Some similarities were observed between the two α-hcp dominant phase alloys indicating the potentially similar response of the two alloys to any surface diffusion treatment.

Ti-6Al-4V was found to have suffered from drastic surface roughness after plasma diffusion nitriding at 800°C for 2hrs of a R_a value of 0.352µm. Timetal 834 was found to exhibit a less increase in surface roughness after treatment by maintaining an acceptable R_a value for all processing parameters (i.e. ≤ 0.2µm R_a). [1] The surface profiles obtained for untreated and plasma nitrided Ti834 can be seen in figure 1. Nanoindentation of the TPN treated samples indicated significant increases with the maximum value for Ti834 recorded as 15GPa, when treated at 700°C for 2hrs. Ti-6Al-4V exhibited a maximum value of 20GPa when treated at 800°C for 60mins. The surface roughness for both alloys when treated at 800°C for 2hrs adversely affected measurements obtained and therefore despite the low values measured, the actual hardness values remain debatable. The results obtained for untreated and treated Ti-6Al-4V and Timetal 834 alloys can be seen in Figure 2.

References

[1] Cassar G., Matthews A., and Leyland A., 'Triode plasma diffusion treatment of titanium alloys,' Surface & Coatings Technology, 2012, Vol. 212, pp.20-31

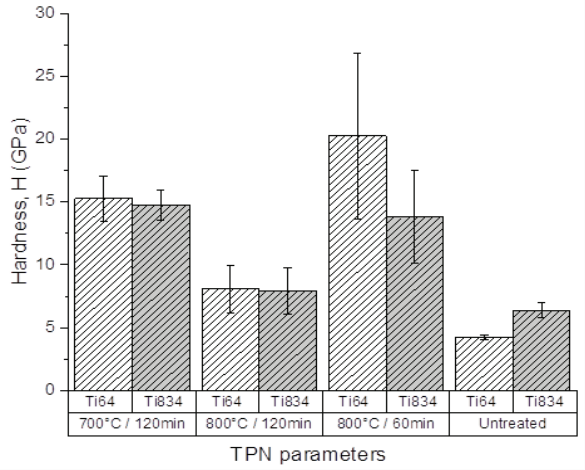

Figure 2: Hardness values for untreated and TPN treated Ti64 and Ti834

The Effect of Austempering Conditions on the Austenite Content and its Stability

Student: Gilbert Simiana / Supervisor: Dr Ing. Ann Zammit / Co-Supervisor: Prof. Ing. Maurice Grech

Introduction

To cater for the increasingly challenging consumer demands, engineers are continuously searching ways on how to improve and maximise the performance of a material. Austempered Ductile Iron (ADI) is produced by applying an austempering process to ductile iron which improves its mechanical properties but maintains its design flexibility. By varying the heat treatment parameters, different mechanical properties can be obtained making ADI suitable for various applications as shown in figure 1.

Project Objectives

This project aims to study the effect of different austempering parameters on the microstructure and its microconstituents of ADI alloyed with copper and nickel. Particular attention was given to the austenite phase and its stability.

Project Methodologies

The austempering process is made up of three main steps. The first step is heating the ductile iron to the austenitising temperature (T_γ) and holding for a specified time (t_γ) to homogenise the microstructure. This is followed by hot quenching to the austempering temperature (T_a) and soaking the material for a specified time (t_a). Then the material is air cooled to room temperature.

In this study, the austempering temperature (T_a) was varied between 240°C and 400°C at steps of 40°C and for each temperature six different austempering times (t_a) were applied varying between 5 minutes and 360 minutes.

X-ray diffraction (XRD) techniques were used to investigate the volume fraction of austenite (V_γ) and the austenite carbon content (C_γ). This was done by analysing the XRD diffraction patterns with specialised computer software (PDXL 2.0). Using a Rietveld Refinement Method, the software identified the 2θ positions of the peaks and their integrated area which were necessary to calculate the values of V_γ and C_γ.

Furthermore, light microscopy and scanning electron microscopy (SEM) were used to image the microstructures obtained. Finally a macro-hardness test was done to analyse the relationship between hardness with varying austempering parameters.

Results and Achievements

From this study it was concluded that as the austempering temperature increased, the volume fraction of austenite (V_γ) increased which, if stable, improves the mechanical properties.

At longer austempering times, more time was allowed for carbon to diffuse into the austenite phase which resulted in higher austenite carbon content (C_γ). This increase in carbon content increased the stability of the austenite phase which contributed to higher volume fractions of austenite (V_γ).

Lastly the use of the product $V_\gamma C_\gamma$ to measure the stability and mechanical properties of ADI was investigated to assess its reliability. By creating a relationship between this product and impact energy results obtained by Grech [1] it was concluded that this product yields reliable results between austempering times (t_a) of 30 minutes and 180 minutes. At austempering times (t_a) of 360 minutes it was evident that $V_\gamma C_\gamma$ underestimated or overestimated the mechanical properties depending on the austempering temperature (T_a) and hence results are unreliable.

Figure 1: Components made of ADI [2].

References

[1] M.Grech, Structure and Mechanical Properties of an Austempered Ductile Iron alloyed with copper-nickel, 1989, PhD.

[2] Samtc.com, "Products & Services – Austempered Ductile Iron" http://www.samtc.com/products31.html [Accessed: 18-May-2015]

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