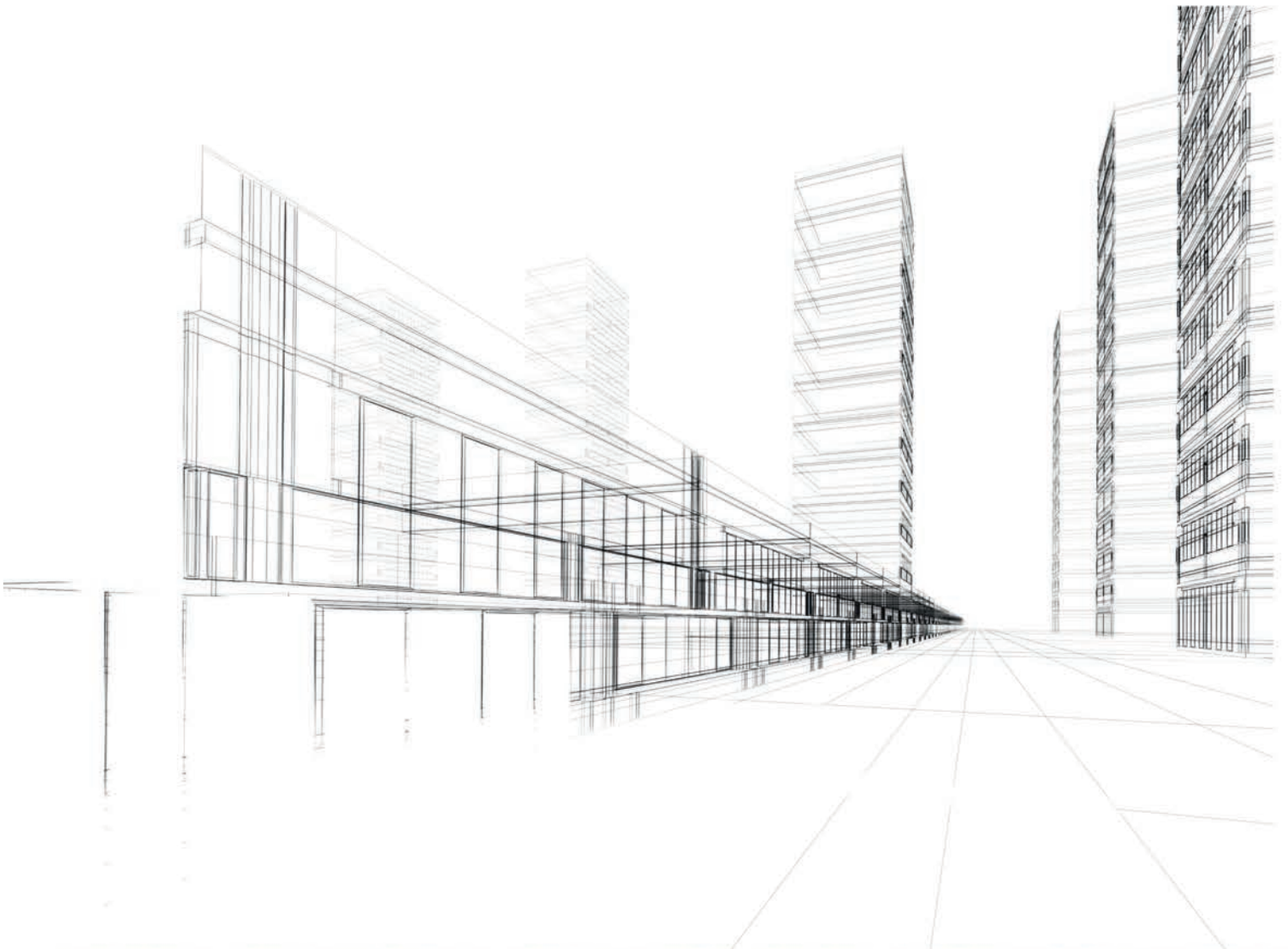

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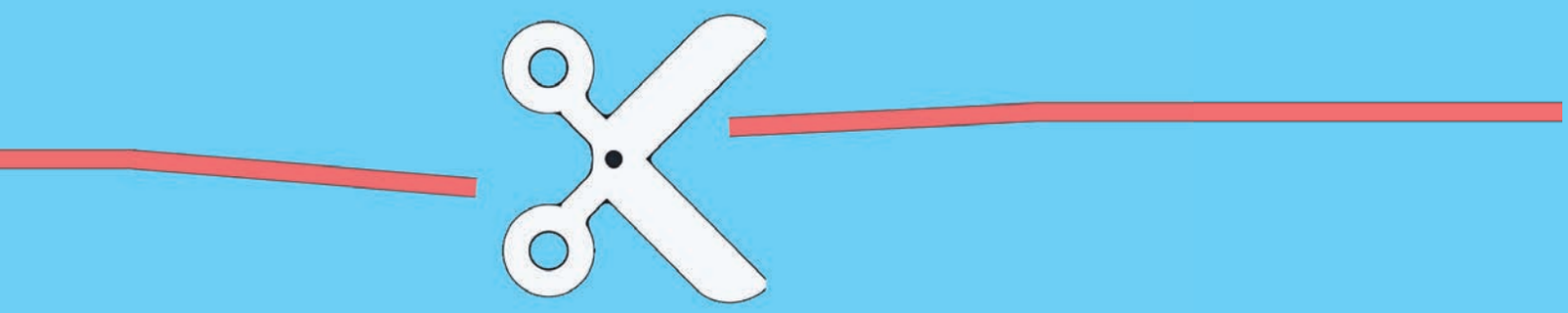

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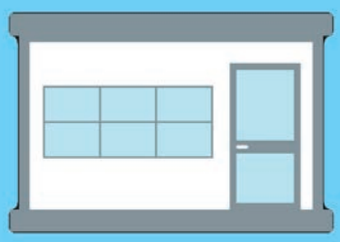

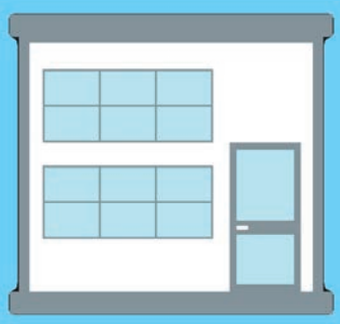

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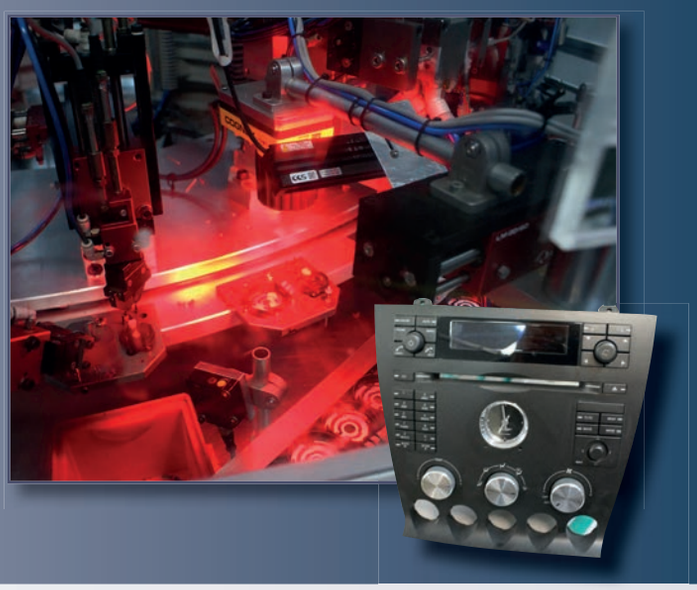

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MECHANICAL ENGINEERING STREAM 80

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

Projects supervised by members of the Department of Mechanical Engineering

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

FOREWORD

Dear Reader,

This is the fourth time I have had the privilege and honour to write the foreword. If you had visited the students' exhibition in the year in which I graduated, you would have been given the 1991 incarnation of this booklet: not a thick, glossy, publication with 74 student projects, but a thin, green-covered leaflet which presented eighteen mechanical engineering dissertations. You would have had no list of equipment or funded projects, there would have been far fewer academics and no researchers, and there would also have been no sponsors supporting this presentation of our students' work, sponsors who I wish to take the opportunity to thank.

The compilation of work presented here includes the final-year projects created by students reading for the B.Eng. (Hons) degree at the Faculty of Engineering during the academic year 2013-2014. Each dissertation is the product of analytical and practical work spread over both semesters of the fourth and final year of studies. The outcome of this work is presented in the 25th edition of the annual exhibition.

Over the brief duration of the exhibition our students present their achievements as they prepare to join the ranks of the hundreds of engineering graduates who preceded them. The engineering degree requires four years of hard work and dedication to attain, and provides graduates with a strong grounding in the engineering discipline which prepares them for a successful professional career. The dissertation is a hallmark of their capability, demonstrating their capability to achieve a set task which requires the application of the knowledge and skills acquired over the course of the engineering degree.

In conclusion, I once again thank all the staff of our Faculty, and in particular the PR team headed by Dr Bertram Mallia, and the Dean's Office Coordinator Mr Michael Spiteri; and our students, whose work and dedication make this booklet and the exhibition possible, and who I heartily congratulate.

Dr Ing. John C. Betts

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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)

FACILITIES

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

FACILITIES

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

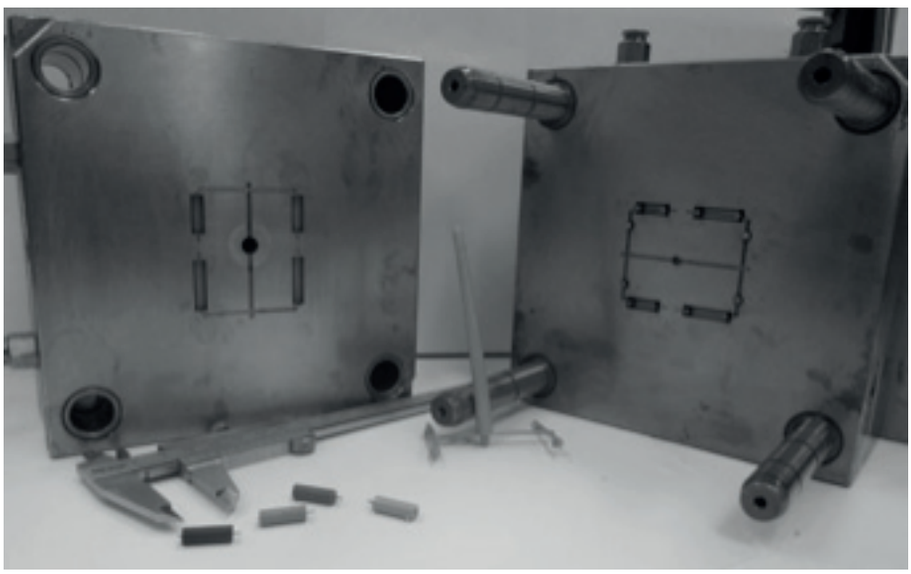
ONGOING EXTERNALLY FUNDED RESEARCH PROJECTS

FACULTY OF ENGINEERING UNIVERSITY OF MALTA

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

This project aims at generating knowledge on the design and manufacture of micro products, using multi-material injection moulding. A micro lens and housing for endoscope applications has been designed. The mould required to produce such micro assembly has also been fabricated. Further details are available at: www.exmmim.com

Funding Body: **Malta Council for Science and Technology through the National Research and Innovation Programme 2012**
Project Size: **€ 141,871**
UoM Workshare Value: **€ 107,061**
Principal Investigator: **Dr Ing. Philip Farrugia**
Co-Investigators: **Dr Arif Rochman, Ing. Pierre Vella**
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**

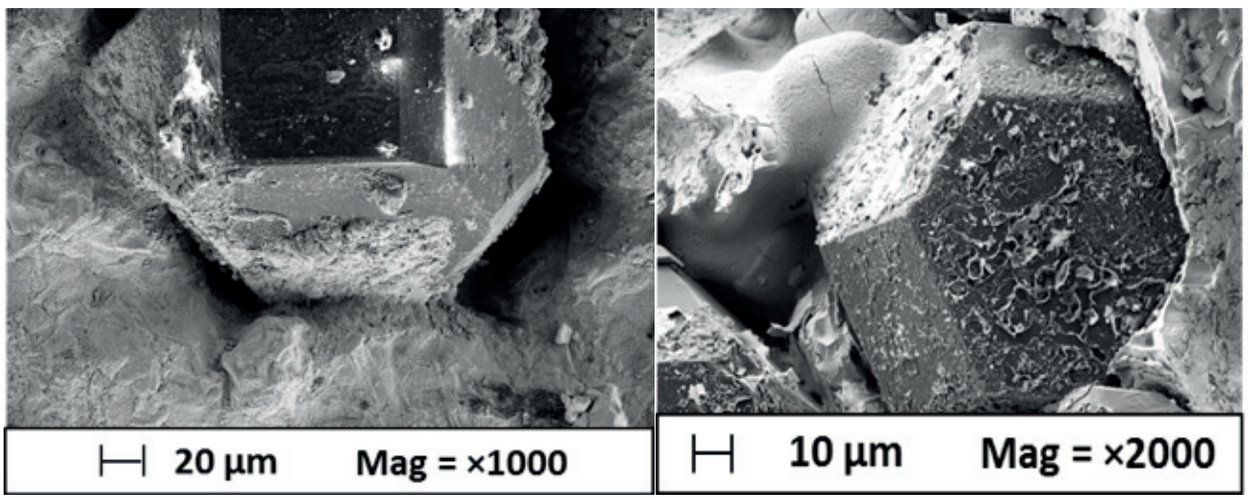


Mould tool with micro features

The Design of Metal-Diamond Composites With High Thermal Performance

This project involves the development of composite materials with various sized diamond particle incorporation to yield ideal thermo-physical properties. The objective is to provide the correct combination of CTEs and improved TC values.

Funding Body: **Malta Council for Science and Technology through the National Research and Innovation Programme 2010**
Project Fund: **€ 88,313**
Principal Investigators: **Dr Ing. Stephen Abela (University of Malta), Mr Michal Attard (IMA. Ltd.)**
Co-Investigators: **Mr David Grech, Mr Chris Abela**
Consortium/Partners: **Department of Metallurgy and Materials Engineering at the University of Malta, in collaboration with IMA Engineering Services Ltd**
Project Start Date: **November 2011**
Project Duration: **2.5 Years**



SEM images from a Cu-DMMCs having (left) 15.53% and (right) 24.88% by mass NiWP interlayer

Across

ACROSS is a research project focussing on the reduction of flight crew workload and is developing new cockpit applications and human-machine interface solutions to achieve its goals. The University of Malta is developing technologies to reduce workload and assist the flight crew during runway operations.

Funding Body: **European Commission (FP7)**
Project Size: **€ 19,000,000**
UoM Workshare Value: **€ 354,000**
Principal Investigator: **Prof. Ing. David Zammit-Mangion**
Consortium/Partners: **Thales Avionics (Coordinators), Airbus, Boeing, Dassault, BAE Systems, NLR, DLR, Jeppesen, Diehl Aerospace, Zodiac, Selex ES, Continental, GMV, ISDEFE, Deep Blue, TAI, Hellenic Aerospace Industry, Technische Universitat Braunschweig, Delft University of Technology, University of Malta, Trinity College Dublin, Warsaw University of Technology, Stirling Dynamics, Triagnosis, Certiflyer, Tony Henley Consulting, Use2aces**
Project Start Date: **January 2013**
Project Duration: **3.5 Years**

Alicia

ALICIA is a research project focusing on the development of all-condition operation capability in fixed and rotary wing commercial operations. The University of Malta is developing technologies to assist the flight crew of fixed wing aircraft to man oeuvre and navigate safely on the airfield in very low visibility.

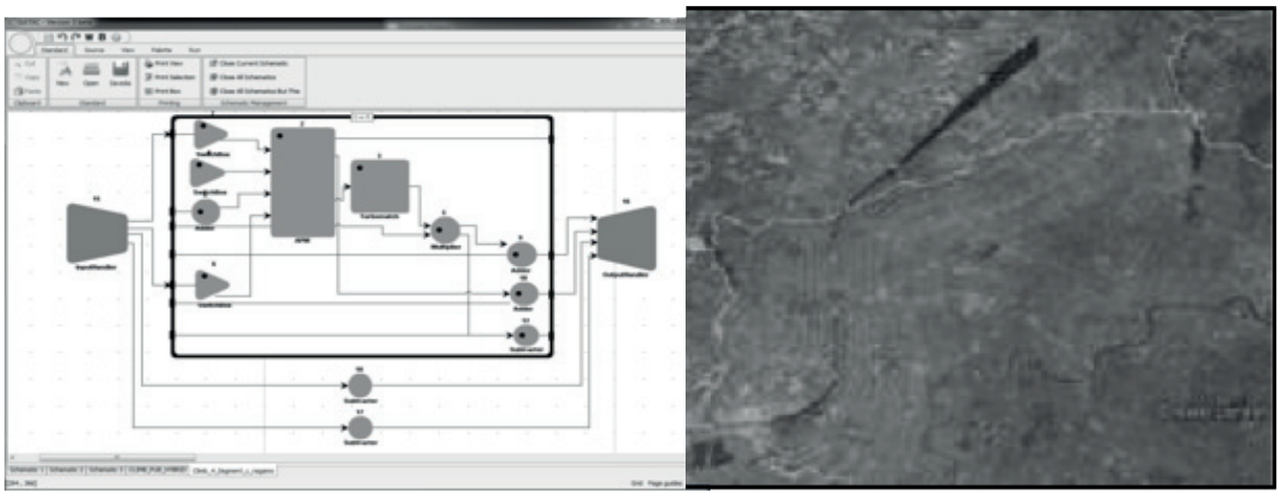
Funding Body: **European Commission (FP7)**
Project Size: **€ 32,000,000**
UoM Workshare Value: **€ 255,000**
Principal Investigator: **Prof. Ing. David Zammit-Mangion**
Consortium/Partners: **Agusta-Westland (Coordinators), GE Aviation, Thales Avionics, Diehl Aerospace, Airbus, Jeppesen, Dassault, Rockwell Collins, Alenia, Barco, SAAB, Latecoere, LET Aircraft Industries, Aydin Yazilim ve Elektronik Sanayi AS, PZL-Swidnik SA, BAE Systems, DLR, NLR, Meteo France, ONERA, CIRA, ISDEFE, Central Aerohydrodynamic Institute, Intuilab, SDT, Use2aces, Tecnalia, GTD, Avtech, Deep Blue, Stirling Dynamics, DBS, Interconsulting Srl, Technische Universitat Braunschweig, Trinity College Dublin, University of Malta, University of Southampton, University of Bologna**
Project Start Date: **October 2009**
Project Duration: **5 Years**

Low visibility taxi (left) and a cockpit display for pilot support (right)

Clean Sky

The Clean Sky Joint Technology Initiative is the world's largest research project focusing on reducing the impact of air transport on the environment. The University of Malta is developing, with SGO ITD partners, a trajectory optimisation tool called GATAC and is using it to study and develop strategies for trajectory and mission optimisation.

Funding Body: **European Commission**
Project Size: **€ 1.6 Billion**
UoM Workshare Value: **€ 1,000,000**
Principal Investigator: **Prof. Ing. David Zammit-Mangion**
Consortium/Partners: **(SGO ITD) Thales, Liebherr, Airbus SAS, SAFRAN, SAAB, Rolls-Royce, Alenia, Selex ES, Fraunhofer, DLR, NLR, Zodiac, Diehl Aerospace, Cranfield University, University of Nottingham, Delft University of Technology, University of Malta, Aeronamic**
Project Start Date: **October 2008**
Project Duration: **7 Years**



The GATAC Graphical User Interface and optimisation output visualisation (Noise footprint on departure)

Raid

RAID is one of nine projects funded by SESAR to demonstrate the integration of remotely piloted air systems (RPAS) in unsegregated (civil) airspace. RAID will focus on the demonstration of ATM procedures, command and control data link technology and sense and avoid technology. This will be carried out through simulation and flight test in Maltese airspace. The University of Malta is involved in flight test design, evaluation and assessment as well as contributing to the logistics of the flight test campaign.

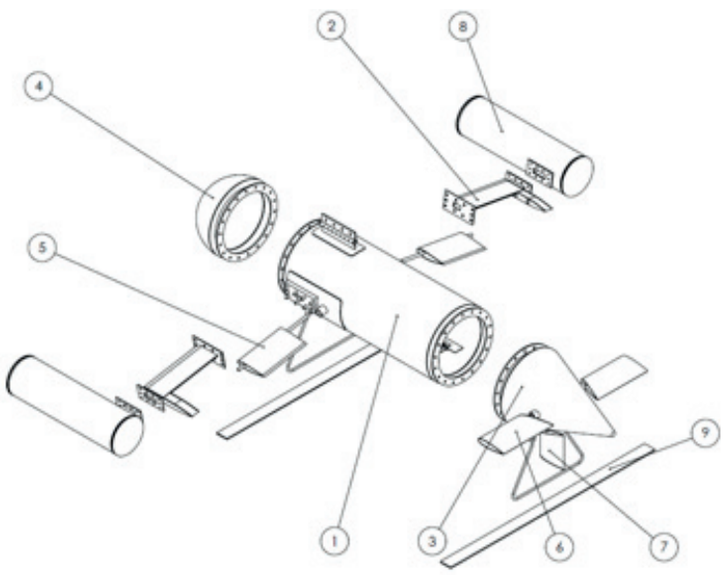
Funding Body: **SESAR**
Project Size: **€ 900,000**
UoM Workshare Value: **€ 90,000**
Principal Investigator: **Prof. Ing. David Zammit-Mangion**
Consortium/Partners: **CIRA, Nextant, Malta Air Traffic Services, Deep Blue srl, Nimbus, University of Malta**
Project Start Date: **September 2013**
Project Duration: **2 Years**

FLARE - the RPAS owned by CIRA that will be used in flight tests within RAID

BioDiValue - Biodiversity and Sustainable Development in the Strait of Sicily

The Department of Mechanical Engineering designed a towfish within the BIODIVALUE project. The towfish which is a towed under water vehicle is equipped with the necessary sensors that can detect various sea water pollutants and can also be used as a platform for cameras to capture images or video of jellyfish and plankton populations.

Funding Body: **ERDF Italia-Malta 2007-2013**
Project Size: **€ 220,000,000**
UoM Workshare Value: **€ 218,000**
Principal Investigator: **Prof. Martin Muscat**
Co-Investigators: **Mr Mark Formosa, Mr Germen Alejandro Salgado Martin**
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**

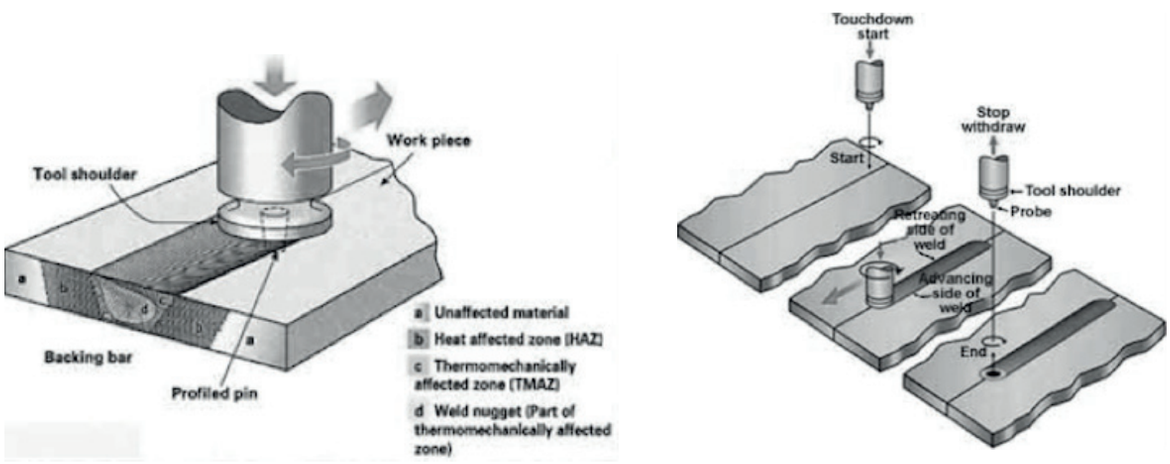


The towfish designed at the Department of Mechanical Engineering as a tool to monitor sea water pollution and plankton activity over a large area

HILDA High Integrity Low Distortion Assembly

The project HILDA seeks to develop the scientific foundation for a reliable Friction Stir Welding process applicable to steel, through experimental and numerical techniques. This provides the foundations to enhance and advance the scientific and practical knowledge on an innovative high performance welding process and its potential application in the maritime industries.

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 Daniel Micallef, Dr Pierluigi Mollicone**
Consortium/Partners: **Department of Mechanical Engineering, University of Strathclyde - U.K (Project Coordinator), Department of Mechanical Engineering - University of Malta, Centre de Recherche en Aeronautique ASBL (CENAERO) - Belgium, The Welding Institute (TWI) Ltd. - U.K, Lloyd's Register EMEA - U.K, Center of Maritime Technologies e.V. (CMT) - Germany, Naval Architecture Progress - Greece, GeonX sprl - Belgium**
Project Start Date: **September 2012**
Project Duration: **3 Years**

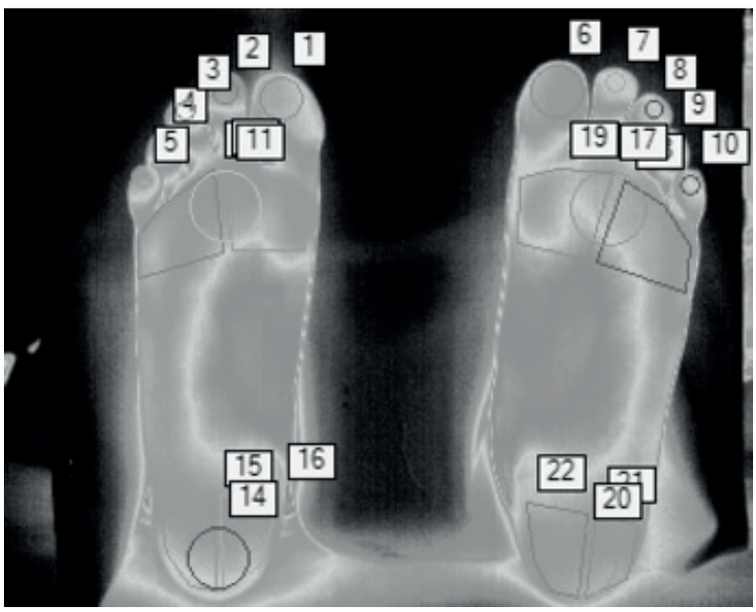


Generic principle of friction stir welding (courtesy of TWI Ltd)

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: **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.

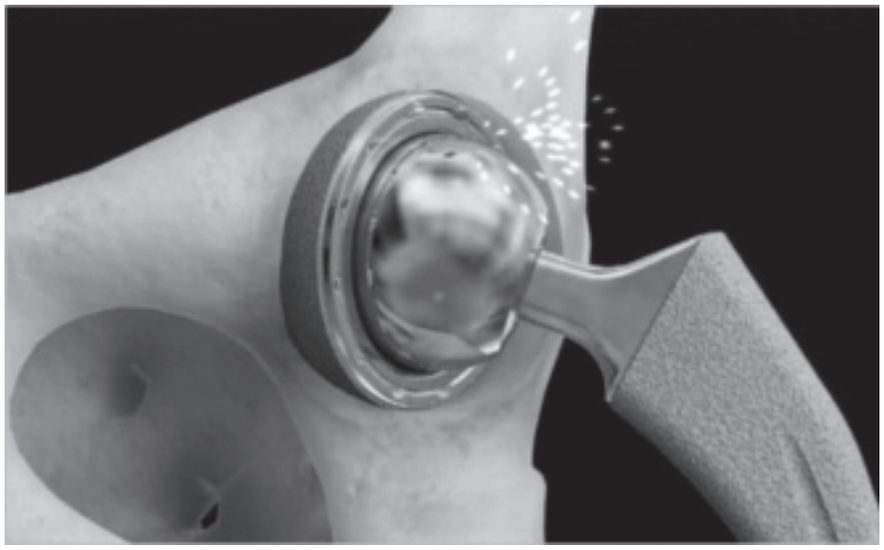
Funding Body: **Malta Council for Science and Technology through the National Research and Innovation Programme 2012**
Project Fund: **€ 167,683**
UoM Workshare Value: **€ 124,883**
Principal Investigator: **Prof. Ing. Kenneth P. Camilleri**
Co-Investigators: **Ing. Stefania Cristina, Ms Marica Gatt**
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: **November 2012**
Project Duration: **2 Years**

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

Towards long lasting metal-on-metal implants

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

Funding Body: **Think10k (Faculty of Engineering) and Bodycote Hardiff GmbH (Germany)**
Project Fund: **€ 25,000 + € 23,500 (Scholarship Funds - Malta)**
Principal Investigator: **Dr Joseph Buhagiar**
Co-Investigators: **Dr Pierre Schembri Wismayer MD; Mr Malcolm Caligari Conti (MGSS funded PhD student); Mr Shaun Maniscalco, Ms Michelle Cortis and Mr Nicholas Brincat (MASTER it! funded MSc by Research Students); Ms Josianne Cassar (STEPS funded MSc by Research student) ; Ms Christine Borg and Ms Michaela Zammit La Rosa (B.Eng undergraduate students); Dr Andreas Karl (Bodycote Hardiff GmbH); Dr Bertram Mallia; Prof Emmanuel Sinagra; and Ing.Pierre Vella**
Consortium/Partners: **The Department of Metallurgy and Materials Engineering at the University of Malta (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) and Bodycote Hardiff GmbH (Germany)**
Project Start Date: **December 2013**
Project Duration: **1 Year**



Wear Debris released by Cobalt-Chromium metal-on-metal implants

ONGOING MASTERS AND Ph.D RESEARCH PROJECTS

FACULTY OF ENGINEERING UNIVERSITY OF MALTA

PROJECTS SUPERVISED BY MEMBERS OF THE DEPARTMENT OF INDUSTRIAL AND MANUFACTURING ENGINEERING

An Emotion Oriented Approach to Integrated Product Development
Student: Lawrence Farrugia Course: M.Phil.

An Investigation of Influences of Melt Mixer on Injection Moulding Process and Part Quality of Thermoset Elastomers
Student: Keith Zahra Course: M.Sc. by Research

Stretching Behaviour of Polymer Materials During Pattern-Heated Thermoforming
Student: Luke Pace Course: M.Sc. by Research

PROJECTS SUPERVISED BY MEMBERS OF THE DEPARTMENT OF METALLURGY AND MATERIALS ENGINEERING

Surface Coatings for Improved tribocorrosion Response of Biomedical Stainless Steel
Student: Sarah Farrugia Course: M.Sc. by Research

Tribological Enhancement of Biomedical Stainless Steel using Duplex Surface Treatments
Student: Nicholas Brincat Course: M.Sc. by Research

Laser Deposition of Stainless Steel
Student: Ryan Cann Course: M.Sc. by Research

Diamond Metal Matrix Composite for Thermal Management
Student: Chris Abela Course: M.Sc. by Research

Improving the Surface Characteristics of Ti-6Al-4V and Timetal 834 using PIRAC Nitriding Treatments
Student: Bonnie Attard Course: M.Sc. by Research

Investigation of Duplex PIRAC-PVD Coated Ti-6Al-4V
Student: Thelma Bonello Course: M.Sc. by Research

Study of Corrosion Response of PIRAC-treated Titanium Alloy in a Body Simulated Fluid
Student: Antonella Scerri Course: M.Sc. by Research

Study of Fluorine-Containing Surface Active Agents Epilame Deposited on Ti-6Al-4V-Alloy
Student: James Camilleri Course: M.Sc. by Research

S-Phase Surface Engineering for Longer Lasting Metal-on-Metal Implants: A Tribocorrosion Evaluation
Student: Shaun Maniscalco Course: M.Sc. by Research

S-Phase Surface Engineering for Longer Lasting Metal-on-Metal Implants: A Tribocorrosion Evaluation
Student: Shaun Maniscalco Course: M.Sc. by Research

Biocompatibility and Surface Characterization of PIRAC – Treated Titanium Material
Student: Michelle Cortis Course: M.Sc. by Research

Alloy-Electrolyte Interface of a Carburised Co-Cr-Mo Biomaterial
Student: Josianne Cassar Course: M.Sc. by Research

Surface engineering ADI for their use in the manufacturing of Gears
Student: Ann Zammit Course: Ph.D.

In-vitro Studies of Surface Hardened Cobalt-Chromium-Molybdenum Alloys
Student: Malcolm Caligari Conti Course: Ph.D.

PROJECTS SUPERVISED BY MEMBERS OF THE DEPARTMENT OF ELECTRONIC SYSTEMS ENGINEERING

Determination of the Current Centre Line of the ITER TF Coils
Student: Karl Buhagiar Course: M.Sc. by Research

Product Industrialization of High-Speed Multivision Instrumentation
Student: Andre' Micallef Course: M.Sc. by Research

Improving Efficiency of Flights on the Approaches To Malta International Airport
Student: Matthew Micallef Course: M.Sc. by Research

Airfield Guidance for Aircraft Using Optical Techniques
Student: Kevin Theuma Course: M.Sc. by Research

Autonomous Taxiing of Fixed Wing Aircraft in Low Visibility Conditions
Student: Christian Zammit Course: M.Sc. by Research

On Trajectory Optimization for the Reduction of Fuel Burn and Emissions
Student: Kenneth Chircop Course: Ph.D.

On-Board Mitigation of Flight Hazards
Student: Brian Zammit Course: Ph.D.

PROJECTS SUPERVISED BY MEMBERS OF THE DEPARTMENT OF INDUSTRIAL ELECTRICAL POWER CONVERSION

Analysis of Malta Freeport Terminals Power System
Student: Joseph Azzopardi Course: M.Sc. by Research

Emulator Test Rig for the Control and Grid Interfacing of Wave Energy Converters
Student: Shawn Azzopardi Course: M.Sc. by Research

Sensorless Permanent Magnet Synchronous Motor Drive for Scroll Compressors in Heat Pump Applications
Student: Terence Moses Bartolo Course: M.Sc. by Research

Analysis and Simulation of Power Quality, Distributed Generation and Interconnection of an Island's Power System to an Infinite Busbar System
Student: Samuel Bonanno Course: M.Sc. by Research

An Intelligent Energy Measurement System
Student: Denis Bonavia Course: M.Sc. by Research

Energy Storage Systems for Self-Consumption of Energy from Grid-Connected Photovoltaic Sources
Student: Jurgen Bonavia Course: M.Sc. by Research

Analysis and Improvement of Energy Efficiency in Local Buildings
Student: Matthew Bonello Course: M.Sc. by Research

The Design of a Brushless Drive operated from a Stirling Engine
Student: Josef Mizzi Course: M.Sc. by Research

Design and Analysis of an Electric Drive for a Domestic Scale CHP Machine
Student: Matthew Schembri Course: M.Sc. by Research

Design and Construction of an Integrated Electrical Drive
Student: David Zammit Course: M.Sc. by Research

Control and Management of Distributed Generation and Energy Storage Systems in Low Voltage Microgrids
Student: Alexander Micallef Course: Ph.D.

Sensorless Control in Steer-by-Wire Application
Student: Kris Scicluna Course: Ph.D.

PROJECTS SUPERVISED BY MEMBERS OF THE DEPARTMENT OF MECHANICAL ENGINEERING

Impact Mechanic of Composite Structures
Student: Rudie Vella Course: M.Sc. by Research

Engineering Stress Analysis using PhotoStress and Computational Techniques
Student: Annemarie Zammit Course: M.Sc. by Research

Engineering Analysis of the S.S. Ohio
Student: Colin Bonnici Course: M.Sc. by Research

Structural Evaluation and Testing of a multiple Bladed Wind Turbine Prototype
Student: Redeemer Axisa Course: M.Sc. by Research

Buckling Analysis of Pressure Vessel Components
Student: Mark Formosa Course: M.Sc. by Research

The Effect of Pre-stressing Structural Members of an Aircraft Wing
Student: Damian Agius Course: M.Sc. by Research

Modelling Fluid-Structure Interaction on Vertical Axis Wind Turbine Blades
Student: Gary Galea Course: M.Sc. by Research

Investigating the Impact of Wind Turbine Rotor Upscaling on the Viability of Floating Wind Farms
Student: Matteo Aquilina Course: M.Sc. by Research

Numerical Modelling of Stall Delay and Dynamic Stall Phenomena on Floating Wind Turbine Rotors
Student: Sean Agius Course: M.Sc. by Research

A Study on the Aerodynamics of Floating Wind Turbine Rotors
Student: Russel Farrugia Course: M.Sc. by Research

The Utilisation of Offshore Wind Turbines for Large-Scale Air Conditioning Applications
Student: Matthew Galea Course: M.Sc. by Research

Investigating the Reliability of Wind Anemometers on Floating Tension-Leg Platforms
Student: Claire Ellul Course: M.Sc. by Research

The Influence of Floating Structure Dynamics of the Energy Yield Characteristics of Offshore Floating Wind Turbines
Student: Kurt Cuschieri Course: M.Sc. by Research

Load and Motion Analysis of a Floating Wind Monitoring Mast in Deep Sea
Student: Marisa Micallef Course: M.Sc. by Research

Design and Build of a Domestic Scale Micro-CHP for Local Application
Student: Matthew Spiteri Course: M.Sc. by Research

Analysis of Spark Ignition Engine Downsizing
Student: Jean Paul Azzopardi Course: M.Sc. by Research

Assessing the Structural Performance of Fibre-Reinforced Composites through Numerical Modelling Techniques
Student: Brian Ellul Course: Ph.D.

Modelling the Unsteady Aerodynamics of Wind Turbines under the Combined Influence of Wind Shear and Yaw
Student: Moutaz Elgammi Course: Ph.D.

Design and Analysis of a Hydraulic Power Transmission System for an Offshore Wind and Thermocline Energy Production (OWTEP) System
Student: Daniel Buhagiar Course: Ph.D.

Evaluation of Wind Flow Phenomena in Maltese Complex Terrain
Student: Ing. Robert N. Farrugia Course: Ph.D.

Analysis of Solar Thermal Distillation
Student: Ing. Paul Refalo Course: Ph.D.

A Solar Powered Absorption Air Conditioning System
Student: Salem M. Osta Omar Course: Ph.D.

Thermo - Mechanical Study of LHC Collimators in case of Accident Scenarios
Student: Marija Gauci Course: Ph.D.

PROJECTS SUPERVISED BY MEMBERS OF THE DEPARTMENT OF SYSTEMS AND CONTROL ENGINEERING

3D Model Based Object Recognition using Assembly of Discrete Primitives
Student: David Paul Agius Course: M.Sc. by Research

A Study of Autonomic Control for Intelligent Traffic Junctions
Student: Dora Lee Borg Course: M.Sc. by Research

Non-linear Control of a Ball and Plate System with Visual Feedback
Student: David Debono Course: M.Sc. by Research

Spatial Modelling for Marine Pollution
Student: Nicolette Formosa Course: M.Sc. by Research

Assistive Environmental Control based on VEPs
Student: Norbert Gauci Course: M.Sc. by Research

Residual Vibration Reduction and Control of Flexible Systems
Student: Diandra Simiana Course: M.Sc. by Research

Vectorisation and interpretation of Drawings with Artistic Cues
Student: Alexandra Bonnici Course: M.Phil./Ph.D.

Modelling Spatial Context in Maltese Sign Language Recognition from Video Sequences
Student: Mark Borg Course: M.Phil./Ph.D.

Autonomic Control for Road Network Management using Geocomputational Tools
Student: Luana Chetcuti Zammit Course: M.Phil./Ph.D.

Eye-Gaze Tracking for Human-Computer Interaction, Behaviour Analysis and Communication
Student: Ing. Stefania Cristina Course: M.Phil./Ph.D.

Representation and Knowledge Extraction from Multiview Image and Video
Student: Ing. Clifford De Raffaele Course: M.Phil./Ph.D.

FINAL YEAR ENGINEERING PROJECTS
ELECTRICAL STREAM

FACULTY OF ENGINEERING UNIVERSITY OF MALTA

Design of an Embedded Differential GPS System

Student: Darren Cachia / Supervisor: Dr Ing. Andrew Sammut

Introduction

Global Positioning System (GPS) is a satellite based navigation system that provides a position and velocity solution with accuracy of tens of meters. Differential GPS (DGPS) was developed in order to improve this accuracy. DGPS uses fixed reference stations that transmit corrections to user receivers so as to obtain a more accurate position.

Project Objectives

In this project, the hardware and software for both the reference and user receivers had to be designed to obtain a functional embedded DGPS system. The DGPS algorithms had to be based on a previous dissertation [1] in which these were implemented and tested on MATLAB.

Project Methodologies

The hardware was designed by first choosing the main components which were the microcontroller and GPS module, and then designing the rest of the hardware to ensure compatibility. An important design choice was the selection of a data link between the two boards which was chosen to be internet, with the reference station using Ethernet and the user receiver using GPRS. Additionally Power over Ethernet was used for the reference station power supply. On a software level the main design issues were the implementation of the off-chip interfaces and GPS algorithms. The DGPS algorithms from previous work had to be adopted and optimized for use on the microcontroller chosen.

Results and Achievements

The hardware for the reference station and user receiver was designed but due to time constraints only the reference station was assembled. This was successfully tested and full hardware functionality was achieved. Figure 1 shows the finished reference station. In order to test the DGPS system development boards were used as the receiver station.

Figure 2 shows the positional error of the user receiver over an 8-hour period. The blue result shows the position error without the DGPS corrections and the red and green plots show the position error with two different differential correction techniques. An improvement of 82% in the mean offset and 68.7% in the standard deviation were obtained when comparing the blue to the green plot, these were comparable to previous work [1].

References

[Dissertation:]
[1] N.Ebejer, GNSS Local Area Augmentation System, B.Eng. dissertation: University of Malta, Malta, 2012.

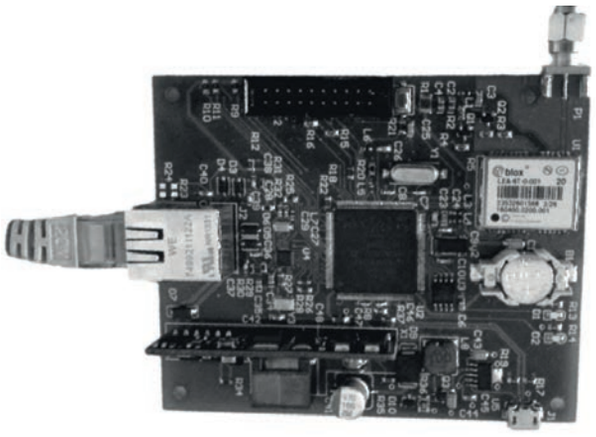


Figure 1: Reference Station Hardware

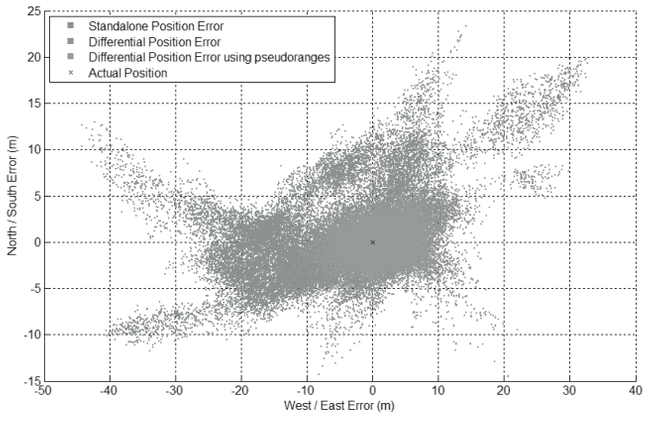


Figure 2: Positional errors of user receiver

Characterisation of Piezoelectric Materials for an Automotive Self-Powered Module

Student: Clare Camenzuli / Supervisor: Dr Ing. Andrew Sammut / Co-Supervisor: Ing. Evan Dimech

Introduction

Automotive sensors need a lot of harnesses to power them safely and reliably. In the automotive industry, it is desirable to eliminate these harnesses to make vehicles lighter and reduce carbon emissions. With the development of ultralow-power sensor nodes and new energy harvesting technology, it has become more feasible to power sensors from sources like vibrations, thus eliminating the use of harnesses.

Project Objectives

This project, which is being carried out in collaboration with Methode Electronics Malta Ltd., aims at investigating the use of piezoelectric sources to power a module that is to be placed in an automotive environment where vibrations are abundant. Piezoelectric sources are materials that generate a voltage when stress or strain, such as those present in vibrations, are applied to the material.

Project Methodologies

In order to establish the feasibility of such a self-powered module, the possibility of powering a system as shown in Figure 1 through the use of piezoelectric materials had to be investigated.

This was done by acquiring several piezoelectric materials after consulting the most important piezoelectric concepts, constants and definitions, and performing several tests on them in order to characterise them. Through characterisation, the best combination of material, shape, thickness and area that yields the most power under certain environmental conditions established by Methode was determined.

Certain frequency, acceleration and temperature inputs were applied to all the piezoelectric materials according to the industrial requirements given by Methode. The inputs were applied through the use of a vibration jig whose frequency and acceleration can be controlled and monitored externally. The temperature was varied and controlled by using a temperature chamber. All equipment was available at Methode.

Results and Achievements

From the characterisation of piezoelectric materials, it was determined that the best combination of piezoelectric materials yielding the most power comes from a piezoelectric disc made of the material PZT-J, having a large thickness and area.

Further tests were then carried out on the six materials that gave the most power during testing. These six materials all exhibited most or all of the parameters that were characterised to yield the most power from a piezoelectric material. From these tests, the materials were shown to be reliable and durable over a prolonged period of 12 hours. The materials were subject to certain random inputs to further investigate their reliability within an automotive environment.

From these tests, a total power of 24.44 W and a current of 49.43 A were generated from one particular material in an environment resembling that found in the automotive sector, thus proving the fact that these materials' energy can be harvested and used to power various sensor modules in a vibration-based environment.

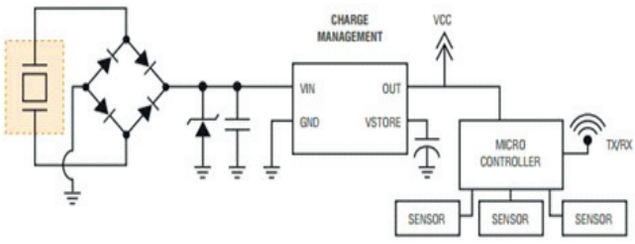


Figure 1: Typical Piezoelectric Self-Powered Module

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Low Noise Amplifier for Square Kilometre Array

Student: Jonathan Camilleri / Supervisor: Dr Ing. Owen Casha* / Co-Supervisor: Dr Kris Zarb Adami*

*Microelectronics & Nanoelectronics Department - Faculty of Information & Communication Technology

Introduction

The Square Kilometre Array (SKA) is an international effort to build a next generation radio telescope having a total antenna surface area of 1 km^2, in the South African and Australian deserts. The objectives of the project are to see deeper into the origins of space, understand dark matter and also find signs of extraterrestrial life amongst others [1].

Project Objectives

The objective of this project was to design a low noise amplifier (LNA) to cater for the needs of the Square Kilometre Array Low frequency range, and provide low power, minimal noise amplification to the low frequency signals picked up by the antenna array.

Project Methodologies

First, a topology for the LNA was chosen amongst several options. The differential cascode capacitively cross-coupled common gate (CCC-CG) topology was chosen for the core LNA, since it can provide adequate amplificatio nwith limited noise figure and low power demand [2]. The main circuit parameters were mathematically modelled for an indepth understanding of the circuit whilst facilitating the design [2]. A transistor was then chosen to ensure the best results possible [3]. The transistor small-signal model was then derived and values for its parasitics were obtained [4][5]. The first design of the LNA was to be with discrete components on a printed circuit board. However, due to several design limitations, the entire LNA was shifted to AMS 0.35µm CMOS integrated technology. The design was then optimised further until the desired specifications were achieved.

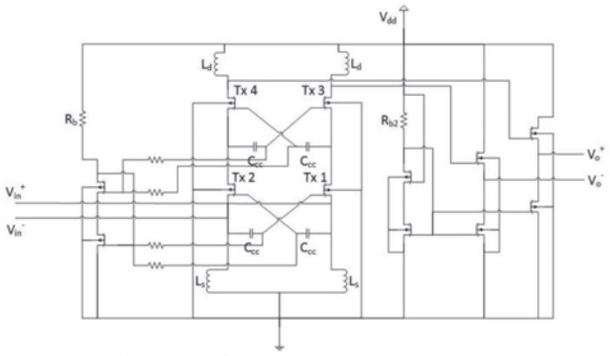

Figure 1: Schematic of the LNA

Results and Future Work

The final LNA was designed, consisting of the core LNA, followed by a differential output buffer stage, and the current mirrors providing the necessary biasing current for the transistors.

The final simulation results shot that the LNA exhibits a broadband response, from 50 MHz to 300 MHz, whislt demanding a power consumption of just 15.22 mW from a power supply of just 1.5 V. An input reflection loss of -15.78 dB and an average gain of 25.62 dB was achieved with a minimal noise figure of 1.183 dB.

Future work may include further improvement of the amplifier's forward gain, the actual layout of the integrated circuit and actual manufacturing and testing.

References

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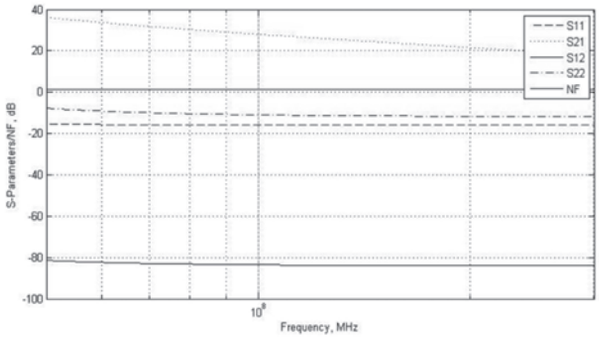

Figure 2: Simulated S-Parameters and Noise Figure of the LNA

An Unmanned Vehicle in Hover Mode

Student: Reuben Camilleri / Supervisor: Prof. Carmel Pule'

Introduction

Recent advancements in micro-electro-mechanical-systems (MEMS) and computational power of microcontrollers have made it possible for unmanned aerial vehicles (UAV) to be realisable on a small scale. Quadcopters are composed of power electronics, low voltage electronics and control circuitry that work in harmony in order to achieve stabilized flight. The idea of amalgamating all these subjects into a single, complex and beautiful system was my main motivation throughout the whole thesis. Quadcopters are still in the research phase and growing, however they are already very useful for film recording, search and rescue, mapping hard to reach areas and surveillance of dangerous areas using powerful cameras and on board sensors.

Project Objectives

The aims of the project were to derive the system dynamics of a quadcopter using the Lagrangian and Newtonian methods, design controllers for the system, simulate the system, implement and verify everything on a real platform.

Project Methodologies

The roll, pitch, yaw and altitude of the quadcopter were stabilized using PD controllers, designed based on the system dynamics of the quadcopter platform being developed. The system was verified and tested in Mathworks Simulink which included the facility of a joystick control input, 3D target output and real-time simulation. The system was also implemented on a real quadcopter platform. This included the interfacing of all the electronic components with the microcontroller, custom flight control software with the implemented algorithms to control the attitude of the quadcopter, IMU configuration and calibration and a power circuit for powering both the low level and high level voltage circuitry. Custom jigs were designed in order to test the quadcopter attitude before eventually testing it in an open area.

Results and Achievements

The controllers were tested both in simulation and on the real platform. Each controller was first tested independently and it was shown that the controlled output behaved according to the specifications set for each controller design. The simulation and real platform results were compared and it was also shown that the results were very close to each other.

Following these tests, all the controllers were tested in simulation at the same time and the results showed that the quadcopter could hover easily despite any external disturbances or quadcopter unbalance.

The real quadcopter platform was then tested in an open area and several flights were carried out in different weather conditions. During the test flights the quadcopter managed to keep hovering despite the windy conditions and also showed that roll, pitch and yaw manoeuvres could be performed together and the quadcopter never lost stability during flight.

Figure 1: Quadcopter hovering during flight

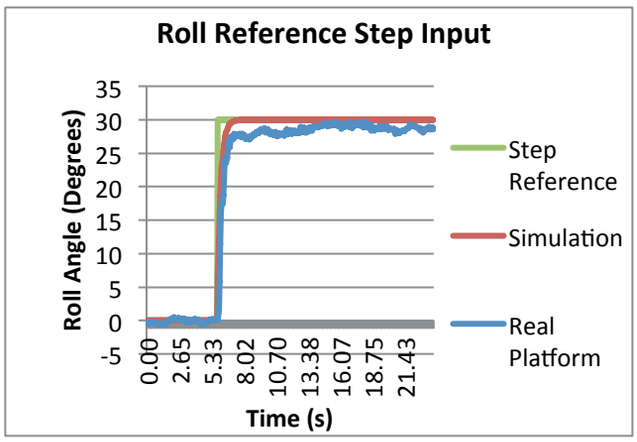

Figure 2: Roll Step input of 30 degrees

Design of an Indoor Localisation System

Student: Johann Cassar / Supervisor: Ing. Brian Zammit

Introduction

Indoor Wireless Sensor Networks (WSNs) have attracted a lot of interest due to their vast and flexible applications. A WSN consists of numerous nodes whereby each node is connected to a sensor. Localisation is a very important aspect of such networks since the knowledge of a sensor's location is critical in order to process information originating from this sensor. Through a minimum network of three fixed location beacons a roaming node can be localised in the region of operation.

Project Objectives

The main targets of this project are to gain knowledge on different techniques of indoor localisation and tracking while also designing and implementing a system capable of exhibiting localisation information over an adequate coverage of a predetermined floor area. The design of specific algorithms in order to handle accuracy issues due to typical inaccurate distance measurements is an essential part of the project.

Project Methodologies

Through a network of three ultrasonic receiver node sensors and an ultrasonic transmitter sensor node on a moving robotic platform, three line-of-sight distances are obtained. The receiver nodes are placed physically at the vertices of an equilateral triangle with 1.5m sides and attached to the ceiling of the room facing downwards. Each receiver sends wirelessly time-of-flight information to the central PC where through data fusion the concept of Trilateration is applied as seen in Figure 1. The intersection of the three circles results in the location of the unknown node. A Least Mean Squares (LMS) algorithmic approach is implemented in the application of this concept to minimize errors. Improvement of accuracy is attained through the use of the Kalman Filter. This recursive algorithm is ideal for this application where noisy data needs to be filtered out.

Results and Achievements

Initial experiments were done for fixed position localisation over a region covering a 3m x 3m area and later on the robot was set to follow a series of both straight line and circular trajectories. Two main Kalman filter implementations were tested out and compared. The Odometric Kalman Filter uses the physical dynamics of the robot as a model and also the wheel encoder readings of the robot to drive the model. The Kinematic Kalman Filter models the robot as a moving target with no use of odometric data. Through the obtained results the Odometric Kalman Filter was deemed to give better results. The Least Mean Squares Algorithm results for fixed position localisation cover an area of 5cm x 5cm for a set of repeated distance measurements. With a properly calibrated Odometric Kalman Filter this region was reduced to 2cm x 2cm. Depicted in Figure 2 is a trajectory example showing the improvement achieved through the use of the Kalman filter as the robot is moving in a slightly curved trajectory.

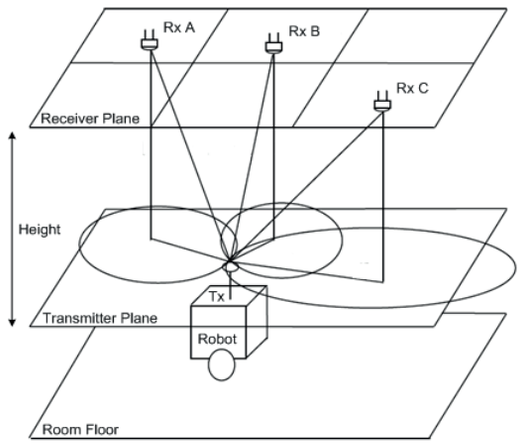

Figure 1: System Setup

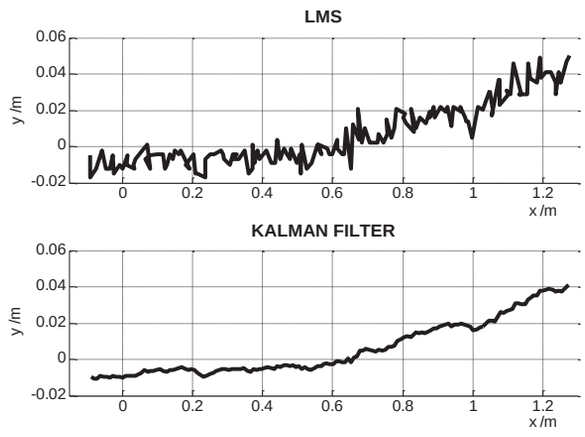

Figure 2: Slightly Curved Trajectory

A Multi-Channel Industry Grade pH Probe Tester: Interface Design and Characterization

Student: Nathalie Cauchi / Supervisor: Ing. Marc Azzopardi / Co-Supervisor: Dr Ing. Andrew Sammut

Introduction

In the chemical industry aqueous solutions are classified into acidic or alkaline solutions depending on their hydrogen ion concentration commonly known as pH. pH measurements are necessary in the pharmaceutical fields, food sciences, environmental research and water treatment. An electrochemical cell, known as a pH electrode characterized by a very high impedance is used to obtain the pH measurement. The pH electrode is made up of a glass and reference electrode separated by an electrolyte across which a potential is generated that is directly proportional to the pH. The high impedance of the electrode requires special interfacing techniques for correct measurements to be obtained. The measurement is temperature dependent necessitating temperature compensation.

Project Objectives

The aim of the project is to design an electronic hardware system that is capable of measuring the pH potential with high levels of accuracy and precision. The electronic hardware is to be interfaced with a LabVIEW based controller and data handler; and will form part of an Industrial grade pH probe tester for ProMinent Fluid Controls Ltd. The whole system design is shown in Figure 1. A series of experiments are to be carried out in order to characterize and evaluate the performance of the designed system. The final design is a multilayer board with all the necessary noise suppression techniques to obtain a precise measuring instrument.

Project Methodologies

In order to achieve a design having Industrial grade performance a review of the published literature on the interfacing of pH electrodes with analogue circuitry is carried out. The second phase of the projects involves developing the hardware and software design for the system. This is then verified by the means of developing and testing a prototype board. Error characterization is carried out to evaluate the performance. The third phase of the project is the design and development of a multi-layer printed circuit board, PCB that is able to measure up to ten pH electrodes concurrently.

The final phase of the project is the complete interfacing of the electronic hardware with the LabVIEW controller. The system is then fully tested and digitally calibrated.

Results and Achievements

A prototype board consisting of the pH and temperature electrode interfacing circuitry along with the digital circuitry was first built on a dual layer PCB. The analogue circuitry was tested and is seen to achieve a tolerance of 0.015%. The measured analogue signals are converted to their digital equivalent value with 15-bit resolution. The microcontroller is capable of receiving commands from LabVIEW and perform the required commands and data collection. Data is transmitted to LabVIEW on request.

Once the design was verified, the final multi-channel PCB was created. The PCB is modular and standalone allowing for future expansion. Two redundant channels are present such that in case of a fault, production is not effected. All the necessary shielding and noise suppression techniques have been implemented to ensure that noise ingress is negligible.

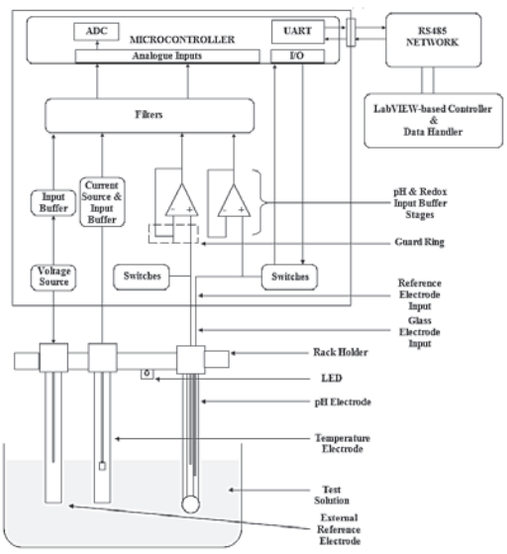

Figure 1: Overall System Diagram

A Multi-Channel Industry Grade pH-Probe Tester: Data Acquisition, Reporting and HMI Considerations

Student: Rachael Darmanin / Supervisor: Dr Ing. Andrew Sammut / Co-Supervisor: Ing. Marc-Anthony Azzopardi

Introduction

The notion of 'sourness' is quantified by a measurement called the 'pH' value [1] which is a measurement that quantifies how acidic or alkaline a solution is. The chemical definition of pH is that it is a measure of the hydrogen ion and hydroxide ion concentration in a solution [2][3]. ProMinent Fluid Controls Ltd is one of the market leaders, producing close to sixty thousand probes annually. As part of the manufacturing process, ProMinent perform thorough testing and certification on each individual probe in order to confirm that this is working according to specification. In order to do this, an efficient, reliable and accurate testing system capable of testing multiple probes at once is required.

Project Objectives

The aim of this dissertation was to design and implement a multi-channel industrial testing station for pH probes that takes into account the process automation of the testing procedure as well as being scalable, reliable and accurate. Moreover, this project forms half of the integrated system that is composed of a hardware project and a software project. The purpose of this project is to develop the software element of the system. This system will be used by testing operators as well as the management personnel. Thus, this project is also aimed at designing an adequate human-machine interface, HMI, through which any user can control the overall process. Eventually, all of the testing results will be stored in a suitably designed database.

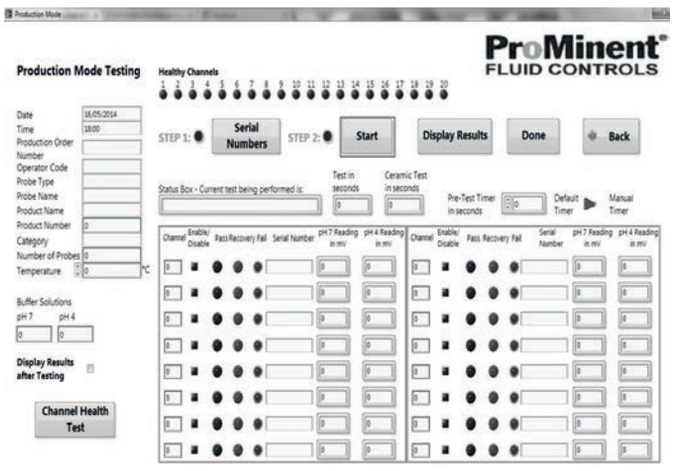

Figure 1: Production Mode – Testing Front Panel

Project Methodologies

The first task involved studying the current testing station and production line, to obtain a good understanding of the operating principle, manufacturing and testing processes of pH probes. Through this analysis together with the predefined requirements, a high level design was developed. This was then segmented into modules concerning four main modes of operation. *Production Mode* is used to test a batch of probes as part of the production process. *Engineering Mode* was developed to allow the authorised users to visualize the response of the probes on a real-time graph. *Calibration Mode* was designed to calibrate the system and *Setup Mode* was designed to adjust the operative system parameters.

Results and Achievements

On completion, each unit was tested for functionality and eventually, these units were integrated to obtain the final product. On verifying that the system is doing what is required, a set of evaluation interviews were carried out to identify how much the system is in-line with the company requirements. All candidates adapted easily to the system while providing valid suggestions for improvement for both the functionality and HMI of the system.

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Design of a Pedestrian Tracker in GPS Degraded Environment

Student: Kenneth Hili / Supervisor: Dr Ing. Andrew Sammut

Introduction

The concept of positional tracking has nowadays become a widely accepted and dispersed practice. These tracking systems usually make use of GPS. Nevertheless, there are circumstances where GPS signals are either completely blocked or severely degraded. Such locations include indoor facilities, underground areas, and highly urban locations.

Project Objectives

This project aims at identifying the best GPS-alternative technology that can be used in these scenarios. The necessary equipment, together with the ideal sensor location, are to be identified. A series of algorithms then need to be developed such that 2-D positional information can be extracted from the acquisitioned sensor output readings.

Project Methodologies

First, several GPS-alternative technologies were researched and compared. Both the advantages and setbacks of each were critically analysed. Inertial tracking systems stood out as the sensing technology which are best suited for pedestrian tracking.

Additional research was carried out in order to compare a number of viable Inertial Measurement Units (IMUs) that emerged as possible candidates. Theoretical comparisons as well as experimental tests were carried out in an attempt to identify the most suitable sensor package, which was found to be the VN-100 Rugged.

By considering the nature of the data available from the chosen IMU, it was determined that the best location to place the inertial sensors was the flat face of the foot.

Gravity cancellation algorithms and axes-mapping transformations were derived and implemented so as to obtain Earth-referenced velocity signals.

Both static period and dynamic period compensation techniques needed to be implemented such that the velocity drift experienced could be dealt with and its effect limited to a minimum. A number of data fitting methods together with different moving-window sizes were considered. It was concluded that an unsmoothed cubic spline with a moving-window of twenty steps was the compensation technique that gave the best performance.

Results and Achievements

From the results obtained during testing, the system was seen to successfully maintain a 1.4% average error for normal walking conditions and a maximum of 5% average error over time and over a range of paces, gaits, directions and distances.

The developed algorithms were seen to be able to track a wide variety of non-linear 2-D walking paths, travelled by a number of different pedestrians, with satisfactory accuracy. Therefore, it can be concluded that this IMU system can be used as an effective means of motion tracking in situations where GPS cannot be used.

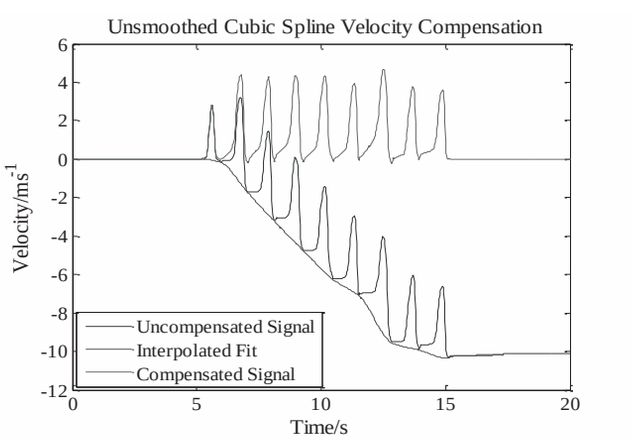

Figure 1: Dynamic Period Velocity Drift Compensation

Figure 2: Tracked 2-D Non-Linear Path for Different Users

An Induction Welder

Student: Christian Mizzi / Supervisor: Prof. Carmel Pule'

Introduction

Induction heating/welding is used for many applications. It creates a high frequency magnetic field by using a coil, which induces high frequency eddy currents in any metal object present in its field. Since the heat energy is transferred very efficiently without any contact with the object, it is essential in applications where oxidisation has to be avoided. [1]

Project Objectives

The objective of this project is to investigate the operation of induction welding by designing and constructing an induction welding system capable of welding a pair of spectacles. This involves studying different topologies and range of frequencies.

Project Methodologies

The induction welder can be separated with three main sections which are; the resonant converter which is used to generate the high frequency magnetic field; the supply which uses an H-Bridge to generate a high frequency power source to drive the resonant converter; and the control circuitry used to control the output power and the H-Bridge operation through the gate drivers. The resonant converter makes it possible to change the power flowing by changing the frequency generated by the H-Bridge. The frequency is set by a feedback system, which monitors the input current and sets the frequency in order to match the current set by the user. [2] – [3]

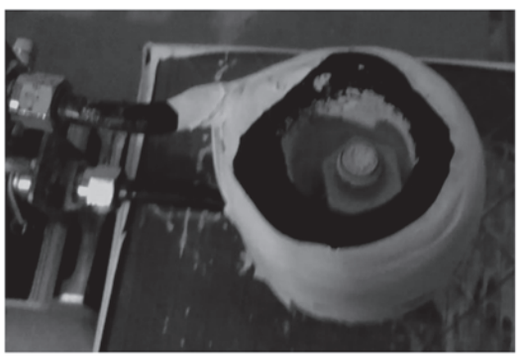

Figure 1: Bolt Being Heated Up at 2000W

Results and Achievements

The system was built by modifying a computer case, to fit the components inside of it. The system was tested gradually by using a DC supply and then with a variac, each time slowly raising the voltage to 240V. The results achieved matched the theory and the simulation results.

The setup was operated at 800W for 15 minutes and no malfunctions occurred. The mild steel bolt used as a load reached a maximum temperature of around 600^0C which is enough to melt lead and braze aluminium. For a smaller coil, this amount of power is more than enough for brazing a pair of spectacles since the magnetic field would be concentrated in a smaller area.

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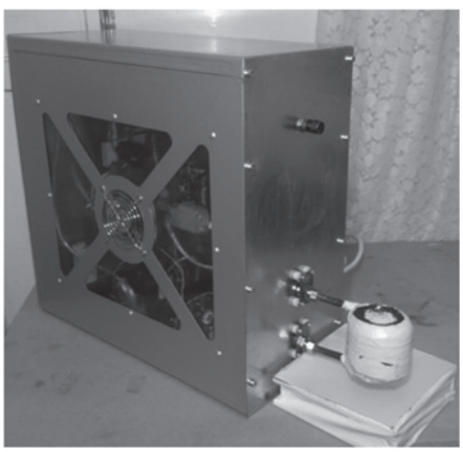

Figure 2: Project Full Assembly

To Study the Performance of a Magnetic Amplifier

Student: Dion Scerri / Supervisor: Prof. Carmel Pule'

Introduction

The saturable core reactor is a predecessor of the magnetic amplifier, a technology first reported in the early 1900s that found most of its uses in radio and television applications. Various researchers, mostly in Canada, America and Germany made major contributions to almost half a century in developing different applications incorporating the use of a magnetic amplifier.

Project Objectives

The magnetic amplifier is today considered an old and lost technology since most of its applications and advantages got replaced and superseded by the introduction of semiconductor devices as early as the 1950s. Documentation and information about its working principles and characteristics to different applications is almost inaccessible or very limited considering the period it was published, the WWI WWII era. This is where it found its major electrical applications within the military. This is practically, the main reason of such unpublished restricted material.

The objective of this project is to demonstrate and document the characteristics of the main components of a magnetic amplifier and lay foundations to the possibility of further additional research associated to it.

Project Methodologies

The project was tackled from basics since no direct approach could be found as to how to build or what approach to take to set up even the basic working model of a magnetic amplifier, that is, a device that could amplify a given input signal within its operational parameters.
Principles of magnetism and electromagnetic induction were revised and reported with the objective of developing a deeper insight of the principles of operation of the magnetic amplifier. Design was not possible and thus off-the-shelf equipment had to be purchased and tested one by one, in different circuit configurations and parameters, for the first indicative results. This involved EI type transformers of various (below 100VA) ratings and resistive loads.

Results and Achievements

The magnetic amplifier set up was primarily focused to target a common application that may still be found in industry today. This is the power regulation of highly resistive loads such as stage and theater lighting control. Of course, this project was based on a much smaller power scale than the one that would be required in practice/ industry.

A working model of a lighting control magnetic amplifier was achieved under different circuit configurations and a respective experimental study was reported.

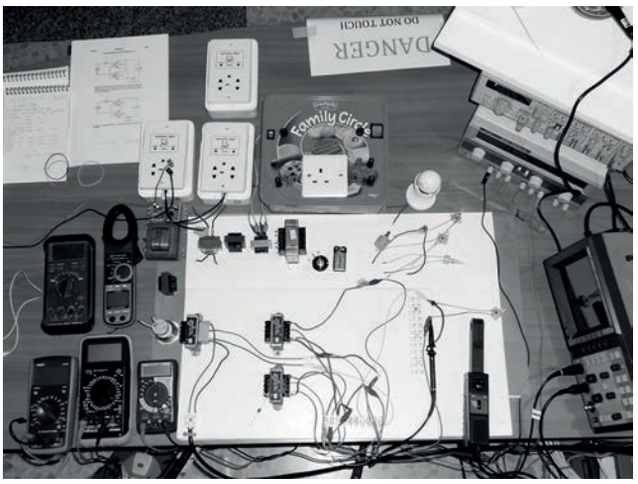

Figure 1: Test-rig used for the magnetic amplifier project

Design of a Three Phase Voltage Source Inverter

Student: James Attard / Supervisor: Dr Ing. Reiko Raute

Introduction

Development in power semiconductors led to an increase in the use of induction motors. Which is a reliable and economical AC motor. The motor speed depends on the input voltage and frequency. Various methods have been developed to control these two parameters, one of them being to use a voltage source inverter.

Project Objectives

The objective of this dissertation was to design, build and test a three phase voltage source inverter. This had to operate from a single phase supply and control the speed of a one kilo watt induction motor.

Project Methodologies

The inverter designed consisted of an AC to DC converter followed by a DC to AC inverter. The former rectified the input AC supply in such a way that a resultant six hundred fifty volts DC supply was obtained. The three phase inverter was built using IGBTs which converted the DC supply back to AC. The benefit of using this method was that the input and output phases were independent of each other. Hence, by using a single phase supply the inverter could drive a three phase motor. Furthermore, an inrush current limiter was also added to limit the input current on startup.

In order to vary the motor speed while maintaining a constant torque, the input frequency and voltage had to be varied proportionally to each other. This ensured that the motor flux remained constant. The inverter output voltages could be varied by using pulse width modulation (PWM). Moreover, a switching algorithm was implemented so that the IGBTs switched in such a way that the output current was sinusoidal, as shown in Figure 1.

Current, voltage and temperature sensors were added for data measurement and fault protection. The control circuitry ensured that in case of overheating or of a short circuit the inverter would be switched off preventing any damage. Control and data acquisition could be done via USB or UART.

Results and Achievements

All the components required to build the inverter were divided among three different circuit boards creating a three level board structure. This resulted in a compact, rugged and low cost inverter. Testing was done by observing the input current waveforms along with measuring the motor speed at different frequencies.

The final result was an inverter which could vary the speed of an induction motor from zero to fifty seven hertz without effecting the maximum torque output of the motor. The inverter built could also serve as a development platform for other control algorithms.

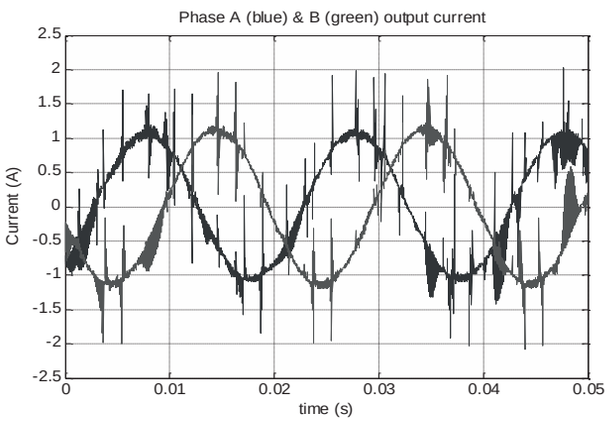

Figure 1: Motor current Phase A and B

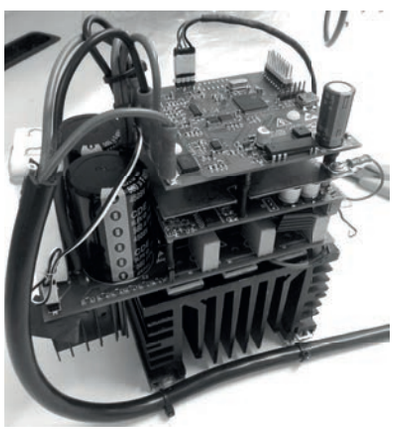

Figure 2: Three phase inverter

Design of a 1KW Isolated Electric Vehicle Charger

Student: Christopher Bilocca / Supervisor: Dr Reiko Raute

Introduction

With the increasing number of electric vehicles on the road, the demand for dc battery chargers is increasing. The aim of this final year project is to design, build and test a 1 kW prototype full bridge isolated dc-dc converter that will be used to charge electric vehicle batteries. A full bridge isolated dc-dc converter was built to provide a variable output dc voltage and current. The purpose of isolation is to provide safety for the user and prevention from damaging the setup. A micro-controller based closed loop control system was designed to work with the full bridge isolated dc-dc converter to control the battery voltage and charging current.

Project Objectives

The main objectives behind this final year project are:

- To build a knowledge on the different engineering niches that the project relates to such as power electronic converters, voltage and current control and micro-controller programming.
- To achieve a high efficiency and reliable dc-dc converter.
- To control the converter's output current and output voltage to be able to charge batteries.

Project Methodologies

In order to design properly the hardware involved, some research was done on the operation of the converter. The full bridge isolated dc-dc converter can be divided into five main blocks as shown in Figure 1: (1) a full bridge rectifier that converts the 230 Vac supply into a dc-link voltage, (2) an H-bridge that switches MOSFETs T1-T4 in pairs to provide a quasi-square wave voltage having a frequency of 50 kHz, (3) a high frequency transformer with a one to one turns' ratio to isolate the input supply from the batteries' terminals, (4) a full bridge rectifier and (5) a passive LC low pass filter to provide the full charge dc battery voltage with a maximum charging current of 5 A.

The project also involved the design and implementation of a high frequency transformer and an output inductor.

A micro-controller based control system was designed to implement the two-step charging method for Lead Acid batteries. This method charges the batteries with a constant dc current of 5 A until the batteries' voltage reaches the full charge voltage. Than the charging current is reduced while keeping the batteries' voltage constant.

Since the charging profile of batteries is slow, two cascaded Integral controllers were designed. One of them controls the charging current while the other one controls the batteries' voltage.

Results and Achievements

The setup was tested to verify the operation of the full bridge isolated dc-dc converter and to calculate the efficiency of the converter at different load currents and duty cycles. The average calculated efficiency was 82%.

Two 70 Ah each 12 V Lead Acid batteries were connected in series and charged using the converter controlled by the designed control system. The charging profiles obtained showed that the converter was supplying a maximum charging current of 5 A and full charge voltage of 28 V.

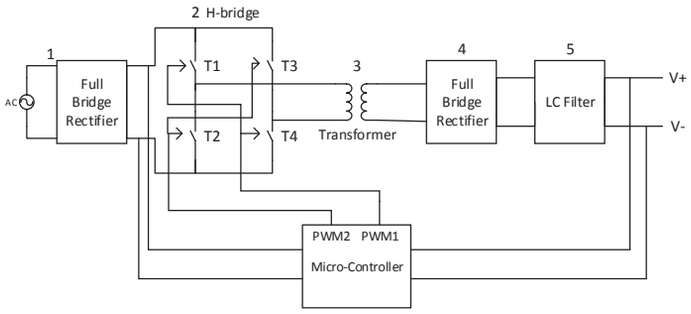

Figure 1: Isolated Electric Vehicle Charger Block Diagram

Interleaved Boost Converters for Low Voltage Electronic Load

Student: Miguel Borg / Supervisor: Dr Ing. Maurice Apap

Introduction

Electronic loads are used to present specific loading conditions at the output of power supply equipment under test. Electronic loads used in industry are still predominantly dissipative, leading to the energy drawn from equipment under test, being dissipated in the environment. This project will look at high efficiency boost converter that could be integrated within a regenerative electronic load for an input voltage of 10Volts.

Project Objectives

This project aims to design, implement, test and simulate a boost converter module for high efficiency and then extend current capability by using parallel interleaved modules for a two phase operation.

Project Methodologies

A boost converter was designed, implemented and tested. For high efficiency at low voltage operation, the introduction of a synchronous rectifier was considered. This consists of a MOSFET connected in parallel with the boost converter diode that is gated in complementary fashion with respect to the main converter switch in order to reduce rectifier conduction losses. At initial testing, ringing at switching transients was observed. A number of modifications were considered to eliminate ringing. These included changes to the circuit layout to reduce stray inductance, introduction of an RC Snubber, removal of the synchronous rectifier and Schottky diode. Following testing with these changes, it was noted that the snubber limited transient overvoltages to levels that were within device ratings. It was also noted however that the cause of the ringing was the reverse recovery characteristic of the integral diode of the MOSFET used for synchronous rectification.

Extensive testing across different loading conditions was performed to observe efficiency variation with load. Analysis of power losses in the various components of the converter was then carried out. Device characterisation was performed in order to use accurate data for the circuit model implemented in PLECS. The circuit model was then used to understand better the efficiency results obtained from practical tests.

Results and Achievements

Results achieved showed a good degree of convergence between simulation and experimental results. Comparison of the synchronous and non-synchronous boost converters showed improved efficiency with synchronous boost converters, particularly in simulation results for the input voltage levels of 2Volts comparable. Practical results however showed that reverse recovery losses of the integral diode of the synchronous rectifier can reverse the gain in efficiency at high currents.

Interleaving was demonstrated through operation of two modules in parallel at a fixed 50% duty cycle with a 180° phase shift. An almost complete cancellation of the input ripple current was obtained in this case, showing that interleaving leads to reduced input current ripple.

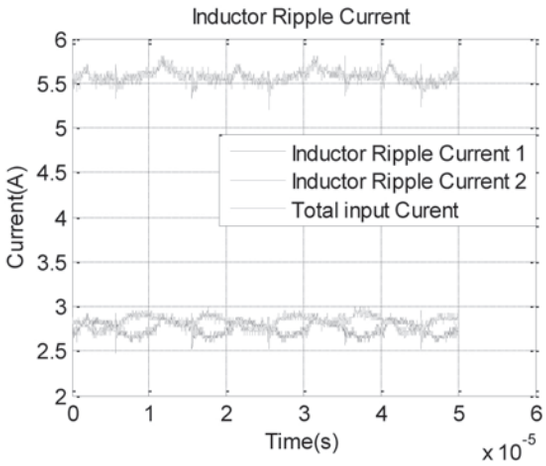

Figure 1: Input Ripple Current at 50% duty cycle

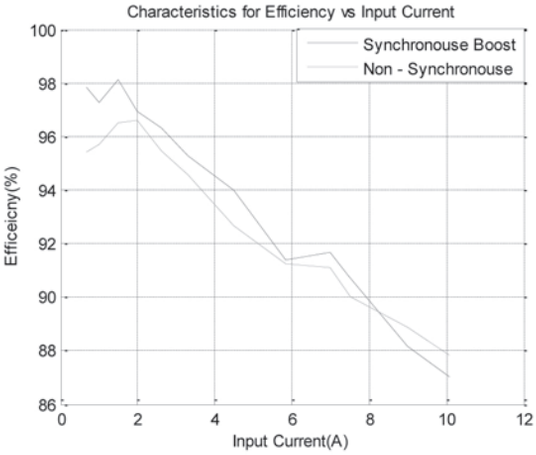

Figure 2: Practical Results

Simulation of a Ship Power System

Student: Noel Darmanin / Supervisor: Dr Cedric Caruana

Introduction

With the on-going rise in fuel prices and global emphasis to safeguard the environment, it is no surprise that many sectors are researching new ways how they can reduce costs. The marine sector is no exception to this. With thousands of vessels circulating in all four corners of the globe daily, effective cost cutting measures lead not only to financial savings but also minimise emissions and pollution. Software simulations are the first stepping stone in testing the feasibility of these energy saving measures.

Project Objectives

This dissertation, in collaboration with Gozo Channel Company Ltd. (GCCL), aimed at firstly constructing a simulation of a ship power system using PSCAD™. The second objective was to then to tune the model with results captured on-board one of the GCCL vessels. Finally, a case study involving the implementation of Dynamic Power Factor Correction that can help in cutting present running costs was then investigated.

Project Methodologies

The major components that constitute the ship's power system were modeled. The system consists of 3 synchronous generators feeding a main 450V, 60Hz busbar to which the 4 main thrusters are connected. Each thruster is equipped with a softstarter to limit the starting currents during startup. After tuning the software model with actual measurements, performance similar to the actual ship's power system was obtained with which the proposed case study was investigated.

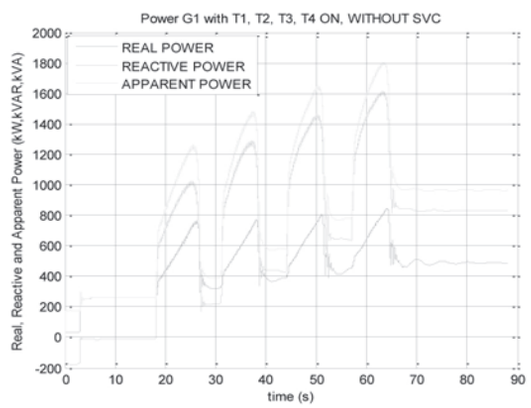

Figure 1: Power delivered by G1, without Dynamic Power Factor Correction

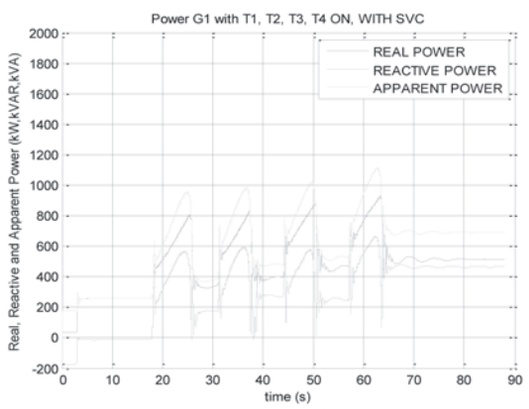

Figure 2: Power delivered by G1, with Dynamic Power Factor Correction

Results and Achievements

The measurements taken on-board clearly showed that a current overload is being experienced by the three generators in operation, during switch on of the fourth thruster. This was analysed in detail from simulation studies using the developed model.

The case study analysed the introduction of a dynamic power factor correction unit at the Main Busbar. With the existing configuration of three generators in operation, the generators' reactive power generation was reduced by an average of 54% (startup) and 41% (steady state) while RMS current decreased by 38% (startup) and 25% (steady state).

The feasibility of GCCL operating with two rather than three generators for the same number of thrusters was then tested. The outcome of these tests showed that all four thrusters could be switched on without overloading the generators.

Design of a Touchscreen Interface for Microcontroller

Student: Philip Farrugia / Supervisor: Dr Ing. Reiko Raute

Introduction

Today, we live in a society where appearance is given the utmost importance especially when it comes to designing new products. In fact, in an effort to make products more eye pleasing, intelligent display modules are being incorporated into the design of electronic devices such as smartphones, laptops and even light switches. Furthermore, the elimination of buttons or switches in favour of touchscreens increases the functionality and flexibility of the product. Thus it is only natural that control panels of inverters and data loggers, should also follow suit.

Project Objectives

The main scope of this thesis is to address the above scenario by designing and building a prototype of a touchscreen interface, which is also known as an intelligent display module which controls the aforementioned devices. The aim is to design the said display module in a way that is practical, cheap and user-friendly.

Project Methodologies

The first step towards designing the intelligent display module is to decide which components to use such as the microcontroller, the LCD screen and the touchscreen. The said components are researched in order to ensure that they are capable of satisfying their respective functions. Once these components are duly researched and chosen, the protocols used to communicate between the microcontroller and the devices are also analysed, chosen and subsequently tested. Once this is done, the intelligent display module's schematic is designed and then implemented on a Printed Circuit Board. A small demonstration program is programmed into the microcontroller so as to demonstrate the capabilities of the intelligent display module.

Results and Achievements

The end result of this project is shown in figure 1. Ultimately the aim of this intelligent display module is to allow devices to show images, animations and even multi-controlled functions on their screens. The design is also capable of being connected to various devices which would provide the user with a wide range of possibilities regarding the use of the said module.

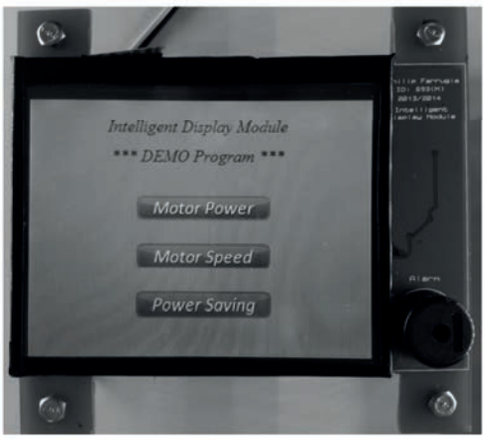

Figure 1: Front side of the Intelligent Display Module

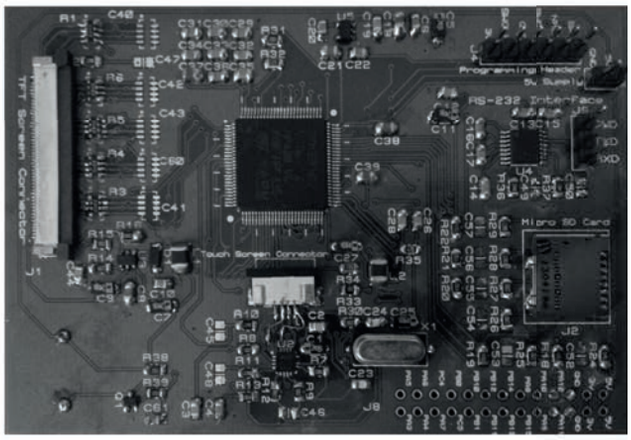

Figure 2: Back side of the Intelligent Display Module

Design of Small Induction Machine

Student: James Meli / Supervisor: Dr Cedric Caruana

Introduction

In today's world, electric motors find a wide variety of applications. The trend has shifted from applying a standard motor to diverse applications to the design of a specific motor for the application. This necessitates a faster and less expensive design process. The use of software packages for the design and analysis of such machines provides a solution.

Project Objectives

The aim of this project is to design a small induction motor through the use of two software packages. The project targets the SPEED and FLUX software which are based on analytic equations and finite element analysis respectively. The design specifications of the target motor are based on an existing 4kW induction motor, providing a reference for the obtained performance.

Project Methodologies

The reference motor is dismantled and specific construction details such as slot shape and dimensions are initially taken. The motor is designed in SPEED and analyzed in FLUX. The resulting performance is also compared to the experimental performance of the reference motor. Various motor parameters such as: stator and rotor slot type and shape, air gap length, turns per coils and diameter of stator laminations are then varied to analyze the resulting effect on the motor performance including power, power factor, torque and efficiency.

Results and Achievements

The designed motor was found to have similar performance characteristics to the reference one, with a rated torque of 30.94Nm at 4.6kW in SPEED and 33.2Nm at 4.9kW in FLUX. The percentage difference between the designed motor and the reference was found to be 2.4% in SPEED and 11.9% in flux.
With this degree of compatibility between the designed motor and the reference motor, designing parameters where varied. It was found out that:

- Open slot type increases the magnetizing current by 10-20% reducing power factor and efficiency.
- Wide slots effect the flux line and density distribution.
- The motor with 32 rotor slots showed an increase of 0.44% and 0.34%in efficiency and power factor respectively but with a 10.4% reduction in performance.
- The motor with 24 slots gave an increase of 5.2% in performance but showed a reduction of 1.07% in efficacy and power factor.
- A 0.1mm air gap gave a reduction of 73% in magnetizing current when compared with the original 0.5mm of the reference motor producing better power factor and efficiency.
- The 0.2mm produced the best power factor and efficiency with an increase of 0.5% from the reference motor.
- Reducing the number of turns per coil in the winding of the motor reduces the efficiency and power factor but increases the output performance.
- Increasing the inner and outer diameters of the stator will increase performance and the power factor but will reduce efficiency.

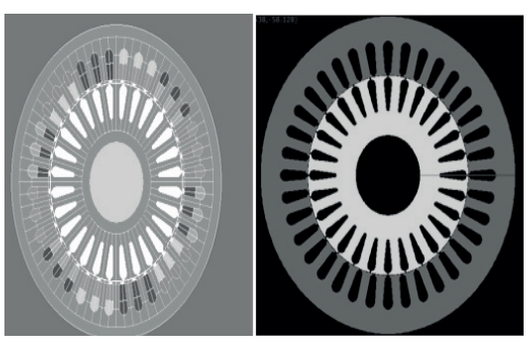

Figure 1: The designed motor in FLUX and SPEED

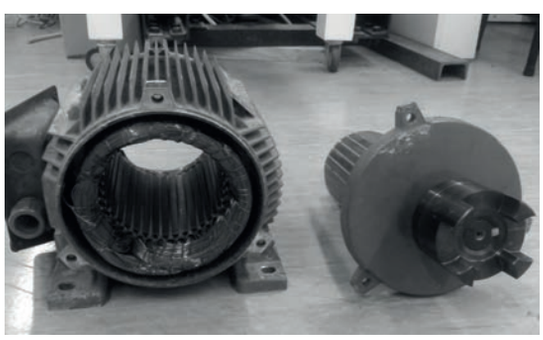

Figure 2: The 4kW reference motor

Permanent Magnet Synchronous Motor Drive

Student: Andrew Scicluna / Supervisor: Dr Cedric Caruana

Introduction

A Permanent Magnet Synchronous Motor (PMSM) is an AC electric motor which has its rotor made of a permanent magnet. It offers more advantages compared to an induction motor which include achieving higher efficiencies due to no copper windings in the rotor, smaller sizes and lower weight. This dissertation considered the implementation of a PMSM drive using vector control implemented on a dSPACE controller board.

Project Objectives

The objectives of this project are to set up vector controlled PMSM drive with the required electronic interfaces, control structure and user interface. Appropriate routines for the motor parameter extraction and tuning are to be developed and tested.

Project Methodologies

The project started by the development of a software model for the motor drive in Matlab Simulink. Different methods were employed for tuning the various PI controllers used for the vector control, such that the best performance could be obtained. The model was made of two inner current loops controlling the d- and q-axis currents and one outer loop controlling the speed [1]. In order to tune the controllers, the parameters of the PMSM had to be acquired. These involved measurement of the number of poles, the stator resistance, the d- and q-axis inductances and the back-emf constant. These were based on experimental tests. The actual built rig consisted of the Matlab Simulink/dSPACE element and the hardware interface element. Four boards were constructed for providing the required feedback.

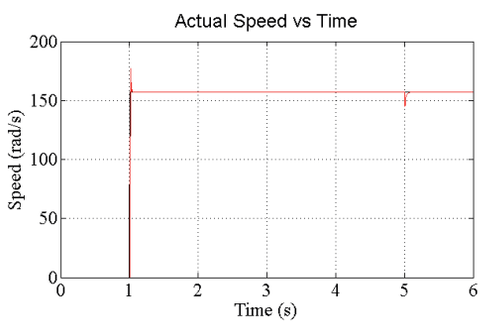

Figure 1: Speed Response Curve

to the control structure. This included sensing the current and voltage at the motor terminals and the rotor position. The transducer signals were conditioned for interfacing to dSPACE control board. The speed and position sensing were obtained by extracting relevant signals from a coded SinCos incremental encoder that was supplied with the PMSM. The dSPACE control board was then interfaced to a commercial inverter for driving the PMSM, allowing the developed control structure to be tested on the actual PMSM.

Results and Achievements

After tuning the control based on the extracted motor parameters, a number of tests were carried out in order to test the performance of the system. Typical test conditions involve the specification of a speed step reference to the system and then applying a load step. For the simulated system a speed step reference of 157 rad/s at 1s (shown below), the system responded with a rise time of 8ms and an overshoot of 12.95%. When loading the system with 20 Nm step after 5s, the system regained to its reference speed at a rise time of 40ms. The current response curves show that when loading the motor, the q-axis current correspond with the increase in torque. The simulated performance will be compared with the experimental tests. The effect of using detuned parameters for the control design was also tested.

References

1] [Zulkifilie I., Cheok Yong S.,], 'Vector Control Drive of Permanent Magnet Synchronous Motor Based dSPACE DS1103 Implementation' University Teknikal Malaysia, Melaka, Paper 2012.

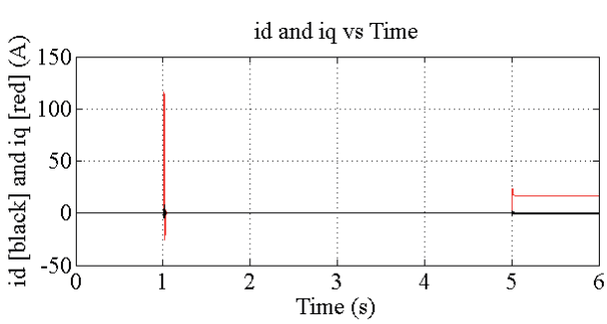

Figure 2: Current Response Curve

Reducing Vibrations in Flexible Mechanical Controlled Systems via Input Shaping

Student: Joseph Agius / Supervisor: Dr Ing. Marvin K. Bugeja

Introduction

Flexible manipulators are becoming increasingly popular due to a number of advantages that they offer. These include higher maneuverability and transportability. However, flexible manipulators introduce higher vibrations within the system. These manipulators are used in crane systems and spacecrafts. The vibration reduction is obtained via Input Shaping techniques, Zero-Vibrate (ZV), Zero-Vibrate Derivative (ZVD) and Zero-Vibrate Derivative-Derivative (ZVDD), Input Shapers (IS) are investigated in detail, starting from the fundamentals given by Singer and Seering in [1].

Project Objectives

The main objective of this project is to design a control system for a rotary single-link flexible manipulator which is able to move the end effector from one place to another with the least vibrations possible. The three Input Shapers should be investigated and analyzed in both simulation and on a physical experimental setup.

Project Methodologies

The first steps included a detailed literature review on input shaping controllers and the different implementation techniques, focusing on the open-loop implementation of the ZV, ZVD and ZVDD Input Shapers. The mathematical model of the flexible manipulator was then derived and simulated on SIMULINK such that the non-linear behavior of the system could be analyzed. The control system consists of three controllers namely; a current controller, a position controller and an input shaper as shown in Figure 1.

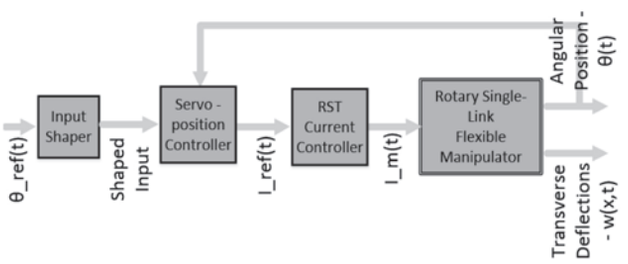

Figure 1: Control System

Firstly, the current loop was designed using a digital pole-placement technique, then a digital PID based servo-position controller was designed. Finally, by analyzing the resulting vibrations, the design of the three input shapers was completed. The control system was simulated and analyzed in detail. Then the control schemes were digitally implemented on the DS1104 control board and tested on the physical experimental setup.

Results and Achievements

The aims of this project were achieved since the designed control system was able to suppress the residual vibrations while still being able to obtain an accurate position control is obtained. The percentage residual vibration reduction (PRVR) is significantly lowered as shown in Figure 2. The ZV-IS PRVR was 85.28%, the ZVD-IS PRVR was 86.81%, and the ZVDD-IS PRVR was 92.91%. Apart from the PRVR, the robustness of each Input Shaper could be analyzed from Figure 2. The most robust to errors was ZVDD-IS while on the contrary ZV-IS was the least, as stated in theory. The theory investigated theory was validated using both simulation and the physical experiments afterwards.

References

[1] Singer N. C and Seering W. P., 'Pre-shaping Command Input to Reduce System Vibration' ASME Journal of Dynamic Systems, Measurement, and Control, A.I.Memo No. 1027

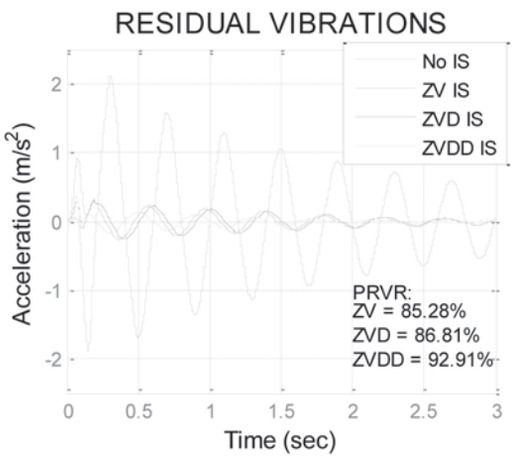

Figure 2: Vibration Reduction on Test Setup

EMG Signal Analysis of the Gait Cycle

Student: Vanessa Azzopardi / Supervisor: Dr Owen Falzon / Co-Supervisor: Prof. Ing. Kenneth Camilleri

Introduction

Electromyography (EMG) is the study of muscle function through analysis of the electrical signals emanated from muscles during muscular contractions.

Existing work by Winter and Yack [1] presents a baseline reference of motor patterns featuring EMG signal profiles. Although valuable, these patterns are limited to the time domain and disregard all frequency-domain information.

The aim of this project is to analyse gait EMG signals from both the time and time-frequency domains and come up with an improved reference of motor patterns which contributes additional information.

Project Objectives

- To analyse EMG signals from lower limb muscles.
- To perform time and time-frequency signal analysis on EMG signals.
- To test for differences in the EMG signal features between scoliotic and non-scoliotic individuals

Project Methodologies

The main methods employed in this project are the signal envelope, obtained through low-pass filtering, and the short-time Fourier transform, obtained through signal windowing and FFT computation.

Additional methods employed in this work include: mean and median signal averaging, amplitude and temporal signal normalisation, and statistical analysis by means of t-tests.

Results and Achievements

Results emerging from this study are the typical EMG signal profiles and spectrogram plots of the muscles under consideration.

While signal envelopes are instructive, spectrogram plots represent more valuable information in the same space.

References

[1] Winter D., Yack H., EMG profiles during normal human walking: stride-to-stride and inter-subject variability' Electroencephalography and clinical Neurophysiology, 1987, pp.402-411

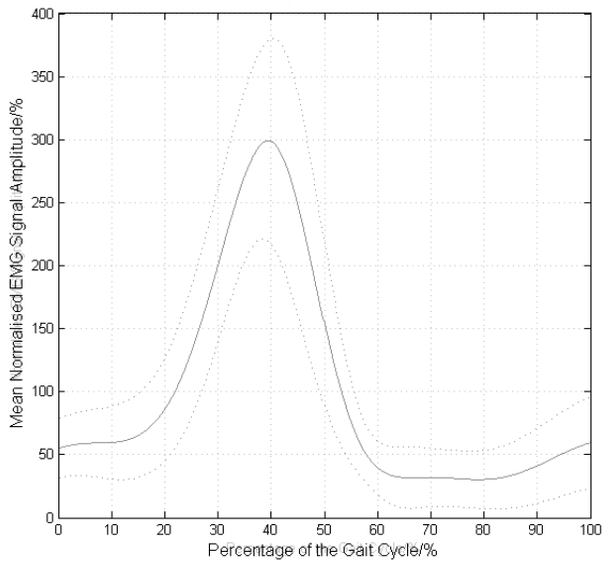

Figure 1: Mean inter-subject signal envelope of the lateral gastrocnemius muscle

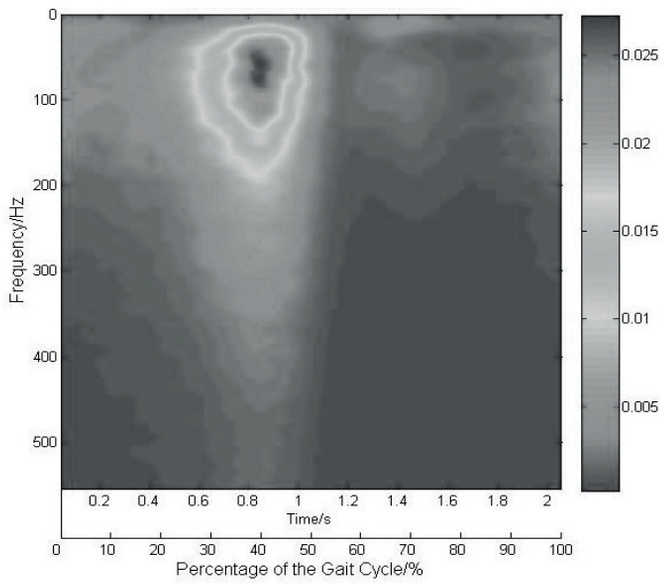

Figure 2: Mean inter-subject spectrogram of the lateral gastrocnemius muscle

Analysis of EOG Signals for Human Computer Interaction

Student: Alison Baldacchino / Supervisor: Dr Tracey Camilleri

Introduction

Electrooculography (EOG) signals can be utilized as an additional input channel by which a person can communicate with a computer through the eye movements performed.

EOG signals are captured using electrodes placed strategically around the eyes and consist of two components, the vertical component and the horizontal component. These can be used to identify different eye movements and the distance moved by the eyes.

Project Objectives

The main aim of this project was to determine the suitability of EOG signals as an input method for Human Computer Interaction (HCI) through analysis of the recorded EOG signals and the development of a prototype real-time system.

Project Methodologies

There are 3 main types of eye movements: blinks, saccades and fixations. Most of the time, blinks are done involuntarily to refresh the frontal part of the eye with corneal tear film; saccades are rapid eye movements while fixations represent those time periods during which the eyes are kept fixed staring at a particular point [1].

These different eye movements can be identified through their characteristic features in the EOG signals. By subtracting the amplitude of one sample from another across an optimal window length and application of an optimal threshold, the salient features of 8 predetermined eye movements, were extracted.

The optimal values for the window length and threshold were identified offline using a set of training data consisting of the EOG recordings for 8 different eye movements. Performance analysis to see the amount of True Positives, False Positives, and False Negatives of the offline system was carried out to choose the optimal values. These parameters were then used in the real-time prototype, shown in the figure, system where the subject was asked to move his/her eyes from the centre of the screen to other predefined positions, at which point feedback was also provided.

Results and Achievements

From the offline analysis, a range of EOG voltages related to each saccadic movement were determined from which classification of the eye movement could be done. It was found that different distances in the same direction could be identified from one another according to the maximum voltage of the saccade, confirming that the EOG signal, and thus the saccade amplitude, change linearly with the distance moved [2]. From the analysis performance carried out, an accuracy of around 90% was achieved.

A prototype real-time system was then successfully implemented in which an accuracy of around 60% was achieved. This accuracy can be improved by introducing a training so that prior to using the system, the latter can learn the required parameters which may vary with time and also across subjects.

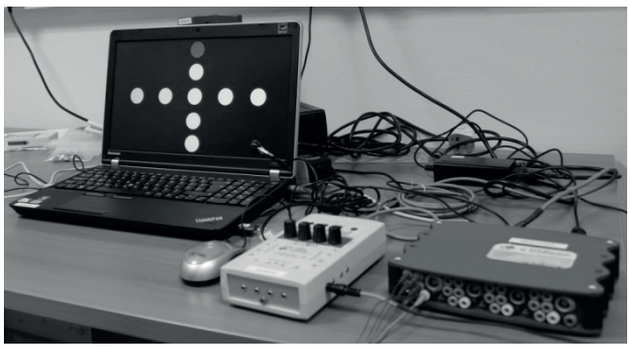

Figure 1: Setup of the real-time prototype system

References

[1] Bulling A., Roggen D., and Troester G., 'What's in the Eyes for Context-Awareness' IEEE Pervasive Computing, 2011, Vol. 10, No. 4, pp.48-57

[2] Barcia J., 'Human electrooculography interface', Masters in physics engineering, Instituto Superior Tecnico, 2010.

A Driver Monitoring System using Image-Based and Physiological (ECG) Signals

Student: Nicholas Lee Bugeja / Supervisor: Dr Ing. Reuben Farrugia*

*Communications & Computer Engineering Department - Faculty of Information & Communication Technology

Introduction

Given the alarming amount of traffic accidents due to driver drowsiness, over recent years numerous researchers have put their effort in finding indicative cues of driver drowsiness, whether it is related to vehicle or driver behaviour. Image-based and physiological measures are just two types of driver-based measures.

Project Objectives

Combine a physiological (ECG) approach with an already-existing image-based drowsiness detection system. Secondly, detect prominent features present in the ECG signal related to drowsiness and find a correlation with the image-based readings.

Project Methodologies

A means to acquire a digitized ECG signal in real-time was developed. After relating to numerous studies a test protocol was also defined, along with determining the correct theoretical tools required for the analysis of the ECG data.

Four subjects were asked to drive for a 60-75 minutes on a driving simulator setup, during which the ECG signals and image-based output were recorded.
After processing the signal, frequency-domain HRV analysis was then used to extract the main features within the physiological data.

Results and Achievements

The LF/HF results from the tests performed on four male subjects showed a decreasing trend, corresponding to behavior in various studies, meaning that an increase in power in the HF band (0.15 0.4Hz) was noted.

However, no correlation of VLF Power and heart-rate to fatigue, was found. Regarding drowsiness-detection via the image-based algorithm, despite detecting instances of fatigue, a strong correlation was not found, and thus any conclusions derived from the image-based system are deemed to be unreliable.

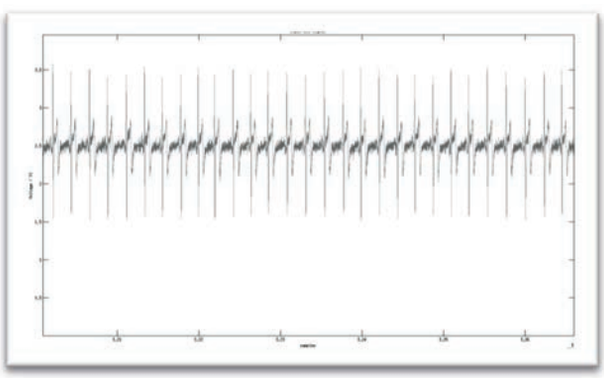

Figure 1: Raw ECG Waveform (from one of the test-subjects)

Figure 2: *Plessey's EPIC* Sensors in Automotive Applications

Object Recognition and Approach for Mobile Robots

Student: Antonella Camilleri / Supervisor: Dr Ing. Marvin Bugeja

Introduction

Wheeled mobile robots are being employed to assist in several aspects of the human life, such as inspection, surveillance, humanitarian aid, and security patrols. Mobile robots need to be autonomous and intelligent in order to deal with the constantly changing environment. Such intelligence can be obtained only if the robot interaction with its surroundings through the use of different sensors.

Project Objectives

The aim of the project is to design, implement and test a 'Recognize and Approach' mobile robotic system that could be commanded to locate a specific target in an unstructured environment. The mobile robot, Khepera III, needs to be able to approach the target object to within a pre-specified distance and keep tracking the target even if it moves

Project Methodologies

An extensive literature review was done about mobile robots. This included research on object detection and recognition based on coloured objects and several viable 'approach' controllers. This task requires the implementation of a control system which follows a moving target in its environment. This comprises the interpretation of the camera images. A suitable monocular camera and other additional hardware for communication were equipped on the mobile platform. Data gathered from the camera, needs to be processed and the information about the distance between the robot device and the target needs to be calculated. An algorithm that selects the target object from the image based on colour was implemented. The information gathered from the image, will provide the feedback demanded by a suitable vision-based controller to approach a target in real-time. The design of a target recognition algorithm, methods for distance extraction (between robot and target), and an 'approach' controller were carried out. Khepera III, the mobile robot used, was configured to handle the expansion modules added. An interface via Bluetooth and Wi-Fi was set-up between the central computer and the robot, to autonomously have control of the mobile robot. The 'recognize' part of the task was implemented by two methods that attained the distance between the target and the mobile robot. Ultimately, a vision based non-linear kinematic controller was implemented on the Linux based mobile robot to have a complete closed-loop system that performs the recognition and approach task specified.

Results and Achievement

The 'recognize an approach' task was successfully implemented on the Khepera III along with the hardware and software components making up the system. The target was selected based on its colour by analyzed in the HSV color space selection. The algorithm was tested to work with several different colors of the target object. Distance between the target and the mobile robot was obtained by two different methods: by the equation of the monocular camera [2] and by a calibration method. The vision based tracking control system [1] was tested with success. The results are depicted in Figure 2.

References

[1] Guerin F., Fabri S. G. and Bugeja M. K., 'Double Exponential Smoothing for Predictive Vision Based Target Tracking of a Wheeled Mobile Robot', Decision and Control, 2013

[2] Yasuda G.and Ge B., 'Object Recognition and Self-Localization for Interactive Soccer Robots', Proc. of the International Conference on Robotics and Biomimetics, 2004.

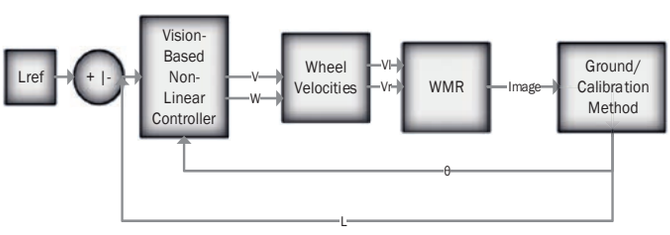

Figure1: System Block Diagram

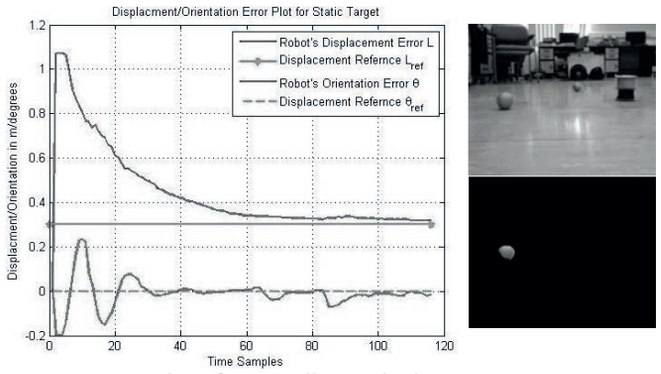

Figure 2: Results of Controller and Object Recognition

Virtual Object Manipulation in an Augmented Reality Setup

Student: Daniel Camilleri / Supervisor: Prof. Ing. Kenneth P. Camilleri

Introduction

Since the introduction of computers, user interfaces have been mainly limited to the keyboard and the mouse which are unnatural and require some degree of training. This project aims to provide a new interface that is more natural by removing the user from the desk and placing him in a 3D environment that allows manipulation of objects in 3D space.

Project Objectives

The objectives of the project are twofold. The first objective is the construction of a relatively cheap Augmented Reality (AR) interface followed by the development of an image processing algorithm that extracts the pose of the hand.

Project Methodologies

In the project methodologies various approaches to the construction of an AR interface are investigated and a custom approach is chosen instead of readily available hardware. Following the construction and software interfacing required for the AR interface, the image processing section of the project was tackled. In this part of the project different algorithms such as those found in [1], [2] and [3] are investigated for skin segmentation as the first step. Their real time performance and accuracy are tested and the best algorithm is chosen to support the next step which is the classification of the hand into fingers, palm and thumb through the use of a custom method.

Results and Achievements

The AR hardware setup with external cameras mounted to the Oculus is shown in Figure 1. It provides the user with an image of his/her surroundings while giving the illusion that there are additional 3D objects present. Furthermore, using the cameras mounted to the user's head, the image from the camera is used to find the hand and then recognize which part of the hand are the fingers, the palm and the thumb. The result is shown in Figure 2 where only the hand is visible with the recognized hand sections on top of it. Also, Figure 2 shows the time taken which indicates the achievement of real time processing greater than 30 frames per second.

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[3] Pai Y., Ruan S., Shie M. and Liu Y., 'A Simple and Accurate, Colour, Face Detection Algorithm in complex Background', Proc. of the IEEE International Conference on Multimedia and Expo. , Toronto, Canada, 2006

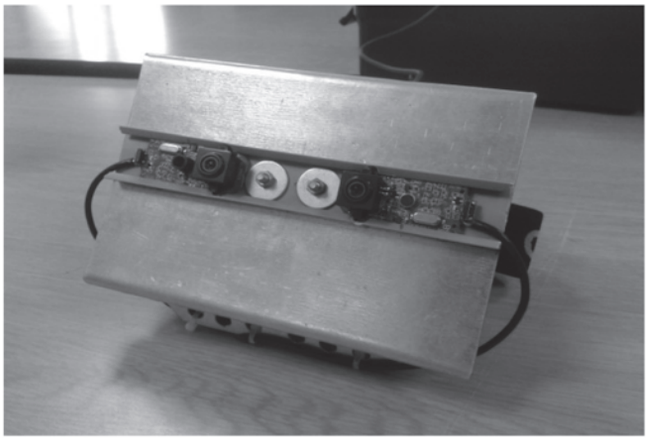

Figure 1: AR hardware system based on the Oculus Rift

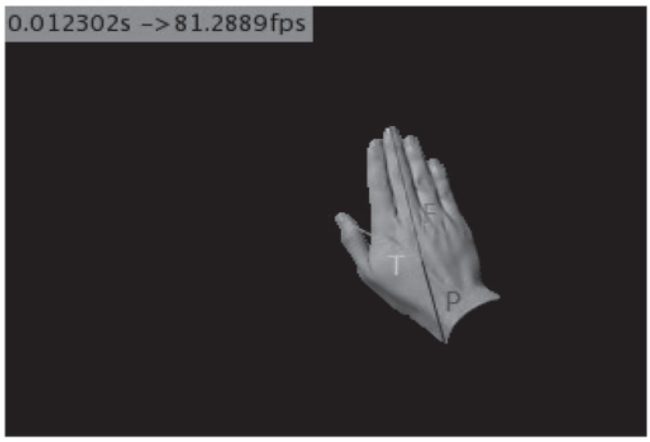

Figure 2: Hand Classification through Image Processing

Electroencephalographic Analysis of the Effect of Pharmaceutical Drugs on Epilepsy

Student: Janice Camilleri / Supervisor: Dr Kenneth Scerri

Introduction

Epilepsy is a neurological disorder characterized by recurring epileptic seizures. [1] Common symptoms range from headaches to repetitive movements of certain body parts, such as the arms or legs, amongst others. Approximately 50 million people worldwide suffer from epilepsy and in Malta, more than 4,000 citizens have been diagnosed with this disorder [2]. Such condition increases the possibility of premature death by two to three times when compared to the general population [3]. This demands for more effective clinical treatments, resulting in the continuous development of various new drugs aimed at suppressing epileptic fits. However, large amounts of data, as shown in Figure 1, cause significant problems in quantifying the effectiveness of the drugs.

Project Objectives

The goal of this thesis is to research and implement different methods aimed at quantifying the effectiveness of three different medications in contrast to a control data-set, through the analysis of EEG recordings from rats.

Project Methodologies

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

- Literature review on successfully implemented methodologies that quantify the suppression of epileptic seizures
- Familiarization with EEG recordings
- Implement the chosen methods on MathWork's MATLAB ©, including a multiple frequency band analysis, a quantitative modelling method and a spike rate measure,
- Test each procedure using the data provided and gather results,
- Perform analysis measures using ANOVA.

Results and Achievements

The classification of the methods starting with the most reliable is as follows:

1) Spike Rate Method
2) Quantitative Modelling
3) Multiple Frequency Band Analysis.

Utilizing the plots from the spike rate method proved to be almost as informative as the statistical results from ANOVA. Moreover, the spike rate method employs the fastest approach, when compared to the other methods, for measuring both the intensity and duration of the seizures.

This study not only proposed which is the most practical method but also identified the most effective antiepileptic drug out of the three tested.

References

[1] "Wikipedia," [Online]. Available: http://en.wikipedia.org/wiki/Epilepsy.

[2] "Caritas Malta," [Online]. Available: http://www.caritasmalta.org/?m=epilepsy.

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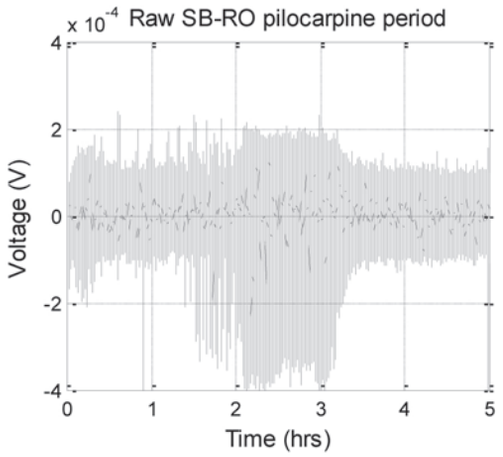

Figure 1: Raw EEG data

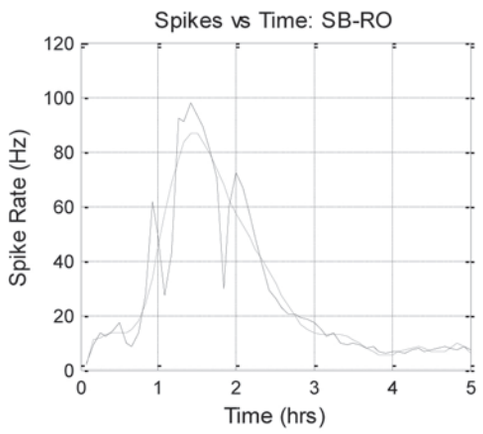

Figure 2: A spike rate measure of the data in Figure 1

Active-SLAM for Autonomous Exploration using a Mobile Robot

Student: Claire Farrugia / Supervisor: Dr Ing. Marvin K. Bugeja

Introduction

Acquiring models of the environment belongs to the fundamental tasks of mobile robots. SLAM constitutes the problem of Simultaneous Localisation and Mapping. Active-SLAM implies the combination of autonomous exploration with SLAM. Hence, this work examines these three questions: "Where am I?" "Where am I going?" and "How should I get there?"

Project Objectives

The main aim is the analysis and development of an Active-SLAM system, by focusing on path planning which is the foundation of this system for autonomous navigation. It should compute shortest path and be computationally efficient.

Project Methodologies

In the project methodologies, the theory concerning all the subsystems of Active-Slam are explored together with their variants and possibilities. Following this, the work was divided into three hierarchical stages starting from the Frontier Based Approach [2] at the highest level which decides where the robot must go next followed by EKF SLAM and a path planning algorithm. Therefore this project deals with the design and testing of the performance of a path planner. After investigating the planners available, the D* Lite algorithm [1] was chosen for its dynamic obstacle handling and real time execution.

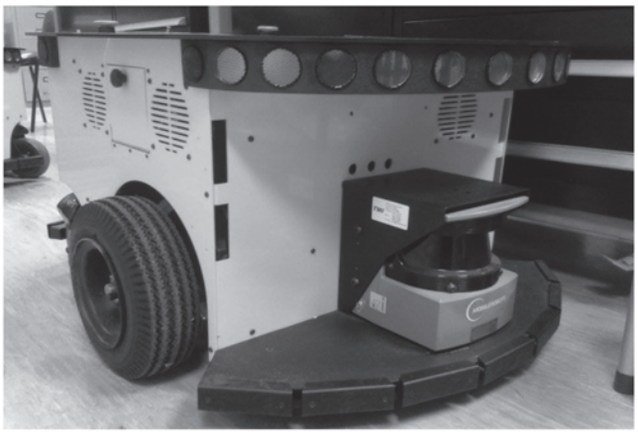

Figure 1: PowerBot™, the Wheeled Mobile Robot

Results and Achievements

The primary achievement of this work in simulation centres on the attainment of good performance (<14ms) in the execution of the path planner even in environments that have a very high obstacle count. Furthermore, this work achieves the execution of path planning and navigation through the implementation of custom commands that enable the autonomous control of the robot to be achieved through wireless networking. The results represent the various correlations between length of the planned path, the number of obstacles present in the map and the time taken. The results also demonstrate the possible flexibility and efficiency of having a robot move either in up/down, left/right mode or by considering diagonal movement as well.

References

[1] Koenig S. and Likhachev M., 'Improved fast replanning for robot navigation in unknown terrain' Robotics and Automation, 2002, Vol. 1, pp.968-975

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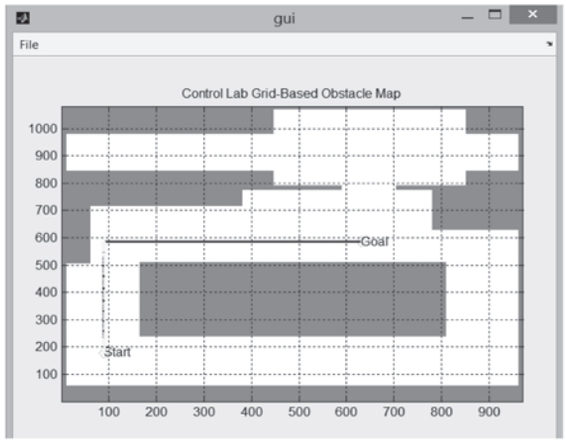

Figure 2: Path Planning and Execution

Analysis of EMG Signals for Real-Time Control of a Robotic Arm

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

Introduction

Biomedical engineering is at the forefront of technological breakthroughs, directly tackling the ever-growing demand for a better quality of life. In conjunction with modern day robotics, functional prosthesis are no longer a thing of the future, providing persons with disabilities the ability to regain lost functionality.

Project Objectives

This project focuses on the in-depth analysis and processing of electromyographic (EMG) signals for the development of a real-time system in which a robotic arm is designed to accurately mimic the elbow movement of a human subject.

Project Methodologies

This project is split into three sections:

1. The analysis of the time-varying characteristics of EMG signals, brought about by fatigue.
2. The identification of a state space model that can translate EMG signals to joint angles.
3. The development of a real-time system that controls a robotic arm solely through EMG signals.

The first part of the project focused on extracting multiple features from the EMG signals which can give an indication of whether the characteristics of the EMG signals are varying as a result of fatigue.

The next step involved the simultaneous recording of the human elbow movements through the VICON motion capture system and EMG signals through wireless surface electrodes, over multiple trials. This data is then used to develop a state space model for the reliable mapping of EMG data to joint angles, as done by Artemiadis and Kyriakopoulos in [1]. Different system identification techniques were used to find an optimal model that translates EMG signals to the corresponding elbow movements, and different speeds for the latter were also considered.

Finally, a real-time system was developed as a prototype to show the possibility of having a robotic arm (specifically the CataLyst-5 robotic arm) mimic the elbow movement of a human subject solely through EMG signals. This system was developed using a combination of C++, MATLAB and Simulink programming, coupled with TCP and serial

Results and Achievements

Through this dissertation, feature indices forming a direct relationship to muscle fatigue were successfully identified. For the subject under test, fatigue was found not to greatly affect the characteristics of the EMG signals given the elbow movement performed over 4 minute trials. This meant that under these conditions a single state space model could adequately represent the relationship between the EMG signals and corresponding elbow angles.

This model was then incorporated within the real time system. The results show that the robotic arm could mimic human elbow movement, performed at a speed of 0.33Hz, with an average root mean square error of $15.52° \pm 2.573°$ and an average cross correlation coefficient of 0.93 ± 0.023.

Figure 1: The CataLyst-5 robotic arm in motion (left), mimicking human arm movement through EMG signals (right)

References

[1] P. Artemiadis and K. Kyriakopoulos, "EMG-Based Control of a Robot Arm Using Low-Dimensional Embeddings," IEEE Transactions of Robotics, vol. 26, no. 2, pp. 393-398, 2010.

Infra-Red Reflectography for the Analysis of Historical Paintings

Student: Adrian Grima / Supervisor: Dr Kenneth Scerri

Introduction

Life without arts would be rather drab, hence time and money were invested on the creation of artistic works. Studies of art throughout the ages show it has changed considerably. This could be noted because art from different points in time still exist. It still exists because it was conserved. Art conservation is very important and conservators use any method possible to maintain art in its original condition.
One of the methods used amongst others is Infra-Red Reflectography (IRR). IRR is a non-destructive technique based on Infra-Red (IR) crossing the paint layer and reflected by the underdrawing layer (sketch) of the painting. This allows the restorer to see the artist's original sketch. The reflection is dependent on the different types of pigment and hence another technique called false colour can be used to identify the type of pigment used.

Project Objectives

The aim of this project is to identify and acquire the best hardware and develop the software needed for the most cost-effective infra-red reflectography setup possible.

Project Methodologies

Two cameras that are capable to capture images in the near-IR are fitted with optical filters such that one camera is able to capture an image only in visible light and the other capture an image in IR.

The two cameras are fitted on an aluminium structure and calibrated to face the same object. A light source which emits IR is used to emit both visible light and IR on the art work.
The software developed is able to acquire images from the two cameras. The underdrawing could be analysed, if available, from the IR image. To develop the false colour the two images have to be matched such that they map to the same points. The red part of the visible light image is substituted with the IR image. The green part is substituted by the red and the blue is substituted by the green part. A stitching algorithm is used in cases where the art work is too big to be captured using one image, and is divided in multiple images.
Finally a graphical user interface is developed to allow the user easy and elegant use of the hardware and algorithms.

Results and Achievements

The setup was used on three artistic works. It was first tested on a control painting were the type of pigment used and the underdrawing were known. The IR image showed the underdrawing and the false colour allowed the correct identification of the type of pigment. It was also tested on a real painting and a statue which gave similar results to the test painting as expected. No underdrawing or sketch was found, as it seems the artist may have skipped this step. The false colour helped in identifying the type of pigments used successfully.

Figure 1: IR image of *Floral Still life* painting

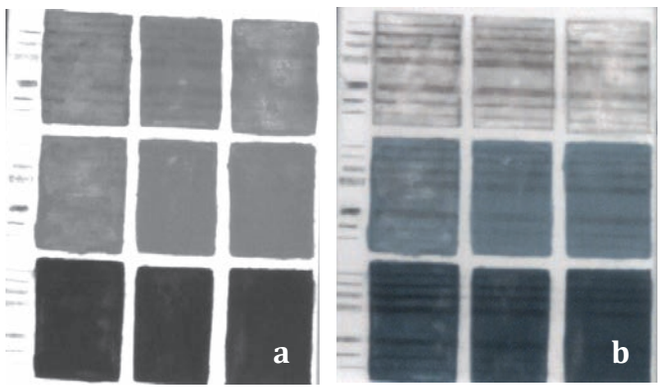

Figure 2: a) The test painting b) IR image of test painting showing the underdrawing

Autonomic Control of Traffic Networks

Student: Daniel Magri / Supervisor: Dr Kenneth Scerri

Introduction

As the mean stock of vehicles in Malta increases, so does the congestion in the densely packed Maltese roads. This in turn causes an increase in the time taken for a vehicle to reach its destination, resulting in an increase in air pollution and driver frustration. This study focuses on a signalized junction in Msida, Malta where these effects are clearly noticeable.

Project Objectives

The project proposes that the traffic light timings should not remain fixed since they are unaware of the fluctuating conditions inside the junction. Instead the timings should be controlled in real time to reduce the waiting times of incoming vehicles.

Project Methodologies

The commercial sensors available which could be installed inside the junction are analyzed and, based on the outputs which could be produced by the sensors, a model which represents the behavior of the junction is developed, analyzed and tested. Controllers which set the traffic light timings in real time are designed based on the developed model. The controllers' performance is tested on simulators which model the junction from different perspectives and are then compared to the performance of the current fixed time schemes to quantify the improvement made and identify the controller best suited to be implemented at this junction.

Results and Achievements

The simulations performed showed that although the simulators model the junction from different perspectives, the resulting queue lengths are comparable for both simulators if the flows of incoming vehicles are equal.

The main simulator used to assess the performance of the controllers implemented was Simulation of Urban MObility (SUMO) [1]. Five controllers were simulated under peak traffic conditions and compared with the current fixed time scheme. The results showed that the mean queue length was reduced by up to 49% in certain arms which resulted in a larger flow of vehicles exiting the junction, thus fulfilling the project's objective of reducing the vehicles' waiting times.

The simulator also provided a comparison between the controllers and the current fixed time plans when a traffic accident occurs. It showed that in such conditions, the current fixed time plans used inside the junction develop long queues quicker than when using any of the developed controllers.

References

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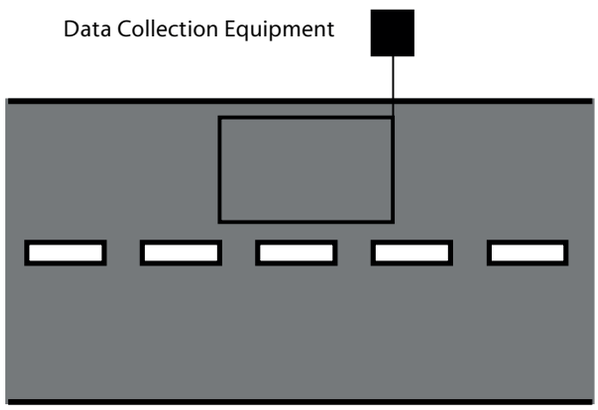

Figure 1: An induction loop sensor

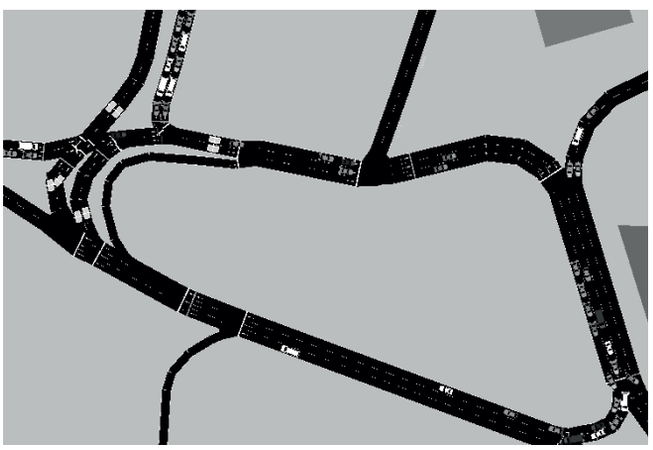

Figure 2: Simulation of the signalized junction

Gesture Recognition with Single and Multiple Kinect Sensors

Student: Anne Marie Muscat / Supervisor: Prof. Ing. Kenneth P. Camilleri

Introduction

The Microsoft Kinect sensor is an off-the-shelf sensor that can provide depth data. One of its applications is gesture recognition where the user can perform gestures which the computer can translate into actions, leading to a more interactive and intuitive system.

Project Objectives

The main objective of this project is to investigate ways of using two Kinect sensors to identify a set of hand gestures. No calibration of the sensors should be needed since the end user can just place the sensors in which ever setup he desires, train the system, and use it.

Project Methodologies

The Kinect sensor emits an IR pattern on the scene made up of a number of speckles which are distorted depending on the depth of the objects in the scene. Based on this, the sensor is able to produce a depth map. Using multiple sensors will cause interference of the IR patterns which will leave missing values in the depth map, leading to high degradation of the same image. To minimize this interference, a vibration motor was used to introduce movement to one of the sensors such that the IR patterns from both sensors will not interfere. This restored the quality of the depth maps.

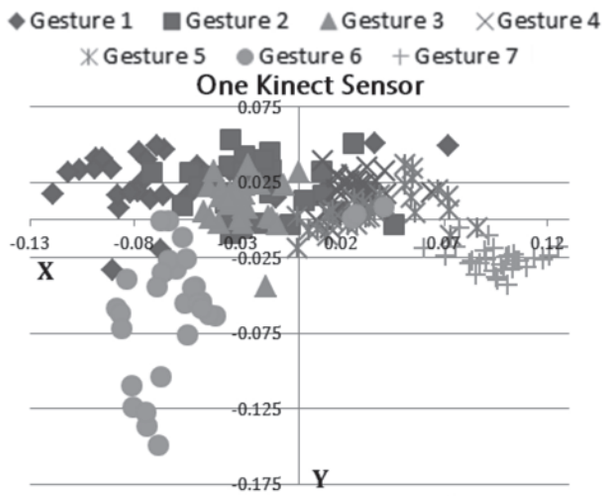

Figure 1: One example data set of all the gestures transformed to two dimensions. Classification is not so obvious in this case

Depth segmentation was performed to capture the hand alone, followed by a number of image processing functions to obtain the contour of the hand. The points on the contour were then sampled to obtain the general shape of the hand pose and their distance from the center point was calculated. The Discrete Fourier Transform of these distances were taken. These provide a scale-, rotation-, translation-invariant description of the hand contour.

Two methods for feature fusion were tested; concatenation of the two single vectors and weighting based on the convex hull area of each view. These vectors were then transformed using PCA and classified using a multi-layer perceptron for each gesture. During training, the best configuration, method of fusion and threshold are selected for each network and these are then used for real time use.

Results and Achievements

Four different setups were tested with seven different gestures. The methods compared were the concatenated vector, the weighted vector and the two single vectors for each setup. Although all gave high accuracies, between 81% and 100%, the concatenated vector seemed to keep consistent high recognition accuracies for all the setups and all the gestures. The single Kinect sensor methods found it more difficult to classify occluded gestures whilst by using multiple sensors, this is mitigated. Thus, for occluded gestures and if a non-fixed setup is used, multiple Kinect sensors surpasses the use of just a single Kinect sensor.

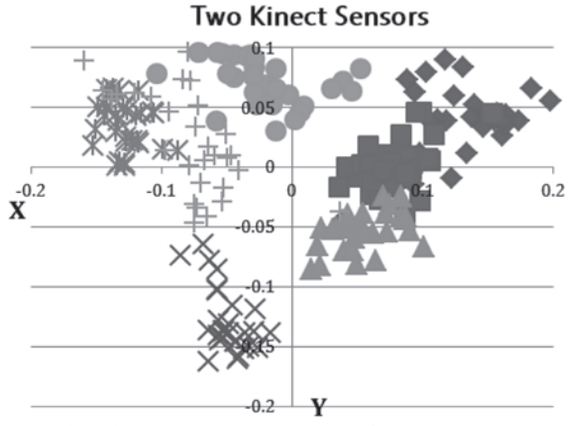

Figure 2: Using two sensors and concatenating the features, the classes are more separable when compared to just one Kinect sensor

Machine Learning of Buy and Sell Signals for Equity Investment

Student: Clive Zahra / Supervisor: Prof. Ing. Kenneth P. Camilleri

Introduction

As financial analysis for forecasting is a demanding field of study, machine learning can be applied to financial applications such that a computer learns to extract the required buy and sell signals as the underlying characteristics of a stock change with time. Such signals provide an indication to an investor to buy or sell shares, which are obtained through time series analysis.

Project Objectives

The main objective of this project was to maximise profitability by analysing historical price data of a stock. It was achieved by the following steps.

- Collect historical share price data for a number of companies to perform analysis.
- Implementation of the 'point-and-figure (P&F) charting' technique as one of the oldest form of technical analysis methods to extract buy and sell signals of a company's share.
- Investigation of a computational intelligence algorithm for machine learning of buy and sell signals.
- Performance analysis of the selected method.

Project Methodologies

An extensive literature review was carried out about the implementation of the P&F charting together with the different trading strategies performed on the P&F chart. From the eight different buy and sell formations [1], the Double Top and Bottom strategy was selected as the basic trading strategy from which an indication to the investor is provided.

Moreover, a computational intelligence algorithm was required to optimise the P&F parameters as from the studies of Anderson and Faff [2], it was established that the profitability is dependent on the P&F parameters. The Particle Swarm Optimization (PSO) heuristic method was opted for after taking into consideration other methods. Its main advantage over the other methods is that the algorithm finds the global best much faster.

The collected historical share price data was then divided into two, one part as past prices and the other as future data. The past prices were used to find the optimised P&F parameters, which in turn were applied on future data so as to test if profitability will improve. Comparison with the typical P&F parameters as found in literature [1] was carried out to confirm the claim.

Results and Achievements

Profitability on future periods improved when the P&F parameters utilised to compute the chart on the same periods were optimised on past periods, as opposed to when the typical P&F parameters were used on the same future periods. However, it was found that the optimised P&F parameters on past periods do not remain the same for future periods of certain stocks. Analysing shorter periods result in inferior performance, hence medium to long term periods must be considered. A stock with high volatility results in noisier price movements but the P&F charting techniques filters out any unwanted disturbances. More complex trading strategies for P&F charting exist and it would be desirable to explore the effect of P&F parameter tuning for such complex trading strategies.

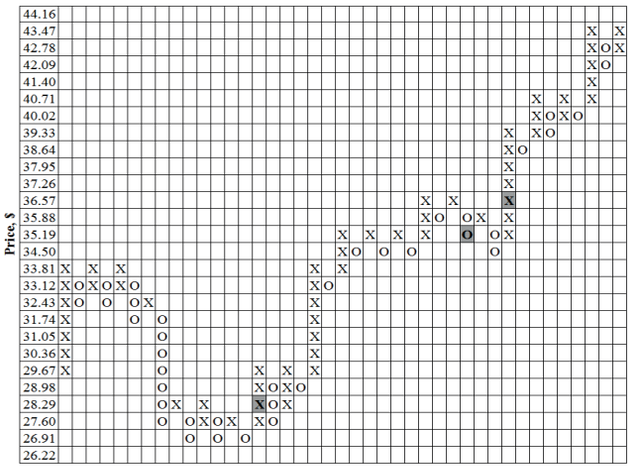

Figure 1: Optimised P&F chart of Texas Instruments Inc for years 2012 2013 using the Double Top and Bottom strategy. The bold 'X' indicates a buy signal while the bold 'O' represents a sell signal

References

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FINAL YEAR ENGINEERING PROJECTS
MECHANICAL STREAM

FACULTY OF ENGINEERING UNIVERSITY OF MALTA

Evaluation and Optimization of Automated IV Set Assembly

Student: Josmar Azzopardi / Supervisor: Prof. Ing. Michael A. Saliba

Introduction

This dissertation was compiled in conjunction with an industrial partner, Baxter Malta Ltd., with the aims of evaluating in detail an existing automated intravenous set assembly line and ultimately propose a number of improvements. Apart from an applied project that aims to improve the company's operation efficiency, from an academic perspective, this dissertation proved to be an intriguing experience due to its focus on the handling of deformable material.

Project Objectives

The study had the following objectives:

- Familiarisation with the existing production line and the scope of each assembly station.
- In-depth Analysis of the Overall Equipment Efficiency (OEE) metrics and its component metrics.
- Identification of Problem Areas and their root causes.
- Propose a number of recommendations to solve the identified issues.

Project Methodologies

Apart from several familiarisation visits on the assembly line, due to the nature of the study a literature review was done on the manipulation of deformable objects. During this stage a proper understanding of a number of methods of analysis, such as the OEE metrics and 5-Why Analysis, design methodology and methods as well as Total Productive Maintenance (TPM) pillars were required.

Through the analysis of the assembly machine's past OEE, alarms and rejects data and trends, the problem areas could be identified. Once the problem areas were identified, a root cause analysis was held. This investigation concluded that the root causes could be mainly classified as either design or maintenance issues. The rest of the project involved using the appropriate methods to come up with a number of recommendations.

Results and Achievements

The investigation into the operational efficiency, alarms and rejects accentuated the fact that the main issues surfaced either during the transfer of the coiled tube from the coiling head to the nest or its positioning during the subsequent operations.

The first set of recommendations tackled the design issues, which involved the redesign of both nest and coiling head as shown in the Figure 1 and 2 respectively. The nest was upgraded to feature better designed nylon supports to hold the coiled tube at necessary locations. An interesting feature involved the proposed change from hard end-tube grippers to interference slot static supports. On the other hand the coiling head was changed substantially; from a front arm hinging realising mechanism to a horizontal moving back arm.

The current maintenance system was reviewed and studied to see the level of TPM implementation. The prioritised recommendations included regular rejects and alarms trends analysis, development of a problem solving strategy and standardisation of adjustments and set-ups.

It was calculated that the above recommendations could have at least a potential of 55% reduction in current lost revenues of the company.

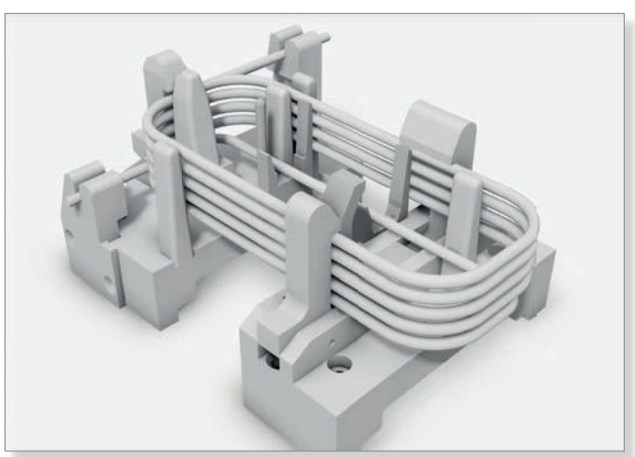

Figure 1: Rendered image of proposed nest

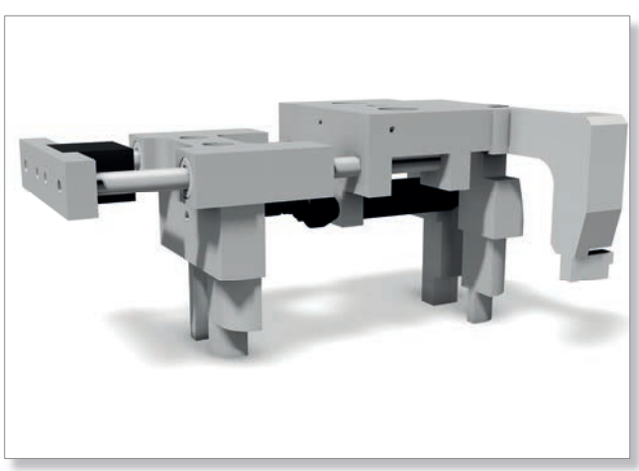

Figure 2: Rendered image of proposed coiling head

A Process Engineering Study of a Compact Production Line

Student: Clayton Bezzina / Supervisor: Dr Arif Rochman

Introduction

For the last 15 years Toly Products Ltd used a standard method for producing compacts. This method has progressed over the years but it has not changed. As the Japanese demonstrate, 'Kaizen' - change for better, must be a pillar tool to improve the process efficiently leading to a continuous competitiveness approach in the global market [1].

Project Objectives

The scope of this project was to first pick a production line which can be seen in the figure and then focus on lean manufacturing tools that are vital to analyse, point out and consequently target the weaknesses of the particular process. As a result, a clear idea where to set improvements was established and finally developments were suggested and evaluated.

Project Methodology

Basing on a lean idea, achieving efficiency in manufacturing is a process which requires dedication from the upper to the lower management. The methodology adopted is a process which keeps optimizing the machine or production line. Thus when the steps of the methodology are finished; that is the worst state that the production line is to be found.

As a guideline for this project a lean methodology was adopted and modified based on the Define, Measure, Analyse, Improve and Control procedure and as described below.

Familiarisation was the first step to start observing the process. Secondly the analysis of the system came into play which included analysing the changeover, producing a process Failure Mode and Effect Analysis, analysing the root cause of the defects and also measuring the Overall Equipment Effectiveness. In this stage the relationship between different losses and performance variables was established.

The following step was related to the identification of the inefficiencies of the automated line. Again tools such as Pareto analysis and Why Why analysis were fundamental to obtain specific targets of weaknesses. Finally a proposed solution was presented which improved the current state of the line.

Results and Achievements

The main weaknesses pointed out included the changeover process which took almost ten hours, the non-value adding activities which amounted to 85% of all activities, the defect causes and the maintenance activities.

Improvement concepts which change parts of the production line were suggested in order to tackle the above inefficiencies. Several concepts included changing the layout using a puck conveyor system, integrating a family mould, improving the sub-runner removal system and modifying the rotary table guides.

The main three concepts included: replacing all rotary tables by a single one, integrating an artificial intelligence system and improving the first rotary table.

Concurrent application of the suggested improvements at the existing production line will result in a reduction of the changeover time by half, an increase in knowledge about where to implement preventive maintenance techniques, a reduction in defects making way for better quality and a reduction in non-value adding activities.

As a conclusion the diffusion of lean manufacturing into the factory creates an overall improvement with better operational performances, increase in operator motivation, superior quality and higher efficiency.

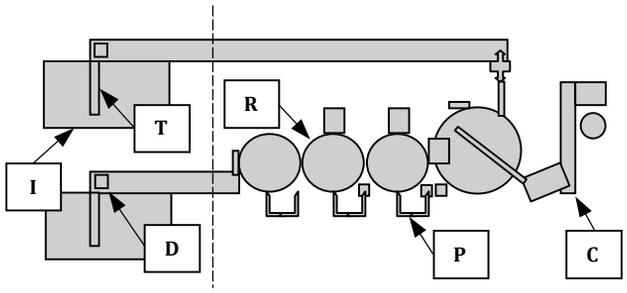

Figure 1: Cosnova production line

C - Conveyor
I – Injection mould machine
R – Rotary tables
D – Drive table
P - Pick and place robots
T – Transfer robot

References

[1] G. Alukal and A. Manos, *Lean Kaizen: A Simplified Approach to Process Improvements*. ASQ Quality Press, 2006.

Analysis of the Accuracy of Electron Beam Melting (EBM) Process

Student: Christian Camilleri / Supervisor: Dr Arif Rochman

Introduction

The EBM Arcam S12 embodies the latest state of the art technology in the Additive Manufacturing industry. Despite being relatively new on the market it is already widely recognized as very valuable for the next generation of advanced manufacturing. Its suitability for the fabrication of complex and customized products, the superior material properties combined with the relatively low lead time gives the EBM technology a significant competitive edge in the advanced manufacturing industry.

Project Objectives

This technology has also its drawbacks, namely the rough surface finish produced and its limited control on dimensional accuracy. This has led to the widespread impression that the EBM machine often produces near-net shape parts that require a post-processing treatment to obtain the required dimensions and surface finish. Within this context the purpose of this project is to evaluate the various factors affecting the accuracy of the EBM process.

Project Methodologies

The project was mainly divided into four major distinct yet interrelated phases. Through the first preliminary investigation, a screening process was carried out to determine major causes that effect the EBM accuracy process and identify areas in which further experiments are required. The relevance of altering the process parameters was clearly indicated in the second experiment which was essential to investigate the relevance of the process parameters on the defects formed and improve the part quality.

The metallographic analysis carried out in the third experiment was also crucial to analyse the metal powder morphology and also the chemical composition of the Ti-6Al-4V material at different stages. The analysis carried out in the last section was aimed to identify causes of dimensional inaccuracies and defects formed when orienting the part at different positions.

Results and Achievements

The preliminary investigation carried out in the first experiment helped to determine the causes of common defects such as swelling, surface roughness and warping at an early stage, and to identify areas in which further experiments were required to improve the process. Through the second experiment the optimum process parameter settings were identified based on an analysis of dimensional accuracy, swelling and surface roughness. The optimal process parameters obtained were used for the subsequent builds in the other experiments.

The lack of regular chemical analysis of the metal powder used for the EBM machine was highlighted through the chemical analysis carried out in the third experiment. The results showed that the accumulation of the metal flake debris does not have a significant effect on the dimensional accuracy of the EBM part. However, it is still important to remove such metal flakes to minimize variations in the composition of the metal powder.

Through the last experiment, it was demonstrated that support structures are the most effective mean to obtain high dimensional accuracy. The case study developed in the last experiment confirmed EBM's significant potential to produce highly accurate customized implants, considering the dimensional accuracy of the part combined with the outstanding material properties.

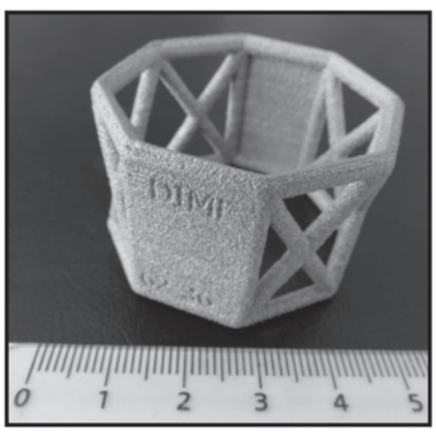

Figure 1: EBM part adopted from a customized spinal implant

Development of a Minimal Anthropomorphic Robotic Hand

Student: Donald Dalli / Supervisor: Prof. Ing. Michael A. Saliba

Introduction

The human hand is a complex organ capable of executing various dexterous tasks. From a recent study [1], it has been found that the majority of the tasks carried out by the human hand only require the use of the index finger, middle finger, and the thumb, only. Hence, by transposing this knowledge to artificial hands, a simplified yet dexterous robotic hand can be developed.

Project Objectives

The aim of this project was to design and develop a dexterous minimal anthropomorphic robotic hand. The following objectives had to be met:

- Optimization of the kinematic and mechanical design
- Development and evaluation of the built robotic

Project Methodologies

A kinematic model of the hand with only two fingers and a thumb was modelled in a simulation software (Figure 1). The model was tested for its ability to perform a series of grasps, defined in [2]. Any ineffective joints of the model were eliminated, while further optimization of the model was conducted to improve its performance.

Several design tools were used to develop a novel mechanical design for the robot hand, based on the obtained kinematic model. A glove input device, constructed out of flexible bend sensors, was integrated to the robotic hand for easier control. An evaluation of the performance of the robot hand was then conducted.

Results and Achievements

The optimized kinematic model of the hand consisted of 8 degrees of freedom. Based on the developed model, the robotic hand was fabricated using fused deposition modelling (FDM) technology. The robotic hand weighed less than 100g, making it an ideal device for robotic applications with limited payloads. Its actuation system consisted of a series of linear actuators which are used to manipulate the joints of the robotic hand.

The final construction of the robotic hand was evaluated for its ability to perform the predicted grasps from the simulation (see Figure 2). The response of the robotic hand from the glove input device was also analysed. Satisfactory results were obtained for both tests.

The robotic hand was also mounted onto a robotic arm, to better emulate the human limb. Some of the grasps were also tested whilst the robotic arm was in motion, to verify that the grasped object was securely held.

References

[1] M. A. Saliba, A. Chetcuti, and, M. J. Farrugia, "Towards the Rationalization of Anthropomorphic Robot Hand Design: Extracting Knowledge from constrained Human Manual Dexterity Testing," *International Journal of Humanoid Robotics,* vol. 10, p. 1350001, 2013.

[2] M. R. Cutkosky, "On grasp choice, grasp models, and the design of hands for manufacturing tasks," *Robotics and Automation, IEEE Transactions on,* vol. 5, pp. 269-279, 1989.

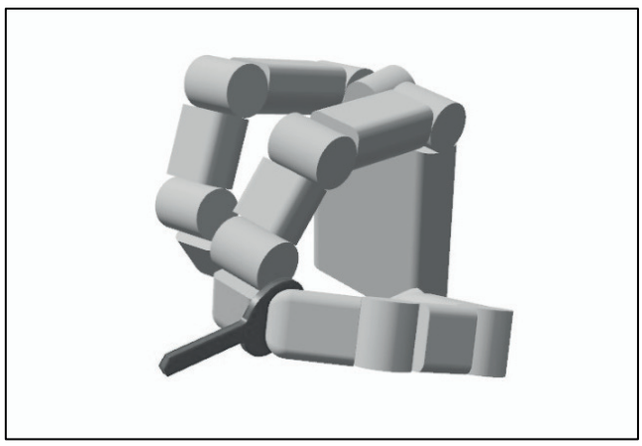

Figure 1: Simulation of kinematic model of the hand

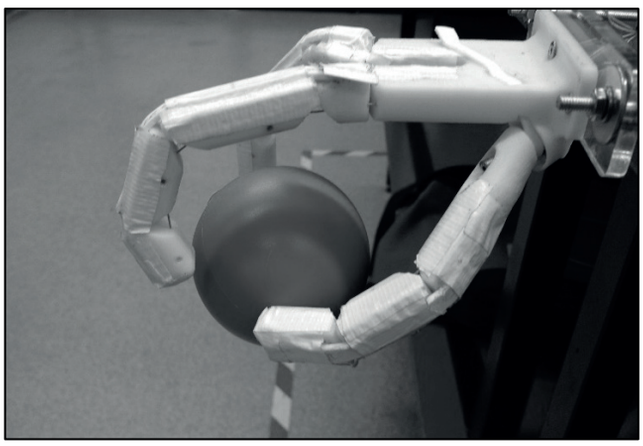

Figure 2: Robotic hand performing grasp

Development of a Fingertip Touch Sensor for a Robotic Hand

Student: Joseph Trapani / Supervisor: Prof. Ing. Michael A. Saliba

Introduction

In this work, a new approach towards the development of a fingertip sensor designed with the aim of achieving tactile acuity for robotic hands, grippers and prosthetics. The philosophy governing this research centres on the achievement of tactile performance capable of allowing for a desirable dexterity with minimal specifications.

Project Objectives

Carry out a literature review on touch sensors. Determine the detailed objectives of the prototype. Generate and evaluate various concepts for the sensor. Select the best concept. Construct and evaluate a first prototype of the touch sensor.

Project Methodologies

A sample of carefully selected candidates was run through two series of tests; a first set, to evaluate tactile acuity and its decrease with inhibition and the second, dexterity tests, similar to those used during previous research by Saliba et al. [1] albeit using the same inhibition system as in the tactile acuity tests. The results were compared and the relationship between the two was extracted for specific tactile information. The resulting data was then used to set product design specifications for a touch sensor. These were then used to produce a concept design and a proof of concept of the system was built and analysed.

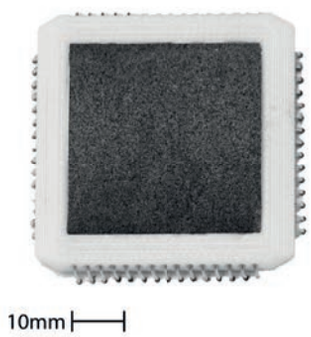

Figure 1: Photograph of sensor built to test the concept

Results and Achievements

By analysing the data achieved through the calibration and dexterity tests, results were found that positively correlate the dexterous performance of the subjects to their texture perception.
Through these tests specifications describing the sensor required were achieved.
These values were later used in the design of a fingertip touch sensor. By using a proof of concept to test the design, the abilities of the design was proved to be capable of achieving the specifications required to allow the achievement of the required dexterity.

References

[1] Michael A. Saliba, Alistaire Chetcuti, Matthew J. Farrugia. 'Towards the rationalization of anthropomorphic robot hand design: Extracting knowledge from constrained human manual dexterity testing' International Journal of Humanoid Robotics, Vol. 10, No. 02., 1350001.

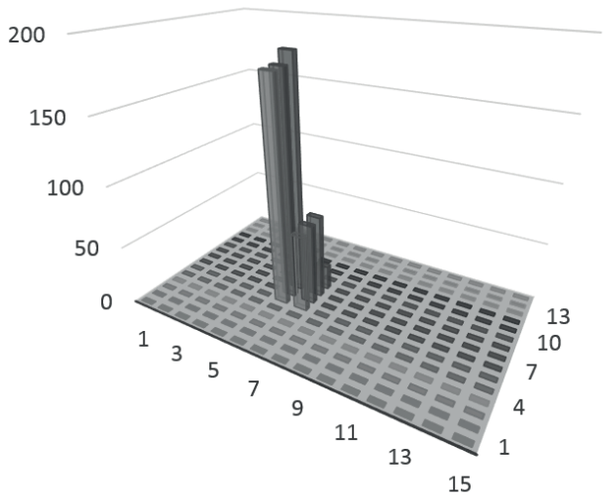

Figure 2: Graph depicting sensor results during operation

Stress-strain Analysis of a Healthy Hip Joint

Student: Maria Kristina Agius / Supervisor: Dr Ing. Zdenka Sant

Introduction

Quantifying hip joint contact stresses is paramount to improving the material and design of hip prosthesis, which are still being thoroughly researched. Unlike experimental methods, the finite element method allows for the non-invasive approximation of subject-specific hip joint contact stresses in response to the physiological load.

Project Objectives

The objectives were to develop a three-dimensional finite element model (FEM) using subject-specific geometry from computed tomography (CT) image data, including the modelling of hip ligaments and muscles, and to assess the stress-strain distribution of the healthy hip joint by simulating the response to the physiological load.

Project Methodologies

Three-dimensional models of the right femoral and pelvic bone of a young healthy male subject were obtained in STL format, based on CT data. Three-dimensional geometrical modelling of the femoral bone, articular cartilages and hip joint assembly were done in SolidWorks software. Within ANSYS the modelling stages namely discretization, application of loading, boundary conditions (BC) and constraint equations, assignment of material properties and geometrical modelling of the muscles and ligaments, were carried out. The applied finite element loading and boundary conditions simulated the physiological loading on a healthy hip joint, while standing stationary on two legs.

Results and Achievements

The initial displacement driven solution verified that the developed hip joint model appropriately simulated the physiological state of a healthy hip joint and also established the proper functioning of the contact analysis applied at the contacting cartilaginous surfaces.

The load driven solution predicted peak hip contact stresses on the femoral cartilage of 1.13 MPa in good qualitative correspondence to other literature results. The contact area on the femoral cartilage and acetabular cartilage was in the supero-anterior region, in close agreement with previous studies.

The stress-strain distribution within the femoral bone showed that bending and compressive stresses developed in response to the physiological loading. The pelvic bone also experienced bending stresses as a result of the applied fixed boundary conditions.

The developed hip joint FEM is thought to be a better representation of the in vivo environment due to the inclusion of muscles and ligaments. This pilot study has successfully provided proof-of-concept results regarding the feasibility of evaluating the biomechanics of a subject-specific healthy hip using FEM.

The developed hip joint FEM may be used, in future studies, for the prediction of hip contact mechanics in response to several physiological loads while acting as a basis for future comparison with hip prosthesis or pathological hip FEMs.

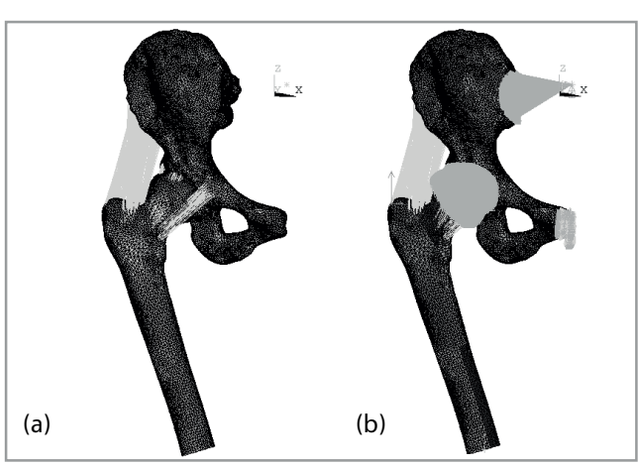

Figure 1: Hip joint FEM (a) without and (b) with loads and BCs

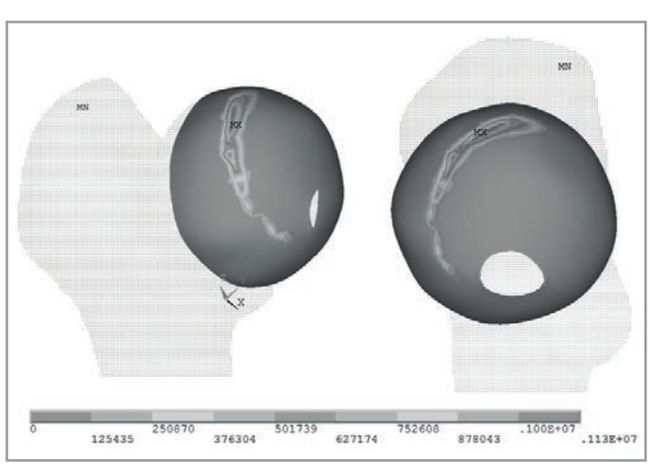

Figure 2: Contact stress (Pa) on the femoral cartilage

The Validation of the Thermal Model of a Tooth during High Temperature Root Canal Irrigation

Student: Analise Bartolo / Supervisor: Dr Ing. Christopher Micallef / Co-Supervisor: Prof. Josette Camilleri Barbara

Introduction

Root canal treatment is required when the dental pulp loses vitality. To treat and remove the microorganisms present in the root canal, an irrigant (sodium hypochlorite) is required. This dissertation forms part of a study that analyses the use of high temperature root canal irrigation for the elimination of microorganisms from the system.

Project Objectives

This dissertation involved the investigation of the behavior of the tooth at high temperatures under experimental conditions. Validation of the thermal model of a tooth was carried out by comparing the results with the experimental data.

Project Methodologies

Several experiments with different methodologies were carried out on various types of teeth until repeatability was attained. The same trend in temperature, from the highest to the lowest was fundamental to be maintained in all the six tests performed: the highest temperature must be recorded in the crown, followed by the cementum-enamel junction, mid-root and apex respectively.

ANSYS® Workbench was used to develop a finite element model of a canine tooth such that the behaviour of the tooth at various temperatures under steady state and transient thermal conditions could be analysed. All the results obtained were validated with the experimental results. The main differences between the simulation results and the experimental results were calculated and analysed. A sensitivity analysis of the thermophysical properties was performed. Such simulations were fundamental to ensure that the assumptions taken in the model were correct.

As the FEA model was verified and validated, further analysis was carried out. The properties of steam were assigned to the root canal and the surrounding temperature was set to 37°C (body temperature).

Results and Achievements

As the experimental setup was further modified, the final experimental methodology developed involved the use of a heat source placed inside the root canal system (Figure 1). This methodology proved to be successful as repeatable results were attained. Furthermore, as the results of simulations were analysed, it showed that the percentage error between model and experiment was minimum. Thus, this percentage error was attributed to a series of non-idealities presents in the system. In addition, it was also concluded that the simulations run were successful. This was highlighted in the sensitivity analysis results.

As further analysis were carried out the data obtained was clinically relevant. Temperatures in the root canal region are sufficient to kill the most persistent bacteria, *E. Faecalis* [1]. Temperatures generated in the root canal did not cause rises in temperature on the external surface of the root.

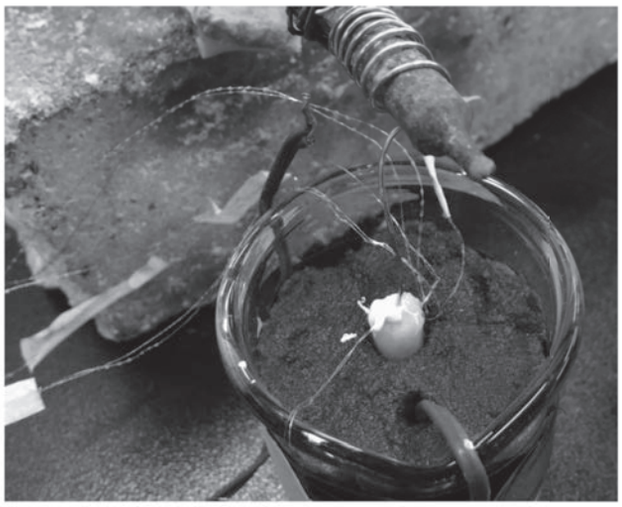

Figure 1: Final Experimental Methodology - Heat source placed inside the root canal

References

[1] Stuart et. al, 'Enterococcus faecalis: Its role in Root Canal Treatment failure and Current Concepts in Retreatment' Journal of Endodontics, 2006, Vol. 32, No. 2, pp.93-98

Construction & Analysis of a Wind Tunnel Enclosure

Student: Joseph A. Borg / Supervisor: Dr Ing. Christopher Micallef

Introduction

Following the installation of an air-conditioning system inside the Fluids laboratory in the Mechanical labs, a proposal was put forward to partition the room in order to reduce the load on the air-conditioners. It was of general concern that the partition would have detrimental effects on the flow quality inside the low-speed, open-circuit wind tunnel.

Project Objectives

A study was therefore set up, where through the use of thermal anemometry, the flow characteristics at the test section of the wind tunnel, both before and after installation of the partition, would be tested.

Project Methodologies

The equipment setup consisted of a Hot-Wire Anemometry system (HWA), a Pitot-static tube and a digital data acquisition system. After proper calibration of this equipment was carried out, a number of flow-quality tests were conducted at the test section of the wind tunnel. These tests involved the discrete sampling of the HWA voltage within five second intervals at different tunnel speeds. Then, using these measurements, the velocity profiles and turbulence intensities were found.
A wall was then constructed 3.9m away from the wind tunnel's intake (Figure 1) to simulate the partition that was to be installed.

Figure 1: Wall and Tunnel setup

The flow quality measurements were repeated once more with the wall in place so as to assess the effect it had, if any. Furthermore, a set of signal analyses were conducted before and after installing a noise filter on the wind tunnel fan frequency controller. This was done in order to attempt to reduce the noise that was being generated by the a/c controller.

Results and Achievements

From calibration, it was immediately evident that the voltage readings taken without the wall contained a significant periodic component. The presence of the wall seemed to diminish these periodic components.
Upon further analysis of the results, it was found that the velocity profile across the test section was more uniform with the wall in place rather than without it.
Another aspect that was found from the measurements taken was that the tunnel had quite a significant turbulence intensity (TI) (around 5 percent). The wall seemed to improve the flow quality, in that the overall turbulence intensities were lower when compared to the control (Figure 2).

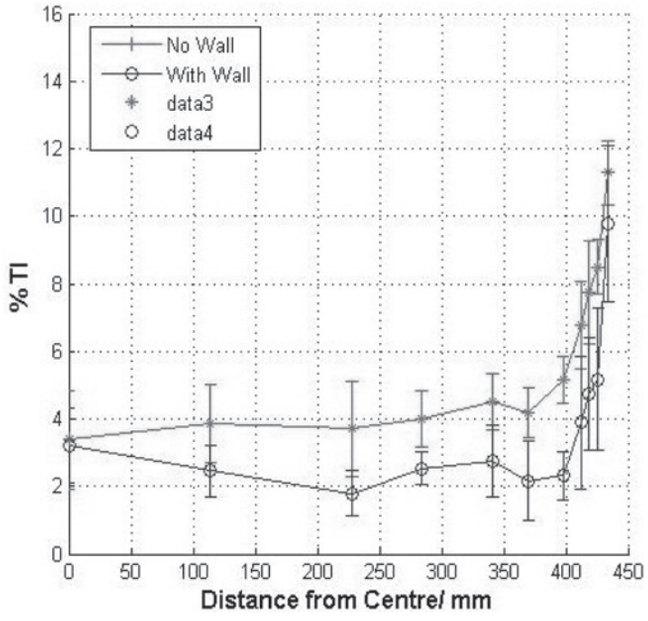

Figure 2: TI profiles at a wind speed of 4m/s

From signal analysis, it was seen that the fan controller was creating significant noise at a frequency of 8kHz. An electrical signal filter was purchased with the intention of reducing this specific frequency, however it did not have the desired effect. The filter reduced the random noise that existed in the signal, but had no observable effect on the 8kHz peaks.

Development and Testing of a small Hoist and Frame

Student: Carl Borg / Supervisor: Prof. Ing. Martin Muscat

Introduction

Nowadays, gas cylinders are used continuously by almost everyone in Malta. A problem encountered is that some households in Malta are not equipped with a passenger or any other kind of lift. As a consequence, the gas cylinder has to be carried up the stairs by the owner of the household or by the delivery person.

Project Objectives

The aim of the dissertation is to develop a small hoist and frame that is intended for lifting a household size gas cylinder (full of gas) and 10 litre buckets of soil onto the roof. The system designed is required to be in such a way that the frame and hoist are easy to assemble and disassemble by only one person working alone.

Project Methodologies

The design of the hoist and frame follows existing standards on hoists and frames which are all related to the machinery directive of the European Union [1].

Load case combinations acting on the hoist and frame including partial safety factors were established [2]. The Finite Element Analysis (FEA) software ANSYS 14.0 was used to perform stress and deflection analysis on the frame and hoist. The necessary serviceability limit states were considered in order to have a structure which is capable of fulfilling its intended function and sustaining the specified loads for its intended life [3].

Figure 1: CAD Model of the Crane Structure

Results and Achievements

The aims of this project were achieved. The equipment was designed to be as lightweight as possible, while at the same time the size of the frame is such that it is easy for storage when not in use. All improvements highlighted from last year's project were achieved. A CAD model was created using Autodesk Inventor 2012. The frame hoist structure was fabricated using various manufacturing processes.

Testing was also carried out on the new designed structure. This was done to check on the deflection allowables and whether these were actually met. Theoretical values obtained from FEA were compared to experimental ones for verification of data. There was a slight variation between the values due to any movement of the crane's base and also due to any movement of the deflection gauges.

References

Journal:

[1] EU Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC

[2] Crane safety. General Design – Part 2: Load actions. MSA EN 13001-2:2011

[3] Structural use of steelwork in building. Part 1: Code of practice for design – Rolled and welded sections. BS 5950-1: 2000

Figure 2: Assembled Crane Structure

Stress Analysis of a Wind Turbine Nacelle

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

Introduction

The Chicago windmills are wind-powered pumps that have been used to aid field irrigation in Malta over the decades. In 2007 the University of Malta started work on developing a new wind turbine prototype with the main aim of one day replacing the old abandoned windmills with new wind turbines to generate electricity [1].

Project Objectives

The main objectives were to analyse the extreme load cases to which the new wind turbine is subjected, and to assess the structural integrity of the existing nacelle through computational stress analyses conducted by Finite Element Analysis (FEA) software, using 'Shell' and 'Beam' elements.

Project Methodologies

All the load cases were calculated, as specified by the design requirements for small wind turbines EN61400-2:2006 [2], using a simplified load model. Other static loads affecting the nacelle structure were also evaluated. These mainly included those loads produced by the weight of the nacelle and its components, such as the rotor and the tail boom.

The model of the nacelle was created in finite element analysis (FEA) software, namely ANSYS, using 'beam' and 'shell' element types. The worst load cases were determined and applied to the finite element model, along with the other external forces acting on the nacelle.

After applying the necessary safety factors as required by the standard for small wind turbines [2], the ultimate allowable design strength of the nacelle's material was calculated. Then, stress analyses were conducted to assess the structural integrity of the nacelle, considering the load cases that have the most impact on the model. The results were compared to those obtained from A. Zammit's dissertation [3], in which the analyses were carried out on a finite element model using 'solid' elements.

Results and Achievements

The worst load cases endured by the nacelle structure were found to be when the rotor is parked under extreme wind conditions, and during yawing of the wind turbine. The first load case produces the highest thrust force, which creates high bending moments at the yaw shaft. The latter produces the maximum gyroscopic moments, which was found to create stresses at the base plate of the nacelle, exceeding the maximum allowable stress.

It was also concluded that using 'beam' and 'shell' elements is a more suitable approach when modelling the nacelle, since with such method only the structural membrane stresses and bending moments are considered, avoiding the generation of unrealistic peak concentration stresses.

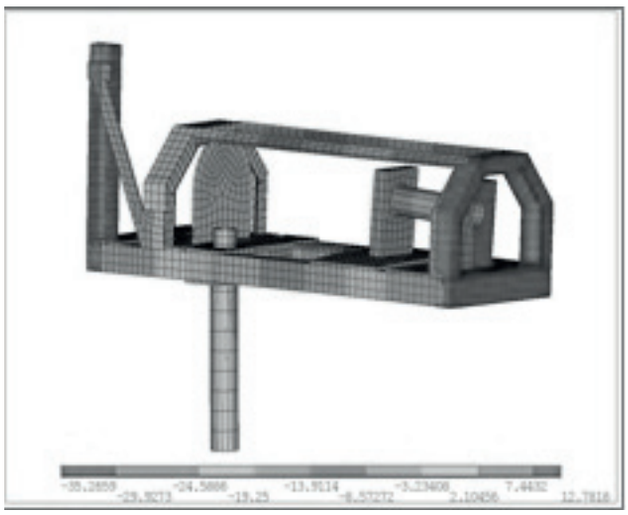

Figure 1: Contour plot of displacement of the nacelle structure

References

[1]: Muscat M., Sant T., Caruana C.,Farrugia R.N., *Part A: Field work to establish the general condition of a sample of existing Chicago type wind pumps*, University of Malta, Malta, 2008.

[2]: International Electrotechnical Commission, *EN61400-2:2006 Wind Turbines Part 2: Design requirements for small wind turbines*.

[3]: Zammit A., *Stress Analysis of a Wind Turbine Nacelle*, B.Eng Dissertation, University of Malta, Malta, 2013.

Reducing Carbon Dioxide Emissions in the Wine Industry

Student: Liana Buhagiar / Supervisor: Prof. Ing. Robert Ghirlando

Introduction

It is a known fact that if no actions are taken to minimise the carbon dioxide emission, our climate will be irreversibly damaged. Although wine industry's contribution to climate change is almost insignificant, it is still contributing towards carbon dioxide emissions. Hence methods to reduce carbon dioxide emissions released by the wine industry were discussed and analysed.

Project Objectives

This project aims at fixing and calculating the carbon dioxide that is released from the fermentation process and to identify the amount of waste that is generated from wineries and vineyards, whilst determining the energy equivalence of all types of winery waste.

Project Methodologies

The amount of carbon dioxide released from fermentation tanks and the total waste generated from the wine industry were calculated from the information gathered by the Permanent Crops Unit within the Agricultural Directorate in Għammieri.

Furthermore, samples of the winery waste were collected to measure their calorific value using a bomb calorimeter. However the equipment's thermal capacitance was initially determined from a standard sample of benzoic acid.

After calibration of the equipment, the winery waste which includes; wine lees, non-fermented and fermented pomace, grape stalks and trimming vine shoots/prunings were cut into very thin pieces to ensure complete combustion.

Two samples of wine lees, non-fermented and fermented pomace and grape stalks were heated at two different temperatures to analyse whether waste content makes a difference in the calorific value of the biomass. Thus, one sample was heated above 100°C whereas another sample was heated up to 40°C. Moreover, three types of trimming vine shoots were randomly picked up from ten different pruning. These samples were heated above 100°C to remove any water content.

Results and Achievements

The largest Maltese wine company released 140,796.2kg of carbon dioxide from 1,152,650 litres of wine during its fermentation process in 2013. Moreover, the total biomass generated from the wine industry adds up to 566,098 tonnes of winery waste. Furthermore, the calorific value of this winery waste ranges from 8.75MJ/kg to 20.07MJ/kg. The least value was noted in the sample of wine lees which was heated up to 40°C whilst the highest calorific value was noted from fermented pomace which was also heated up to 40°C. Other calorific values can be noted in the image shown below.

The amount of carbon dioxide emitted during fermentation suggests that wineries can be self-sustainable. As regards to biomass, the amount of biomass produced over such a small period indicates that wineries should collect and valorise this waste instead of disposing it in landfills due to the diverse nutrients that may be extracted from this waste. In addition, although the calorific value of winery waste is not as high as that of conventional fuels, it may still be used to release energy. However this waste will have to be prepared beforehand to eliminate any water content.

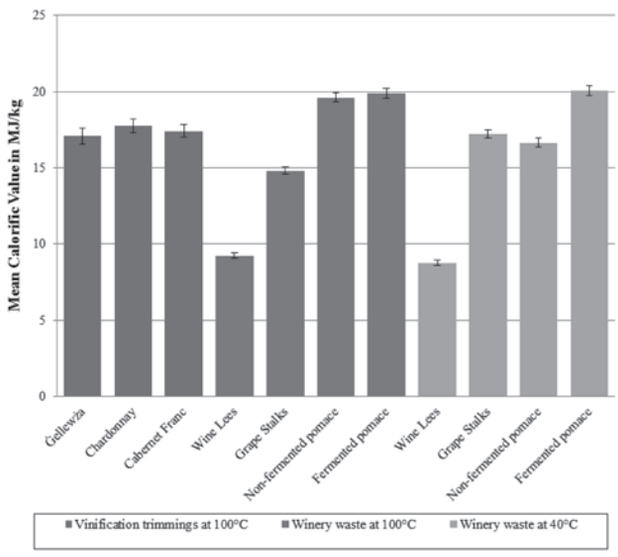

Figure 1: Graph of calorific value in MJ/kg against eleven types of winery waste samples

Further Improvements to the Water Injection in a SI Engine Setup

Student: Daniel Busuttil / Supervisor: Dr Ing. Mario Farrugia

Introduction

Water injection to the intake charge dates back to the 1930s to suppress knock in engines during high power outputs. Manufacturers opted for compression ratio reduction of the engine, compromising the thermal efficiency. Water injection allowed cooler intakes, suppressing knock, and allowed the use of superchargers as well. Water injection was very effective when fuels had a very low octane number, which greatly increases the probability of knock. Modern engines have a higher compression ratio due to the refined fuels.

Project Objectives

1. Achieve spark timing from the ECU
2. Supercharge the engine
3. Water injection variable control
4. Valvetrain simulation using VALDYN®

Project Methodologies

Water injection needed to be investigated while varying spark advance to capture the Maximum Brake Torque (MBT). This necessary made the conversion from the magneto to spark generation from the ECU using an ignition coil. The ignition coil was energised by the ECU by switching it on for 8 *ms* before the spark is required. MBT without water injection was found to be at a different spark advance than with water injection.

The engine was supercharged by means of compressed air supply. The intake pressure was regulated by hysteresis control. This was achieved by LabVIEW®. The controller output from LabVIEW® is LOW or HIGH. An electronic driver was built so as to power a solenoid valve according to the controller output. This process repeats to keep pressure as desired at the intake of the engine.

Water injection was achieved by tapping the fuel injector signal and designing a circuit to inject water at the instant the petrol injector is opened. A 555 Timer was used to vary the duration of injection. A dual potentiometer was used for the 555 Timer circuit and also to pass a signal to the Electronic Control Unit (ECU) of the engine to log data of the duration of injection. Fuel injection duration was tuned against a Lambda sensor. The setup is shown in Figure 1.

Valvetrain simulation of the engine was carried out using Ricardo Valdyn®. The program allowed for the kinematic and dynamic analysis of the engine's valvetrain. A cam profile was determined using MATLAB® as illustrated in Figure 2.

Results and Achievements

Maximum obtained torque improvement with water injection was 16%. The latter was achieved at a manifold absolute pressure of 120 kPa, with air temperature at ambient. With the same load condition with air heated as if isentropically compressed, a torque improvement of 7% was noted.

Optimum water injection quantities were found to be about 0.015 *ml* to 0.031 *ml* of water per cycle. These correspond to about 0.22 to 0.44 water to fuel by volume.

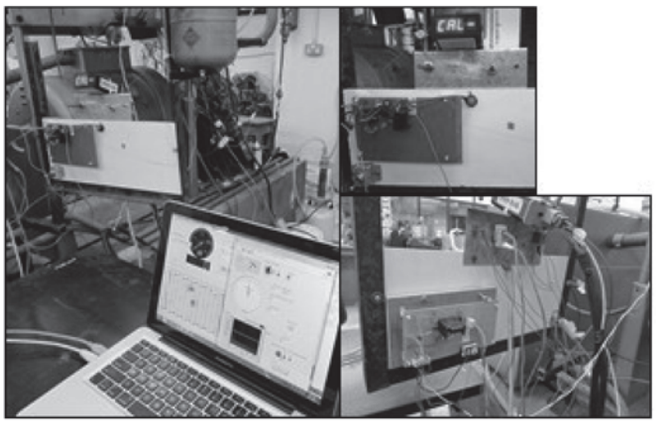

Figure 1: Experimental Setup

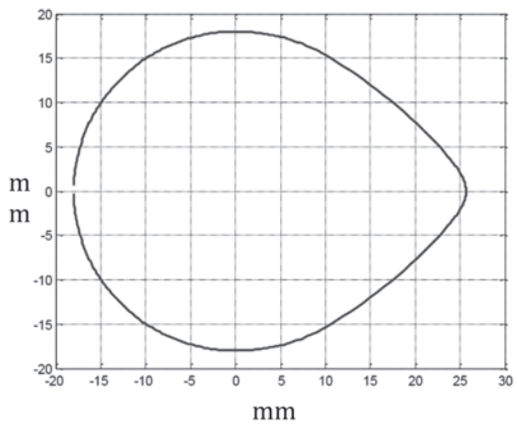

Figure 2: Cam Lobe Profile in Cartesian Coordinates

Modelling of the Intervertebral Disc

Student: Lara Buttigieg / Supervisor: Dr Ing. Zdenka Sant

Introduction

Finite element modelling is an essential tool in biomechanics used to study the response of biological structures to the load. The accuracy of a finite element model of a Functional Spinal Unit (FSU) is highly dependent upon the model of the intervertebral disc which determines the load transfer from one vertebra to another.

Project Objectives

The aim of this project was to modify an intervertebral disc within a finite element model of a functional spinal unit between the L3 and L4, and study the effects of material, geometric and element properties within the model.

Project Methodologies

A model of the SFU was derived from the work by Cauchi [1]. The intervertebral disc of this model was modified, to create three new different models of the structure. These models were replaced into the original FSU and the system response to the same loading condition for each model was analyzed and compared. The first modification imposed on the first new model was a decrease in the Young's Modulus of the Nucleus within the disc. In a second model, the number of lamellae within the annulus was increased from three to twelve. In the final model the solid element type used originally was replaced with a Hydrostatic Fluid element type.

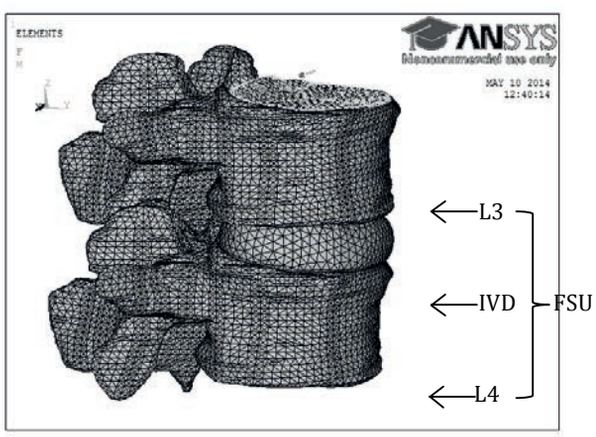

Figure 1: Meshed Functional Spinal Unit in ANSYS

Results and Achievements

The original model of the IVD poses a stress concentration on the nucleus within the disc, therefore transferring all stresses towards the center of the vertebrae. In reality this would pose excess stresses within the weakest part of the bones. The second model contained stress concentrations between the second and third lamellae in the annulus of the disc due to an abrupt change in material properties. This poses excess stresses within the disc. In the third model stresses are better distributed within the bone and disc, yet still the IVD lamellae bare a lot of the load, experiencing relatively large loads. In the final model, loads are better transferred to the outer parts of the lower vertebra and less stresses are borne by the IVD lamellae. Therefore the results of the final model seems to be most realistic of all results.
Further studies should analyze the use of shell and beam elements for the intervertebral lamellae, and the difference between different shell and solid element types for the cortical and cancellous vertebral bones

References

[1] Cauchi M., 'Comparitive Analysis of the Stress-Strain Distribution for the Healthy and Pathological Spinal Segment': B.Eng Dissertation, University of Malta, Department of Mechanical Engineering, 2010.

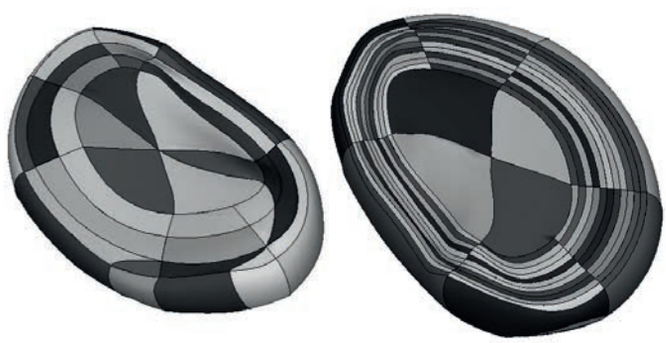

Figure 2: Original (left) and new (right) geometric models of the IVD within ANSYS

Analysis of Injection Die Cooling

Student: Andre Caruana / Supervisor: Dr Ing. Christopher Micallef / Co-Supervisor: Dr Arif Rochman

Introduction

Humanity's most defining characteristic is the instinct to improve and advance. Industry continues to grow through whatever means possible. One such achievement was the advent of mass production, a precondition for the high quality of life enjoyed by many industrialized countries. Injection molding is an operation that is absolutely essential in this context, and its improvement is one such example of this trait. This project centers around a case study

Project Objectives

Injection molding can be improved in terms of part quality and cost, reflected in the temperature gradients and cooling time respectively two antagonistic objectives. The objective was therefore to enhance both, with an emphasis on cooling time.

Project Methodologies

Computational Fluid Dynamics (CFD) would be utilized to model the problem a case study, plastic horse; taking certain assumptions to enable efficient computation.CFD is a software that models fluid flow and heat transfer through modeled geometry as required, by discretizing space and time and then solving iteratively. The adopted methodology was to test a selection of design variables within set constraints: a sensitivity analysis. The selected variables were the fluid inlet velocity, the cavity size, configuration of the fins and the flow direction. The mold thickness was also investigated mechanically. The cooling time for the different design points was investigated to obtain optimal cooling trends.

Results and Achievements

The final data, despite efforts to ensure its mesh independence, was invalidated, simply because of modelling errors. Basically, the time factor could not be relied upon because of inadequate meshing. The hydrodynamic effects within the mold, and the cooling effects on the part are, however reasonably accurate. Below, a volume rendering of the part at t=0 shows uniform cooling of the injected ABS, minimizing the surface temperature gradients and hence improving part quality. From the below figures, it can be extrapolated that decreasing the mold depth will provide generally better cooling in the body whilst retarding the cooling in the legs, again reducing temperature gradients within the part. The degree to which remains undefined, however, setting the stage for future work to be done.
Several, more appropriate analyses have since been performed, proving that cooling times can fall to a fraction of the original channel cooled model, with the appropriate optimizations. The main achievement has therefore been a simple confirmation of the method, requiring more resources to solve reliably.

References

[1] Choi, J.H; Choi S.H; Park, D; Rhee, B; Choi, D, 'Design Optimization of an Injection Mold for Minimizing Temperature Deviation' International Journal for Automotive Technology, 2012, Vol. 13, No. 2, pp.[273-277]

[2] Agazzi, A; Sobotka, V; Le Goff, R; Garcia, D; Jarmy, Y, 'A methodology for the design of effective cooling systems in injection molds' International Journal or Material Forming, 2010, Vol. 3, No. 1, pp.[13-16]

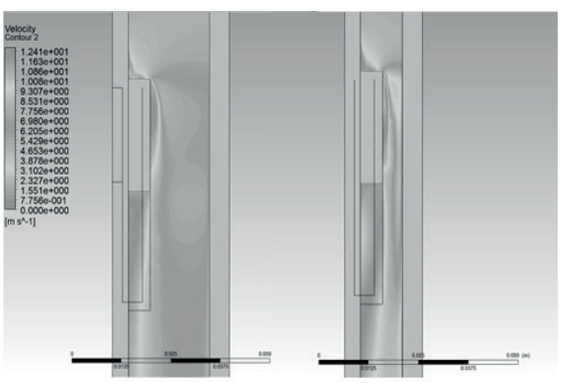

Figure 1: Velocity contours for different fluid depths

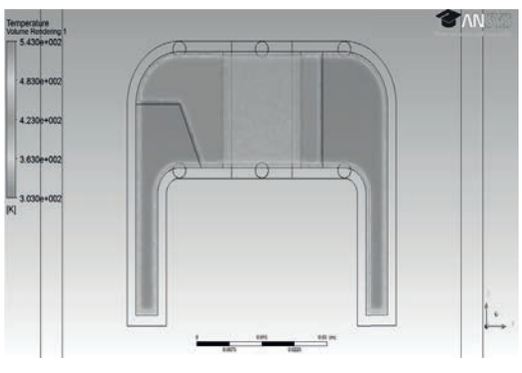

Figure 2: Volume rendering of the cooling part

Assessing the use of Biofuels in Compression-Ignition Engines

Student: Ryan Cauchi / Supervisor: Prof. Ing. Robert Ghirlando

Introduction

The introduction of sustainable fuels into regular fossils fuels has been developing since changes in the global climate became of a concern. Two of the most popular sustainable fuels are biodiesels and ethanol which are extracted from renewable resources which are bio-based. Their chemical compositions are found to aid in the reduction of certain emission levels, especially the Hydrocarbons and Particulate Matter.

Project Objectives

The main objective of this project was to investigate the effects that sustainable fuels impose on diesel when blended together. These were covered by analysing the miscibility characteristics of several fuel blends, which were then tested on a CI engine to analyse the performance and exhaust effects.

Project Methodologies

To fulfil the purposes of this project, three main sets of tests were carried out namely: miscibility tests, engine performance tests, and engine emissions tests.

Miscibility tests were carried out through observation of the fuel blends which were formulated in test tubes by syringing all the constituents to form the required blend ratios. Then, observational procedures were carried out with respect to phase separation occurrences, "clouding" of the sample, and long term stability. Figure 1 shows the test apparatus for the miscibility tests.

Engine tests were performed to analyse both performance and exhaust characteristics of several fuel blends composed of diesel-biodiesel, biodiesel-ethanol, and diesel-biodiesel-ethanol. The main parameters required for the performance investigation included the specific fuel consumption, and the air-to-fuel ratio and these were tested for a range of brake power outputs. Carbon Dioxide and Hydrocarbon emissions were analysed by the use of a Plint Re200 exhaust analyser which was connected to the engine's exhaust system and synchronised to a computer software capable of logging all the data being inputted in the analyser. Figure 2 shows the engine's test stand, as set up for this project.

Results and Achievements

From the miscibility tests, it was concluded that although ethanol blends easily with biodiesel, its miscibility with diesel is narrowly permissible and limited solubility can only be achieved with the aid of biodiesel which acts as a bridging agent.

From the engine tests, biodiesel and especially ethanol increased the overall specific fuel consumption substantially over diesel fuel. The presence of both alternative fuels decreased the total Hydrocarbons emitted as exhaust, but only biodiesel was capable of reducing CO_2 since ethanol outputted CO_2 levels which were similar to those of diesel.

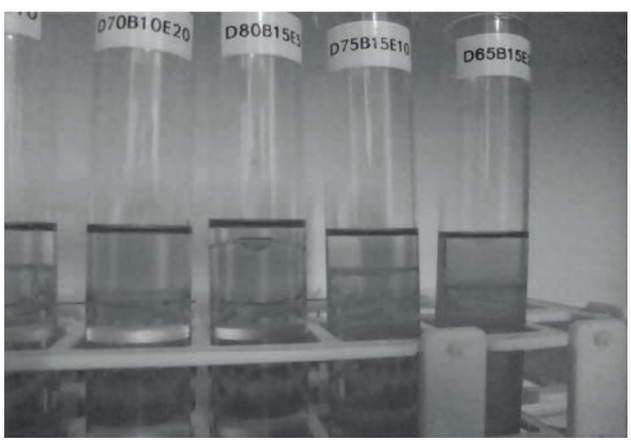

Figure 1: Miscibility Test Apparatus

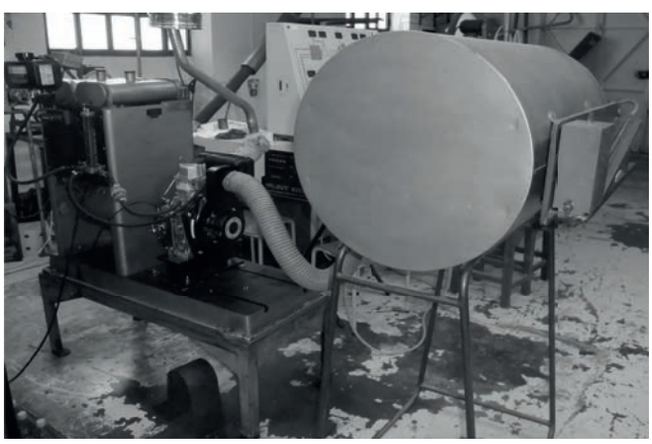

Figure 2: Engine's Test Stand

Design of a Waste-Water Treatment Plant for the Winery Industry

Student: Mark Cilia / Supervisor: Prof. Ing. Robert Ghirlando

Introduction

Winery wastewater treatment is a new concept in Malta. This wastewater is presently being discharged into the public sewer with concomitant loading on sewage treatment plants. Treatment at source would reduce such loading and provide usable water. This thesis was intended to design a winery treatment plant, taking into consideration the quality of the influent (wastewater) and of the effluent (usable water).

Project Objectives

- A review of the winery wastewater characteristics
- A review of what would be the best options to use the wastewater discharge after treatment
- A review of the parameters that the effluent has to reach in order that it may be used.
- Literature review on wastewater treatment technologies that may be applied to winery wastewater
- Design of a waste water treatment plant based upon reasoned justification and evaluation of the best treatment options.

Project Methodologies

In view of the fact that no samples of winery wastewater or at least data on the characteristics of it were available, extensive research was carried out to put together a coherent and reliable profile of this wastewater, for use as a departing point for analysis and design. The volume of wastewater produced was based on a winery of similar size to the ones in Malta.

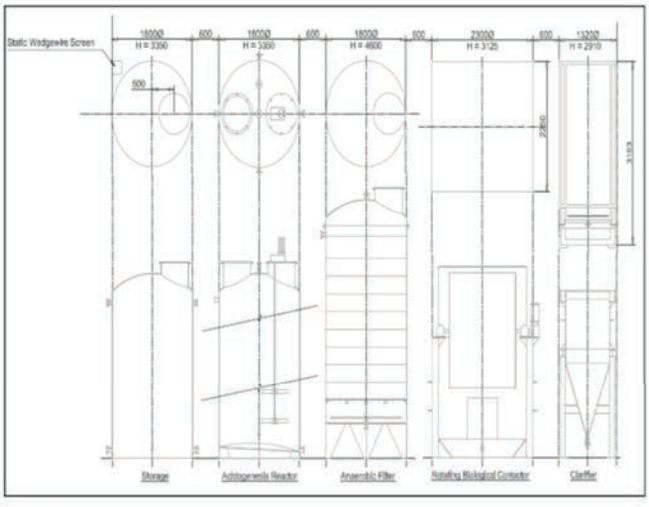

Figure 1: Schematic Diagram of Plant Components

The characteristics of the treated effluent was put together based on guidelines by Van Schoor [1].

The next phase of the research was the extensive evaluation and identification of preliminary (screen), primary (Aerobic, Anaerobic and Ponds/Lagoons) and secondary treatment systems with the potential for application to the case at hand. Consideration of each system's various advantages and disadvantages led to the selection of the process and components that were to be used in the design.

Results and Achievements

The implemented design was made from a number of components starting with a static wedgewire screen feeding into operational storage. Then the primary treatment was composed of an acidogenesis reactor, followed by an Anaerobic Filter (both anaerobic process) and then into a Rotating Biological Contactor (aerobic process). The secondary and final component was made up of a Lamella Clarifier. A schematic diagram showing the components in sequence is illustrated in Figure 1. Detail design of each component was carried out based upon influent and effluent requirements, retention times, sizing, operational parameters, efficiency and economic considerations.

References

[1] Van Schoor, L.H., Guidelines for the Management of Wastewater and Solid Waste at Existing Wineries, Winetech, South Africa, 2005.

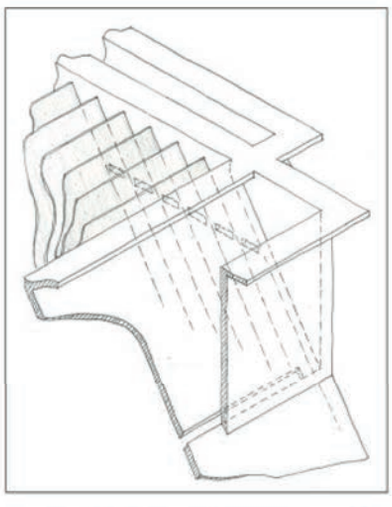

Figure 2: Schematic Diagram of Inflow of Lamella Clarifier

Continuation to Catalytic Converter use in SI engines

Student: Anton Darmanin / Supervisor: Dr Ing. Mario Farrugia

Introduction

Catalytic converter technologies are nowadays widely used to reduce vehicle emission gases that are harmful to the environment. The most popular type, the three way catalytic converter is typically employed used on spark ignition engines and it treats the three main exhaust gases: hydrocarbons, carbon monoxide and nitrogen oxides. Although built to last for a very long time these devices can rapidly degrade when exposed to certain inappropriate operating conditions.

Project Objectives

The main aim of this dissertation was to better understand the operation of catalytic convertors under common typical operating conditions, when implemented on spark ignition (SI) engines. Additionally, the objectives of this dissertation were to:

1) Test how a second hand catalytic convertor performance can be improved by using two different conversion efficiency-enhancing techniques.
2) Buy and test a new catalytic convertor under certain given operating conditions, i.e. various engine speeds and loading parameters and note what conversion efficiencies are attained.
3) Install and test a catalytic convertor on a Liquefied Petroleum Gas (LPG) running vehicle that did not have a catalytic converter and analyse the tailpipe exhaust gases.

Project Methodologies

During all engine dynamometer testing, the air to fuel ratio (AFR) was manipulated so as to oscillate in rich to lean cycles and vice versa at varying frequencies around stoichiometry. The second hand catalytic convertor was tested at analogous operating conditions while it was exposed to different efficiency-enhancing practices. Flow tests were aimed at determining the catalytic converter flow restriction. The new catalytic converter was tested at various rpm ranges, loading parameters and AFR windows to observe any significant trends where the catalytic converter attained optimum conversion efficiency results. LPG vehicle tests were performed around the University campus ring road while the tailpipe exhaust gases were analysed for hydrocarbon and carbon monoxide contents. For both catalytic converters during every single test temperature readings upstream and downstream of the catalytic converter were also recorded and noted.

Results and Observations

From tests on the second hand catalytic converter it was shown that a catalytic converter that attains an overall conversion efficiency less than 75% or is clogged is not worth trying to 'repair' and has to be replaced.

While from the tests on the new catalytic converter it was observed that a wide (97 to 103%) AFR window allows a catalytic converter to obtain better optimum conversion efficiency characteristics. The range of AFR fluctuation frequencies were optimum conversion efficiency was obtained was between 1.5 to 1.7 Hz.

LPG vehicle testing showed that although the catalytic converter is the main feature of emissions treatment, it is ineffective if the operating conditions are not properly adjusted. That is the ECU has to be set so that during operation the AFR ratio oscillates around stoichiometric point at the optimum frequency range.

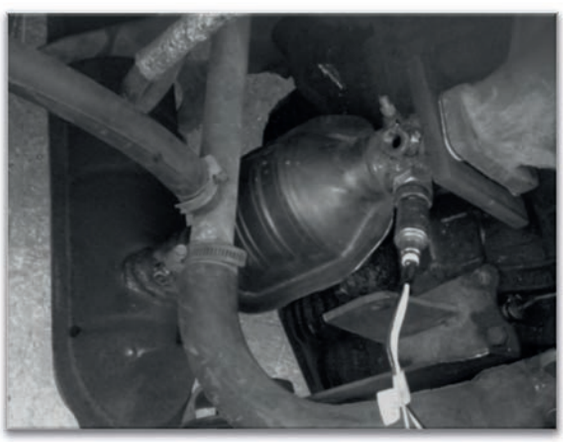

Figure 1: Catalytic converter installation on test vehicle

Experimental and Numerical Investigation of Composite Pipe Elbows

Student: Leonard Diacono / Supervisor: Prof. Ing. Duncan Camillieri

Introduction

Composite materials are increasingly being used in aerospace, automotive, marine and civil industries. For example, composite piping system are currently being used in the civil and, oil and gas industries. Composites are relatively modern type of materials and the structural behaviour, knowledge and understanding is relatively, limited. In this study GFRP Pipe Elbows will be studied and analysed.

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Project Objectives

The aim of this study is to investigate current fabrication method used to fabricate pipe elbows with the overall scope of identifying a structurally efficient and cost effective elbow. The study follows two strands - an experimental testing regime and an analytical and numerical modelling analysis, where pipe elbows are subject to internal pressure and combined pressure and bending loads.

Project Methodologies

The GFRP Pipe Elbows were fabricated by *Silvercraft Products Ltd* via a hand lay up process. Owing to the variability in hand lay-up a consistent fabrication method, for the GFRP Pipe Elbow was developed and used to ensure all tested specimens follow similar material composition.

A text rig (fig 1) consisting of a series of fixture, hydraulic circuits and data acquisition was designed to subject pipe elbows to different loading conditions and at the same time record various parameters. A system of hydraulic circuits was designed and ensured full control on pressurizing and bending the pipe at preferred loading configuration.

Various data acquisition was implemented including; an accelerometer to identify first ply and progressive failure, strain gauges to monitor strain development at various strategic positions, and pressure sensors to establish internal pressure and bending loads. Furthermore the change in circumferential deformation, at various positions, was recorded through a series of potentiometers and LVDT's.

The pipe elbows were also numerically modelled through the FEA software ANSYS 14.0 and analytically analysed via a coded Mathlab program to predict the first ply failure loads following the Tsai-Wu failure criterion. The results were also compared to the experimental tests.

Results and Achievements

This project was limited to four test configurations subject to internal pressure and combined loading. Significant knowledge and understanding of failure, strain development and deformation was attained providing a benchmark for validating the numerical and analytical models.

The analytical and numerical models successfully predicted the first ply failure loads and accurately identified the location of failure. For example when, the pipe elbow was subject to internal pressure only, the specimen failed at the intrados both numerically and experimentally (fig 2). In the case of combined loading of pressure and bending failure occurred at positions further away from the intrados towards the extrados. A relatively good agreement between the experimental and numerical models was attained for the strain development and deformation.

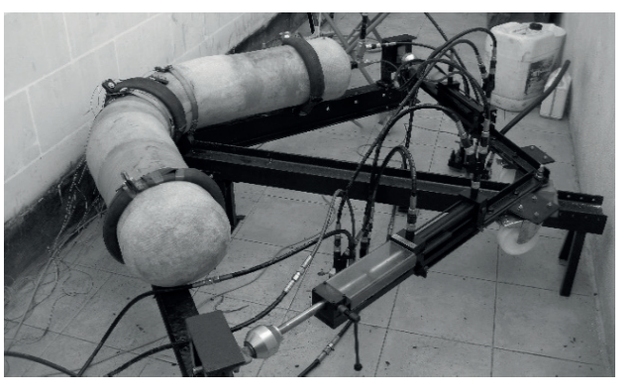

Figure1: Set-up for bending and pressurizing the GFRP Elbow

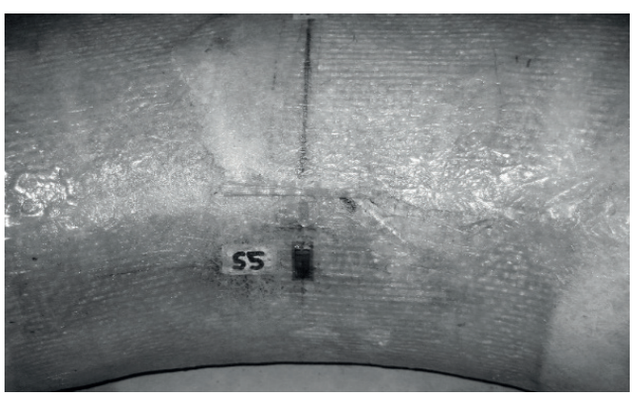

Figure 2: Failure Location of a Pressurized GFRP Pipe Elbow

Investigation into the Effects of Exhaust Silencers on Performance of SI Engine

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

Introduction

The signature sound produced by an automobile is an important factor for well-known brands, as this defines its character. The addition of a suitable silencer will give this characteristic sound, however it can also have a severe effect on engine performance.

Project Objectives

This dissertation was undertaken to understand the production and mitigation of engine noise and the effect and interaction of silencer on engine performance. The experimental results were then compared to the simulation performed by Ricardo Wave.

Project Methodologies

Apart from the standard off-the-shell silencer, a manufactured silencer was constructed. This allowed various arrangements of internal packings to be tested. Modifications were performed on convergent and divergent apparatus and various engines as a source of noise. This permitted testing on the manufactured silencer. Tests were performed on constant mass flow rate apparatus, Escort 1400cc engine and Formula SAE Honda 600cc engine. Torque, manifold mass flow rate and pressures were recorded from the Escort engine, while pressures and sound was recorded from the FSAE engine. A standard procedure was followed during all tests.

Results

The constructed silencer was initially tested on a steady mass flow rate apparatus. The silencer did not have any effect on parameters such as pressure and air mass flow rate, but had a significant effect on the sound emitted, attenuation of more than 10dB.

Results obtained from the Escort engine, showed that the variation of internal packing arrangement shad an effect only on exhaust pressure and differential pressure across the silencer. It was concluded that high packing densities restricted gases from entering or escaping the silencer. This resulted in a higher exhaust pressure pulses and sound levels.

The final tests were conducted on the Honda engine, where sound was mainly investigated. A relationship between exhaust pulses and sound levels emitted from exhaust was found. It was seen that for a particular engine speed, the pressure wave emitted resulted in corresponding sound level pulse. The best packing found was $200 kg/m^3$ with a layer of supporting steel wool. It was concluded that experimentally the addition of a steel wool layer helped exhaust gases to flow through the silencer and thus reduced sound levels emitted.

Comparison between experimental measurements and Ricardo Wave simulation models allowed better understanding of the results obtained experimentally. During simulation, it was noted that Wave does not support the addition of two layers inside the silencer, eg. steel wool layer and rock wool. This could be a future improvement to Wave.

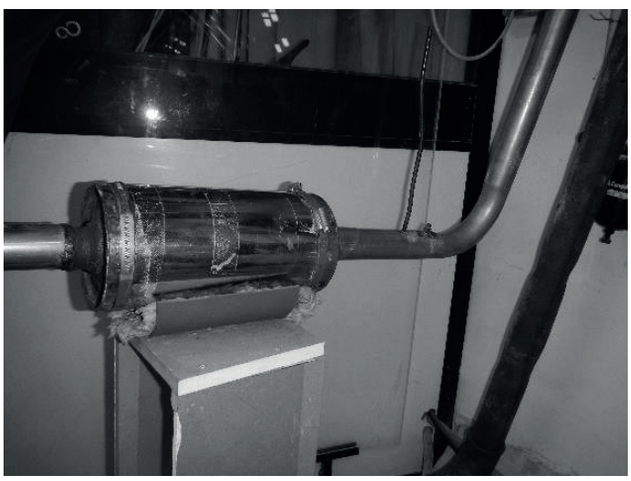

Figure 1: Escort engine tests with manufactured

Circular Silencer – 300 kg/m^3 with Steel wool		
RPM	Reading 1 in dB	Reading 2 in dB
1500rpm	98	96
10000rpm	120	115
Circular Silencer - 200 kg/m^3 with Steel wool		
2000rpn	98	98
9500rpm	112	110
Circular Silencer - 360 kg/m^3 with Fiberglass		
2100rpm	100	99
9000rpm	118	112
Circular Silencer -200 kg/m^3 with Fiberglass		
2300rpm	102	102
9000rpm	125+	105
Circular Silencer – 117.2 kg/m^3 with Fiberglass		
2200rpm	100	110
9000rpm	120	122
Circular Silencer - Empty		
2200rpm	100	99
9000rpm	125+	125+

Figure 2: Sound Levels measurement recorded Formula SAE Honda engine for different packing arrangements

Modelling Sternotomy via Finite Element Analysis

Student: Nicholas Farrugia / Supervisor: Dr Ing. Zdenka Sant

Introduction

Median sternotomy is a surgical procedure in which access to the vital organs is obtained by sternum dissection. Amongst the postoperative complications, dehiscence of the median sternotomy wound has a high mortality rate [1]. Studies on how to improve the closure techniques by reducing the micro-motion between the dissected sternal halves are being carried out. The application of the finite element method to carry out this analysis of the mechanical behaviour of the sternotomy model has increased in the past years [2].

Project Objectives

The scopes of this project were to obtain a virtual human sternum model following median sternotomy and to investigate its biomechanical behaviour during a cough. The objectives of this dissertation were:

1. to obtain the finite element (FE) model of two sternal halves
2. to create a FE model of the closure techniques used by a local cardiac surgeon
3. to run a pilot attempt of the contact solution simulating a fixed sternum under physiological loads

Project Methodologies

The three-dimensional sternum model following median sternotomy was generated using the sternum model created by Christabel Borg in her dissertation entitled "Computational Model of Human Sternum" [3].

The model was imported in the Finite Element (FE) modelling software Mechanical APDL Product Launcher 14.0, ANSYS , whereby virtual dissection of the sternum model and creation of sternal wires were carried out.

Following the geometrical modelling, discretisation and application of the loading, contact and boundary conditions on the sternum model were implemented in order to simulate the biomechanical behaviour of the dissected sternum model after median sternotomy in response to a physiological load, as illustrated in Figure 1.

Results and Achievements

All the project objectives set have been tackled and fulfilled throughout the duration of this project. The preliminary results indicated that the contact set up failed and resulted in non-convergence or rigid body motion of the sutures, which is not physically possible. Since the FE model is a very complex three-dimensional model and multiple contact pairs exist, this problem was expected as one of the possible outcomes. It was concluded that more time was required in order to change the parameters affecting the contact analysis, such as the normal contact stiffness and the load-step size.

This study confirms that FEA can be a viable means to analyse the sternotomy model using different closure techniques in order to reduce the occurrence of sternal dehiscence.

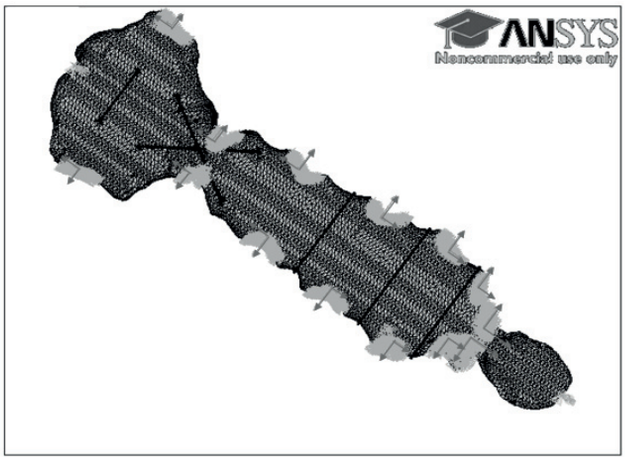

Figure 1: Sternum FE model after application of loading and boundary conditions

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Continuation of the Turbocharging of the Kawasaki 600cc Engine for FSAE

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

Introduction

Formula SAE is a student based educational motorsport competition where university students are challenged to design, build and test a single seat race car to compete in events to demonstrate their abilities and engineering skills. The major rules imposed are that the engine used must be a four-stroke engine with a displacement limit of 610cc and a 20mm restrictor must be placed between the throttle body and the engine air inlet [1]. The latter regulation imposes a major limitation on engine power. To counteract this, the Kawasaki ZX6R engine was previously turbocharged and preliminary ECU mapping was carried out. In this project, further improvements and modifications to the engine were carried out so as to achieve a more reliable and operationally-flexible experimental testing setup.

Project Objectives

- To achieve the control of boost pressure through the control of the variable geometry turbocharger or the addition of an external wastegate.
- To familiarize with programmable ECU for turbocharged applications.
- To continue engine mapping with MAP as load parameter.
- To map the engine at different air temperatures.
- To continue testing the VNT turbocharger and turbocharged engine.
- To familiarize oneself with turbocharged engine simulation using Ricardo WAVE .

Project Methodologies

The addition of an external wastegate together with the development and implementation of a system to control it (PID control via LabView), made it possible to control the manifold absolute pressure which hindered proper engine mapping in previous projects. With the proper control of the manifold absolute pressure, proper mapping of the engine was carried out enabling the engine to be operated in its full rpm range of up to 12000 rpm. This was vital to fully exploit the engine's power output, considering that such racing engines, are typically operated in the 6000 to 12000rpm range. Testing on the turbocharged engine was performed with the successful implementation of a system to control the intake air temperature while further understanding of the GT15V turbocharger on the Kawasaki ZX6R engine was carried out through simulations using Ricardo WAVE .

Results and Achievements

Tests performed on the engine to test the effects of the intake air temperature showed that with low inlet air temperatures, more power can be produced from the same engine. On the other hand, tests carried out on the GT15V turbocharger indicated the ideal procedure to operate a variable geometry turbocharger. Vanes closed provide better boost pressure response while vanes open provide better engine throttle response.

Results obtained from the simulation on Ricardo WAVE agreed with the findings from the physical experiments. In addition, analysis of the exhaust gas pressures in the exhaust manifold indicated a considerable rise in pressure with the vanes closed which led to the conclusion that this should only be used when requiring sudden response in boost pressure to avoid losses in throttle response.

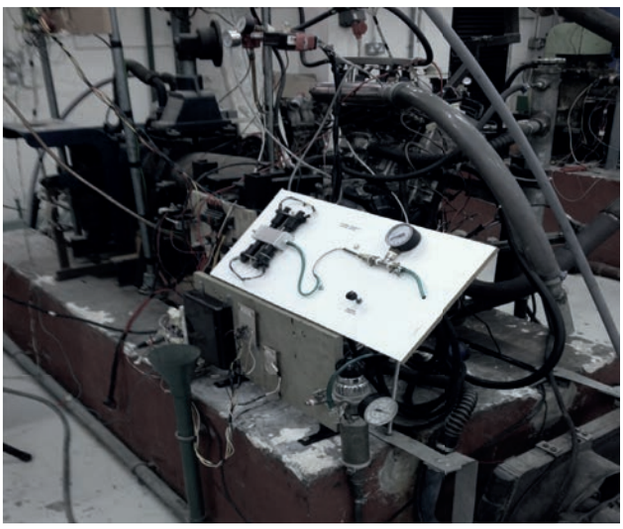

Figure 1: Engine experimental setup

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The Investigation of Slats and Flaps on an Aerofoil

Student: Ryan Paul Galea / Supervisor: Dr Ing. Christopher Micallef

Introduction

High lift devices are used to aid lift, increasing the stalling angle of attack of an aerofoil. Flaps increase lift when the aircraft is in two phases of flight: The *Take-Off*, where the take-off roll is made shorter and the *Landing* phase, were the landing speed is reduced, making the landing roll shorter. This will make short-field take-offs and landings possible [1].

Project Objectives

The objective was to perform an analytical and experimental analysis on an aerofoil with five attached high lift devices. The performance of each was studied together with obtaining a solution via Computational Fluid Dynamics (CFD) software.

Project Methodologies

A wind tunnel was used to achieve pressure readings which were read from a multitube manometer. A series of 0.5mm pressure tappings were built inside the mahogany models. Airflow velocity was measured via a pitot-static tube. From the area under the pressure plots, lift and drag coefficients, C_L and C_D were found.

This procedure was done for AoAs varying from -5 to 20 degrees with 5 degree intervals. Also, these readings were taken for Reynolds numbers 100,000 (Figure 1), 200,000 and 300,000, repeating the same procedure for the six models. Most importantly, the necessary safety and experimental precautions were followed.

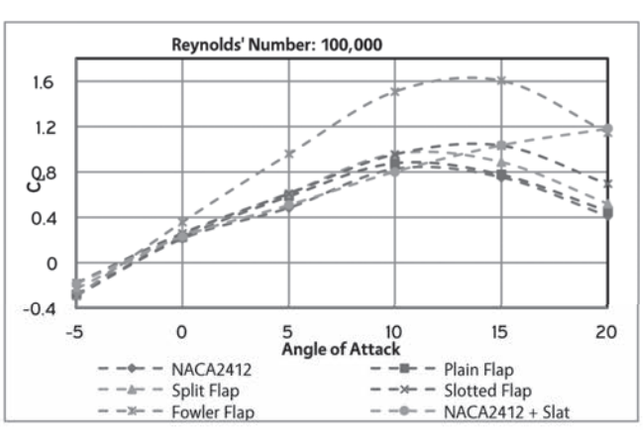

Figure 1: Result from experiments on all models

Results and Achievements

Experimental Results

Experimental analysis showed that the magnitude of pressure gradient had an effect on the degree of lift generated. The fowler flap proved to be the most effective high lift device configuration to obtain from a trailing edge device. The leading edge slat had a drastic effect on the boundary layer, as the NACA2412 aerofoil did not show any signs of stalling, not even at an angle of attack of 20 degrees.

This happened because the slot positioned between the slat and the aerofoil interface as can be seen in Figure 2, provided as a means to accelerate the flow over the upper surface of the aerofoil, re-energising the boundary layer and preventing any region of reversed flow from being created.

Computational Fluid Dynamics (CFD) Results

CFD analysis showed that there is good agreement in the trends achieved from wind tunnel experiments. Flow visualisation was carried out in CFD and a comparison between the six models was carried out. Results showed that a larger camber as well as a slot between the aerofoil and the leading edge high lift

References

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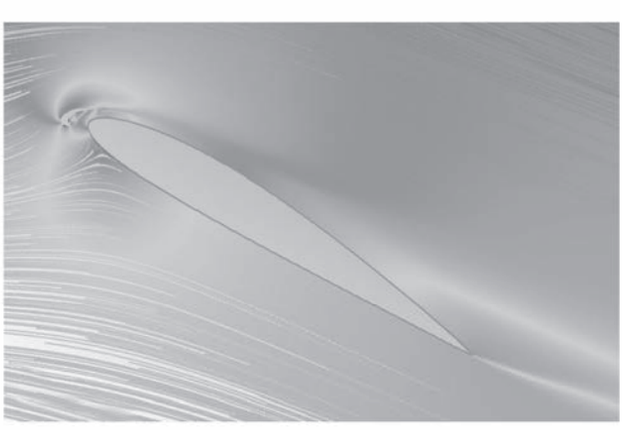

Figure 2: Velocity Streamlines in CFD on NACA2412 aerofoil profile with attached slat

Heat Exchanger Modelling and Optimisation of a Wound Condenser

Student: Mark Gatt / Supervisor: Dr Ing. Christopher Micallef

Introduction

The scope of this dissertation was to investigate the performance of a wound condenser, provided by the industrial partner Seifert Systems. This consists of a copper pipe wound around an aluminium core. The investigation was carried out on the two different cores, shown in Figure 1 and 2.

Project Objectives

- Conduct a physical experiment, involving the condensers, under normal operating conditions.
- Provide a review on the performance of both the cores, and suggest any possible optimisation.

Project Methodologies

The wound condensers, were placed in an air conditioning laboratory unit, and placed under testing conditions used by Seifert Systems. Water was circulated through the copper tubing, whilst various thermocouples were placed on the aluminium profiles, in both the axial and radial directions. The temperature readings obtained from the thermocouples, would allow verifying how the heat was being transferred through the wound condenser. The configuration of the heat exchanger, along with the air flow rate, were varied so as to verify the best performance conditions of the condenser [1].

Results and Achievements

The first aluminium core was found to have a random temperature variation. This led to the conclusion that there was an uneven contact of the copper tubing with the aluminum profile. Consequently, when considering all the eight fins present, the uneven contact between the copper tubing and these fins, would produce different values of heat dissipation through the fin, dependent upon the contact of the copper tubing with the fin.

Also, air gaps present between the copper tubing and aluminium profile lead to high contact resistances. Theoretical calculations carried out, proved that these air gaps were the source of a considerable thermal resistance, amounting approximately to one-third of the total thermal resistance. The first profile in the parallel flow configuration, showed quite a low effectiveness for the test parameters used. When the counter flow arrangement was applied, the effectiveness increased, especially when the circulating water was at a higher temperature. This suggests that the counter flow configuration, with circulation of the refrigerant at higher temperatures would result in a better heat transfer rate between the hot and cold fluids.

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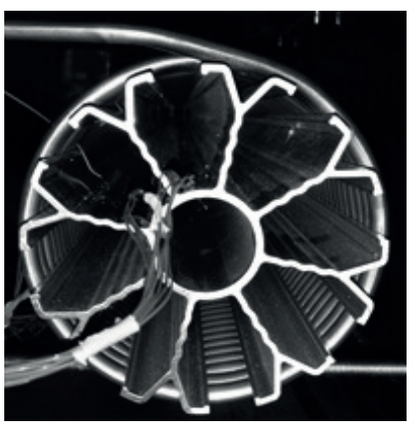

Figure 1: The first profile, placed in duct and showing thermocouple connections

Figure 2: Cross Sectional view of the second profile

Numerical Modelling of Friction Stir Welding

Student: Stephen Mallia / Supervisor: Prof. Ing. Duncan Camilleri

Introduction

Over the past fifty years the production of aluminium has constantly increased. Since aluminium is a light weight material, it has been considered an energy-saving structural material in advanced applications for several industries, such as the automotive and aeronautics industries. This situation has led to the need for research of new joining processes, since conventional joining processes such as fusion welding, do not produce sound joint when welding aluminium and steel.

In 1991, inventors at The Welding Institute (TWI), a British research and technology organisation, introduced an alternative method of welding called friction stir welding (FSW). Friction stir welding is a solid-state joining process meaning that the metal is not melted during the welding process. In FSW, a tool, designed with a shouldered pin, rotates at constant speed and is plunged into the joint line. Once the tool has been completely inserted, it is moved at constant velocity along the welding line while rotating.

Project Objectives

The aim of this project is to develop a rigid-viscoelastic numerical model of friction stir welding, by investigating and validating the temperature-dependent viscous models used in FSW, by various authors' of scientific papers. Afterwards, the heat generation in FSW, is studied by using various welding parameters.

Project Methodologies

The modelling strategy used to simulate FSW; is a steady-state, pressure-based, rigid-viscoelastic, laminar process. The computational fluid dynamics software ANSYS Workbench FLUENT is used throughout this project. The thermal analysis was investigated using 3D modelling.

The temperature-dependent models used throughout this investigation are the Zener-Hollomon and Norton-Hoff viscous models. In these simulations, the sliding friction condition was not considered.

This numerical model was solely based on the sticking condition, were heat is generated exclusively by the shearing action from the rotating shoulder. The material properties, geometrical dimensions and viscosity parameters used for the simulations were based on the values from existing scientific papers.

Results and Achievements

The welding parameters considered for investigating the heat generation are: the convection heat transfer coefficient, welding velocity and rotational speed. Varying these parameters will in turn greatly affect the heat generation during the welding process. The heat transfer coefficient acting on the surface of the workpiece depends on the thickness of the workpiece and the backing plate; increasing the thickness will increase the thermal resistance, thus increasing the temperatures on the surface. Using a higher rotational speed of the tool will also increase the heat generation, but increasing the welding velocity will have a contrary effect, and the heat generated will be less.

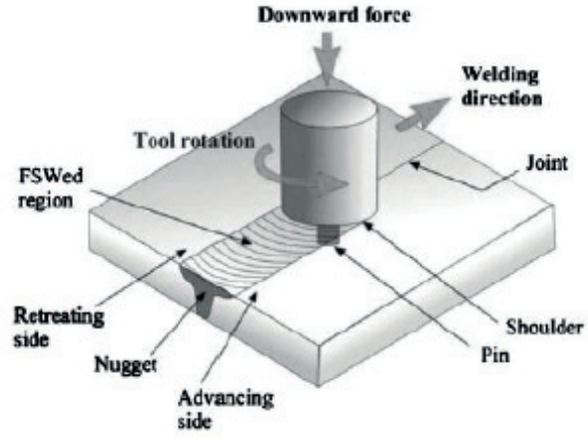

Figure 1: The FSW process[1]

References

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Testing of Sternal Foam Model

Student: Gerald Frank Mercieca / Supervisor: Dr Ing. Zdenka Sant

Introduction

Medicine has come a long way in the past few years as is evident in the increase in life expectancy of a person. However, a lot still needs to be done. The biomedical field is working hand in hand with engineers so that the possibilities new technology has created could be utilized in order to improve the general health among the population. Sternotomy involves the vertical bisection of the sternum in order to perform open heart surgery. Mechanical instability in the reapproximation could lead to serious medical problems. Such problems could cause potential fatal complications to the patients. This therefore calls for a commitment to improving sternal closure techniques by conducting research on sternum foam models.

Project Objectives

The aim of this project is to design and construct a loading frame that is attachable to the "Instron Tensile Tester" that is available at the Mechanical Engineering Department laboratory at the University of Malta. This loading frame should be designed in a way that it could simulate a patient's specific bone geometry by having the possibility of controlling the different angles of each rib in all three-axis. Test on a polyurethane foam model are to be carried out and validate the results obtained from an FE-analysis done on ANSYS software.

Project Methodologies

After all necessary calculations of certain parts and components used for the loading frame, the design of the loading frame was done using Autodesk Inventor Professional 2013. To obtain the flexibility in all three-axis, a movable pulley system was designed.

The parts were manufactured using a range of manufacturing processes such as laser cutting, CNC machining and traditional machining. Using a 3D scanned model, the angles of the sternum foam model were calculated and the stainless steel cables attached accordingly using epoxy resin. The test was setup using components such as the E-Cells and tensioners to monitor the loading applied on the model. Finally, the testing was carried out by applying continuous translation and recording the applied load and strain values.

Results and Achievements

Following the design and construction of the loading frame, a total load of 610N was used during testing. The ensuing results indicated that the constructed loading frame is capable of producing repeatable results. Moreover, results obtained from testing were comparable to those obtained from the FE-analysis. Some discrepancies in the results led to significant refinements in the loading frame.

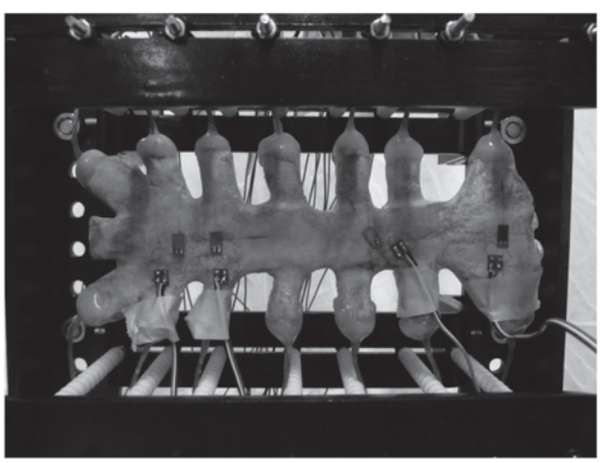

Figure 1: Final assembly of Foam Model in Loading Frame

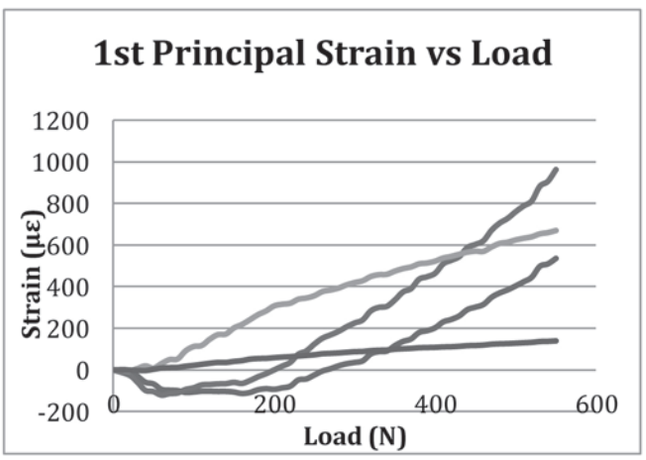

Figure 2: Variation of strain along sternal midline

Load for Finite Element Models using AnyBody

Student: Carl Muscat / Supervisor: Dr Ing. Zdenka Sant

Introduction

The forces exerted by the muscles during walking are of critical importance in biomechanics. Currently, surface electromyography (sEMG) is the only non-invasive method in which such forces can be measured, although this method can be used only for muscles laying just under the skin surface. This can be solved by using motion capturing techniques to record walking and simulating the human body during the walk. Then the muscular forces can be calculated using inverse dynamics.

Project Objectives

The objectives of this project were:

- To obtain the muscular forces during walking by computing inverse dynamics through simulation.
- To observe the effect that muscle activity has on the L3 and L4 spinal vertebrae.

Project Methodologies

First, the anatomy of muscles was studied in order to gain an understanding of how the muscles generate forces and in which way they can affect the bones to obtain better understanding of how sEMG works.

After this, the way in which the muscular forces are calculated from simulation in the open source software AnyBody was studied. It was found that muscular forces are calculated by using inverse dynamics. However, since the body is considered an indeterminate system the optimization model has to be used in order to carry out inverse dynamics. There are various optimization models that can be used. The model providing results close to reality was identified to be the min/max criterion.

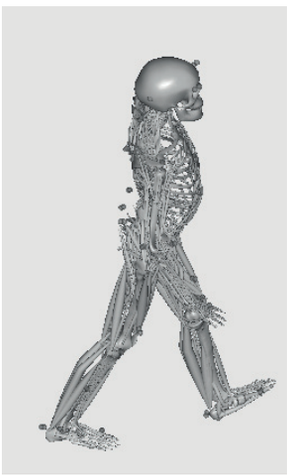

Figure 1: Simulation of the human walk

The gait cycle, together with typical muscle activation patterns were also studied in order to obtain information about the typical muscle activity during the walk.

A human walk was recorded using motion-capturing apparatus, and the data was used to create a virtual model of a human walking. An inverse dynamic analysis was then carried out and muscular forces were calculated. After validation, the forces were exported to finite element software (ANSYS) and the effect of the forces on the L3 - L4 spinal segment was simulated.

Results and Achievements

Analysing the stresses on the L3 and L4 vertebrae, shows the maximum stresses for both vertebrae occurring at the bottom front of the vertebral body throughout the whole walk. It was also found that these stresses reach their peak magnitude when one of the limbs is impacting the ground. This is realistic because at the impact, there is an extensive change in momentum over a small span of time, leading to a large force on the vertebra. It was also noticed that the maximum stresses on the vertebrae occurred at situations where abrupt changes in geometry occur and on the locations where the forces were applied. This situation has to be taken into consideration when analysing such stresses since they would lead to unrealistic stress magnitudes at these locations.

References

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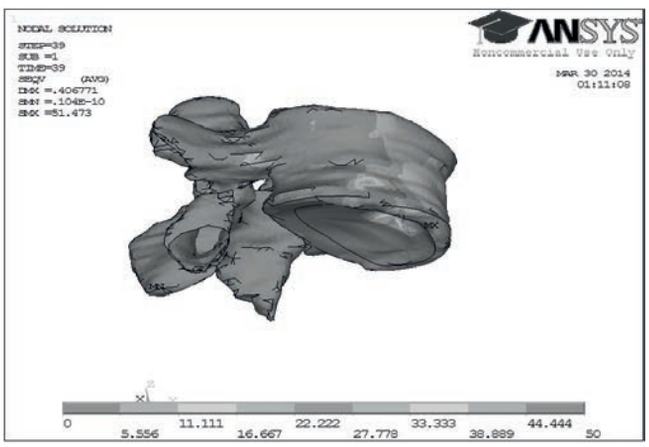

Figure 2: Contour plot of the Von-Mises stresses on the L3

Fatigue Analysis of Vertical Axis Wind Turbine Components

Student: Thomas Sciberras / Supervisor: Dr Ing. Pierluigi Mollicone

Introduction

Fatigue as a phenomenon includes failure of a material due to the accumulation of damage brought about by cyclic loading. This failure may occur at stress levels well below the parent material's yield strength. It has been the cause of failure of many engineering structures. Cyclic loading is unavoidable, which is why it is important to cater for fatigue at a design stage. [1]

Project Objectives

The objectives of this project were to develop Finite Element Models and carry out a fatigue analysis of a vertical axis wind turbine blade composed of either an isotropic material (Aluminium 6061) or a composite material (Woven fabric E-Glass-Polyester). A comparison of the fatigue performances of both materials as determined from the finite element analyses and analytical models was to be carried out.

Project Methodologies

Finite Element Models of the turbine blade composed of both Aluminium and glass fibre were developed and validated. Both blade models were optimised with the intention of keeping stresses acting on the blade as low as possible for the given working conditions. In both cases, stress for one complete revolution done by the blade about the turbine's axis of rotation was extracted at 20degree intervals from the location experiencing the highest stress (Fig. 1 shows the maximum stresses for the Aluminium model).
In the case of the Aluminium blade, the multi-axial stress state was reduced to a uni-axial one with the use of von Mises (equivalent) stress and mean stress effects were accounted for with the use of the Goodman criterion. Number of cycles to failure was then determined with the use of S-N data unique to Aluminium 6061 as presented in [2]
In the case of the glass fibre blade, stresses in both the woven fabric's fibre directions were extracted in 20degree intervals. A piecewise linear constant life diagram was developed to predict uni-axial fatigue performance at the given working conditions. The *Failure Tensor Polynomial in Fatigue* was then used to predict the blade's number of cycles to failure under the action of a multi-axial cyclic stresses.

Results and Achievements

The Aluminium blade experiences a cyclic load having a maximum stress below its endurance limit. Hence, the Aluminium blade is said to have a theoretical infinite fatigue life.
The glass fibre blade on the other hand was found to be operating at multi-axial cyclic stresses, which the material is able to endure well into the giga-cycle regime.
Unfortunately, fatigue analysis of composite materials is still in its infancy and fatigue performance is not as well documented as that of isotropic materials.

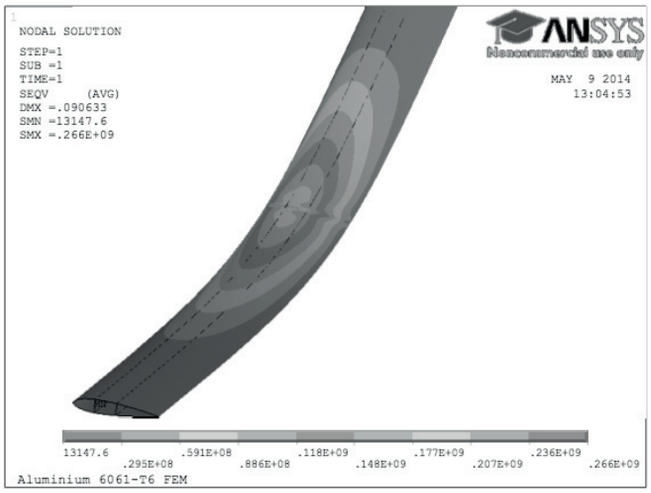

Figure 1: Detailed view of location of Maximum von Mises Stress acting on blade (von Mises Stress: 0.013 266 MPa)

References

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Structural Analysis of a Vertical Axis Wind Turbine

Student: Francesca Vella / Supervisor: Dr Ing. Pierluigi Mollicone

Introduction

This project sought to optimise a particular type of Vertical Axis Wind Turbine (VAWT) blade, in terms of structural integrity. This was done by means of a finite element (FE) structural analysis using ANSYS.
The main focus is on the material constituting the blade, however other factors affecting performance were also considered.

Project Objectives

- Literature review regarding VAWTs and the materials used in their manufacture
- Blade structural analysis for two material models
- Optimisation of factors affecting VAWT structural integrity

Project Methodologies

A particular VAWT model, an H-rotor (Figure 1) as described in [1], was selected as a case study, in order to perform a structural analysis on its blade. Most of its parameters are described by Paraschivoiu [1], while others were chosen on the basis of structural integrity optimisation. Two FE material models were developed; modelling two typical materials used in the VAWT blade industry:

1. Aluminium alloy 6061
2. Glass-fibre reinforced polymer (GFRP)

Stresses and deflections of the blade at steady state operating conditions were simulated, while comparing the performance of the two materials.

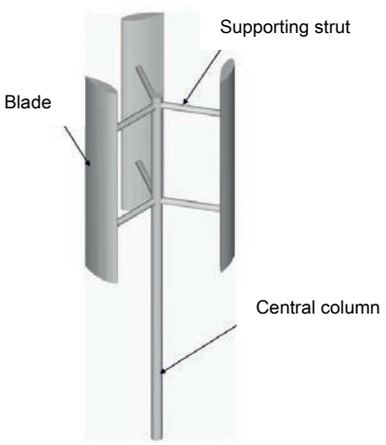

Figure 1: H-rotor VAWT [2]

Results and Achievements

Important parameters were optimised for minimum stresses and displacements during operation. These comprised a 1.5mm thickness for the hollow blade cross-section and the blade supports location at 1.44m (~ 24% of total blade length) distance from the blade ends.

The results obtained from the finite element simulations set the ground for a conclusion regarding the more favourable choice of material for such an application. It transpired that GFRP performs better overall. Although it generally experiences larger displacements when the blade is in operation, this becomes negligible at the optimised thickness and blade support position. Moreover, the stresses produced in the GFRP blade (Figure 2) were consistently lower than those in its aluminium alloy counterpart.

References

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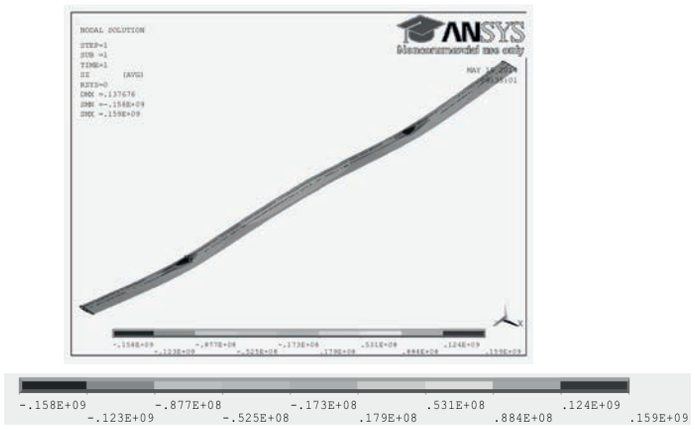

Figure 2: Contour plot for axial stress of GFRP blade; range of -0.158GPa to 0.159GPa

Improved Methods for Cleaning Reverse Osmosis Membranes

Student: Mark Vella / Supervisor: Prof. Ing. Robert Ghirlando / Co-Supervisor: Prof. Ing. Maurice Grech

Introduction

Reverse Osmosis is a process based on membrane technology whereby dissolved solids contained in the feed stream are separated to produce purified water. Its high operating efficiency leads to versatile applications in both domestic and industrial areas. However membranes do get fouled and thus the main aim of this dissertation is to improve cleaning methods currently employed on fouled membranes used by Water Services Corporation.

Project Objectives

Modify and repair the existing sea water Reverse Osmosis test rig so that it could accommodate more easily the various cleaning solutions and methods to be tested.
Clean the membrane samples with a Citric Acid Solution varying the chemical weight percentage, pH and Temperature.
Test the membrane samples after being cleaned and analyze and evaluate the test results with those obtained from spectroscopy investigations.

Project Methodologies

In total, the following tests were performed:

- Membranes were cleaned with 1wt%, 2wt%, 3wt% and 4wt% Citric Acid.

The tests were all done at a temperature of 35˚C and un-adjusted pH. A 2wt% citric acid showed best performance and thus keeping the same weight percentage, the pH was varied

- Membranes were cleaned with 2wt% Citric Acid only, pH 3 and 4.

There was no improvement with a higher pH than that of 2 so the temperature was then varied.

- Membranes were cleaned with 2wt% Citric Acid only, (pH unadjusted), Temp. 30˚C & 40˚C

Results and Achievements

The high presence of Manganese and Iron can be said to be brought directly from the sea where they are deposited through the interaction of soil with sea water as our Maltese soil is highly enriched with these two elements. Other elements such as Aluminum, Silicon and Cobalt indicate that there might be some degradation of steel equipment from the membrane modules, pump propellers or piping which could be fouling the membranes.

It showed that Citric Acid is a very good cleaning agent when it comes to metal oxides fouling, where all the oxides of Manganese and part of Iron were removed and reduced respectively. The best solution turned out to be of 2wt% Citric Acid, pH 2.25 and temperature of 30℃ which had an average water flux improvement of 41.5% over the fouled membranes and 5% improvement over the runner up test, i.e. 2wt% Citric Acid, pH 2.25 and temperature of 35℃. Other element traces which were removed completley include Floruides, Phosphorous, Calcium and Cobalt. Other elements, for example oxides of Sodium, Magnesium, Aluminium, Silicon and Potassium were reduced to a lesser extent when compared to Iron and Managanese.

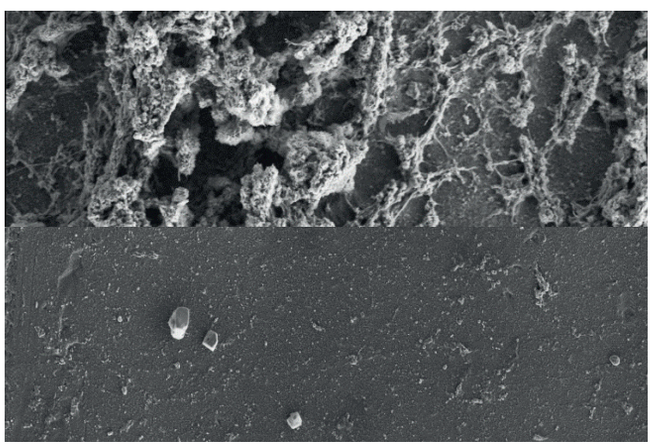

Figure 1: SEM Images of a Fouled (top) and a Cleaned Membrane (Bottom)

Element	*Fouled*	*Cleaned **
	Wt %	*Wt %*
C	32.21	66.52
N	02.81	--
O	32.89	19.62
F	00.34	--
Na	01.77	01.36
Mg	00.48	00.44
Al	00.88	00.15
Si	02.30	00.08
P	00.23	--
S	03.70	07.25
Cl	03.10	02.54
K	00.25	00.22
Ca	00.33	--
Mn	11.92	--
Fe	07.93	01.81
Co	00.38	--

**2wt% Citric Acid, pH2.25, Temperature 30 ℃*

Figure 2: EDS Analysis of a Fouled and Cleaned Membrane

Experimental Measurement of Residual Stresses induced by Friction-Stir Welding of Dissimilar Materials

Student: Nathan Zammit / Supervisor: Dr Ing. Pierluigi Mollicone

Introduction

Residual stresses are stresses which can be found within a component when no external forces act on it, and are usually detrimental to the mechanical performance of a component. This project forms part of a larger project done in collaboration with the Universit Catholique de Louvain who provided friction-stir welded Aluminium/steel plates.

Project Objectives

- To Measure the residual stresses of dissimilar materials welded by a friction-stir welding method which has just been patented by the partner University [1]; using the Hole-Drilling method.
- To design a jig to support the plates and the hole-drilling apparatus.
- To compare the residual stresses between joined and un-joined dissimilar plates.

Project Methodologies

The Vishay RS-200 Hole drilling apparatus was used to introduce holes into the surface of the material; causing the material to relax and subsequently allowing residual stresses measurement. The provided test plates were too small to fit the RS-200 apparatus and hence a jig was designed to support both the plates and the apparatus. Since the plates were bent, cement moulds were made in order to support them completely.
Vishay 062UL strain-gauge rosettes were used to measure the change in strain before and after introducing the hole. The strain readings were converted to Residual stress values using the H-Drill stress calculation software. All readings were carried out in accordance to the ASTM E837-08 Standard.

Results and Achievements

Residual stress values were achieved for all the Aluminium and Steel plates; including samples in which the Aluminium and Steel were welded together. Particular interest was given to the Longitudinal and Transverse stress components since they were approximately equivalent to the Maximum and Minimum principal stresses in the material. The results achieved from the plates were analysed and compared, and the stress distributions noted.
Most readings showed that the residual stresses within the advancing side of the weld were higher, or else tended to be greater in tension.
It was also observed that the residual stresses were greater (greater in tensile) within the plates having joined Aluminium and Steel. The only readings within which this was not observed were those of Transverse residual stress on the Aluminum plates.
Two of the readings taken from the Aluminum side of the joined plates tended beyond 60% of the yield. Therefore, when having the Aluminium welded to the Steel, the load bearing capability of the Aluminium could be reduced significantly.

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[1] C. van der Rest, A. Simar, P.J. Jacques, Method for welding at least two layers (Patent), International Publication No. WO2013164294 (A1), International Publication Date: 7 November, 2013.

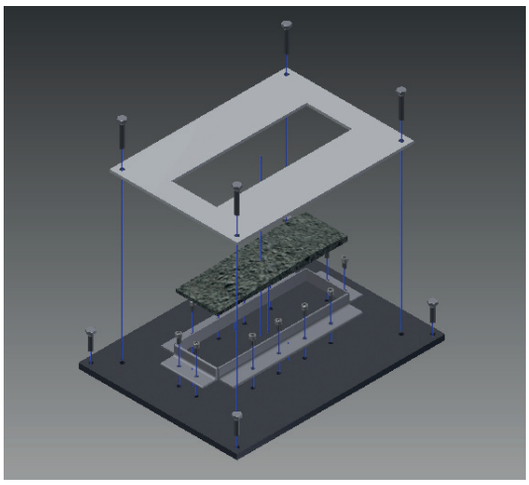

Figure 1: Support Jig Assembly

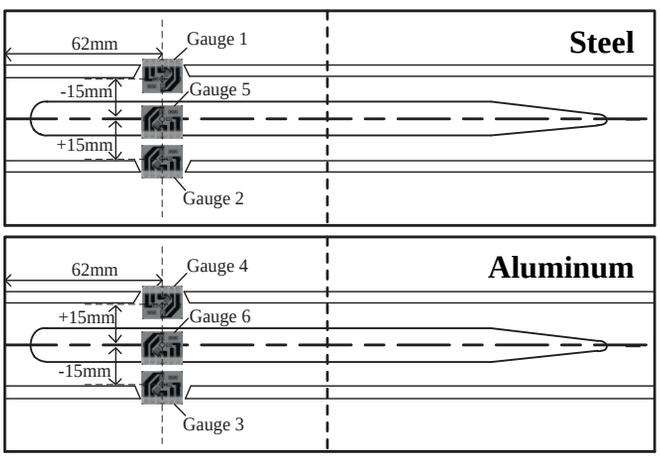

Figure 2: Strain-gauge positioning on Steel and Aluminium plates

Nanoscale Graphene under Deformation

Student: Anthea Agius Anastasi / Supervisor: Dr Ing. Glenn Cassar / Co-Supervisor: Dr Matthew Borg

Introduction

Graphene is the thinnest material known to man, consisting of a single layer of carbon atoms arranged in a hexagonal lattice. It is known as the "miracle material" and is expected to feature in nanocomposites, flexible displays, night-vision contact lenses, solar panels and many electromechanical devices, amongst other, due to its extraordinary mechanical and electrical properties [1, 2]. However, in-depth studies need to be carried out to allow for full exploitation of this decade-old material.

Project Objectives

The principal aims of this project were:

- To measure the Young's Elastic Modulus, fracture stress, and fracture strain of graphene under tensile loading, using computer simulation;
- To develop a more representative model of carbon-carbon bonding which allows motion in all three dimensions;
- To apply a thermostat which allows for a homogeneous local constraint of the temperature of the sheet;
- To develop a loading method that avoids unrealistic high stresses from being built up at the clamped regions;
- To model various atomic defects with reconstructed bonds in the graphene sheet;
- To correlate the mechanical properties of graphene to the sheet size, orientation zigzag and armchair, temperature and the presence of defects.

Project Methodologies

Single layer graphene sheets with diagonal lengths varying from 1.3 nm to 18.6 nm were modelled and simulated using molecular dynamics. The Morse bond, angle bending, torsional and Lennard-Jones potential functions, together with the Langevin thermostat were adopted. OpenFOAM, an open-source software package, was used to run the simulations of graphene sheets under axial tensile loading at temperatures between 0 K and 1000 K. Several types of atomic defects were also introduced to study their effect on the graphene sheet mechanical properties.

Results and Achievements

The simulations carried out reveal that graphene has a Young's Modulus of Elasticity, fracture stress and fracture strain of up to 1.3 TPa, 94 GPa and 0.16, respectively, which are in good agreement with literature sources [3]. Graphene sheets smaller than 5 nm in length exhibit a drop in elastic modulus by up to 35% while an increased temperature of 1000 K reduces the Elastic Modulus, fracture stress and strain by 13%, 20% and 37%, respectively. An increase in the concentration of vacancy defects in the sheet linearly decreases the mechanical properties of graphene. The fracture patterns were also analysed, concluding that cracks tends to follow the zigzag direction during propagation, in both zigzag (Figure 1) and armchair oriented sheets.

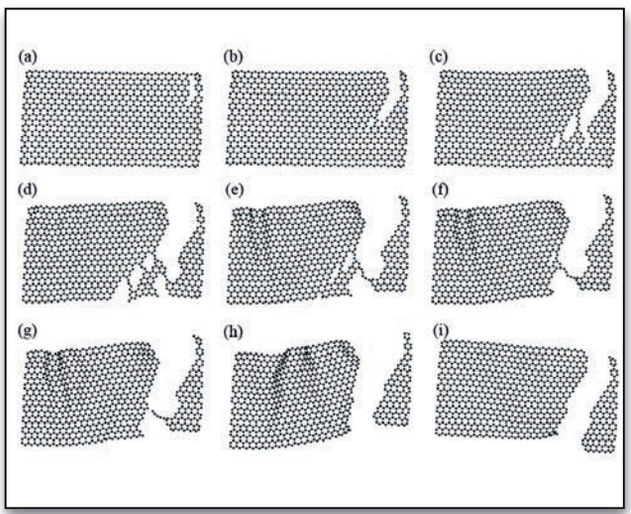

Figure 1: Fracture process of a zigzag graphene sheet at 300 K

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[3] Zhao H., Min K., and Aluru N. R., 'Size and Chirality Dependent Elastic Properties of Graphene Nanoribbons under Uniaxial Tension' Nano Letters, 2009, Vol. 9, No. 8, pp. 3012-3015.

Extending the Range of Steels which can be Spot Welded

Student: Greta Attard / Supervisor: Prof. Ing. Maurice Grech

Introduction

The spot welding process is fully automatic and once the machine is set, not much skill is required. It is thus a desirable process used in many industrial sectors even if its use is frequently limited to low carbon, low alloy steels. With high and medium carbon steel, the fast cooling rate associated with the process results in the formation of untempered martensite and associated undesirable mechanical properties. With most machines (similar to the one used in this study) this can only be avoided through optimization of the process parameters. Setting the parameters requires skill and full understanding of the effect of each parameter.

Project Objectives

The objective of this study was to lower the deformation whilst at least maintaining the strength and ductility values, from a study previously conducted by an MCAST engineering student for his dissertation. A number of quality tests and screening tests were used to compare the different results and confirm optimal conclusions. This was achieved by introducing a post-weld heating process, using the same spot-welding machine.

Project Methodologies

Preliminary tests were carried out to establish values of parameters such as welding current, welding time and pressure, which yield welds with deformations less than 10%. The shear strength and ductility of these welds were then improved by post-weld heating. The main variables investigated were post-weld current and number of pulses. The peel tests (Figure 1) was used as a screen to identify range of values worth investigating. Optimization was carried out using microhardness, optical and scanning electron microscopy and shear testing.

Results and Achievements

The introduction of the post-weld heating to otherwise brittle welds resulted in an increase in shear strength from 7.58kN to 10.30kN and an increase in an extension from 1.04mm to 1.46mm (improved ductility), whilst simultaneously reducing the deformation during welding. Figure 2 below displays this improvement on Shear force with respect to the previous study.

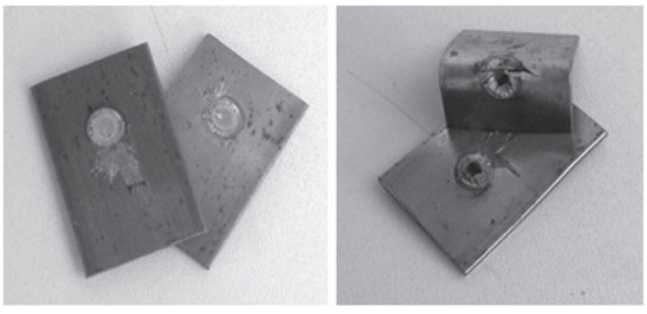

Figure 1: Brittle (Left) and Ductile (Right) Weld Failures Following Peel Testing

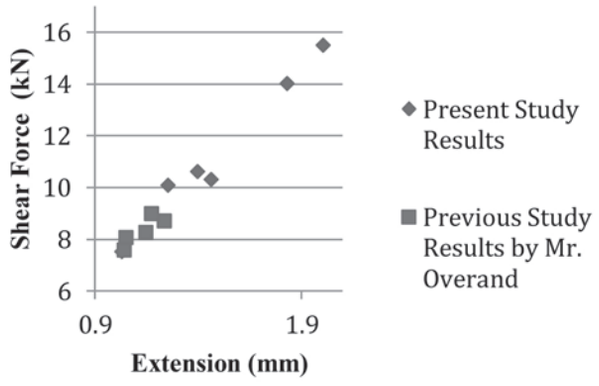

Figure 2: Shear Force vs Extension Results

Metal on metal Hip Joint Prosthesis: Reduction of Wear

Student: Christine Marie Borg / Supervisor: Dr Joseph Buhagiar / Co-Supervisor: Dr Bertram Mallia

Introduction

Metal-on-metal hip implants, have been reported to pose serious risks, mainly due to the generation of metallic debris, which results in the release of toxic ions. This issue has challenged their longevity, as has been reported in the Lancet [1], where it has been suggested that the use of such implants, should be stopped. A possible solution to this problem would be to surface engineer the metal, using a carbon-diffusion surface treatment known as Kolsterising®. This creates an S-phase layer, aimed at improving the corrosion and wear resistance of metals.

Project Objectives

The aim of this study is to investigate the tribocorrosion properties of metal-on-metal tribopairs. Few studies have been carried out to-date on such tribopairs, such as the ones carried out by Buhagiar et al. [2] and Maniscalco [3]. This study shall focus on the performance of Cobalt-Chromium-Molybdenum alloy tribopairs and 316LVM Austenitic Stainless Steel alloy tribopairs, when tested in their untreated and Kolsterised® state.

Project Methodologies

Characterization tests were performed on the discs and balls of both alloys (in the untreated and treated state). Tribocorrosion tests were performed on a linearly reciprocating ball-on-flat tribocorrosion tester on cobalt-chromium-molybdenum tribopairs as well as stainless steel tribopairs at different potentials. These tests were performed having both the ball and disc untreated and Kolsterised®, sliding against each other, for the two alloys involved in this study. Analysis of the wear characteristics of the two metals was carried out followed by the identification of the wear mechanisms involved. An investigation of the volumetric loss of the untreated and treated metal involved in terms of wear, corrosion and the synergy between the two, was also performed.

Results and Achievements

The Kolsterising® treatment improved the mechanical properties for both alloys in discussion; an improvement of 100% and 400% in terms of hardness was recorded for the cobalt-chromium and stainless steel discs respectively. It was noted that the treatment had a different effect on the balls, when compared to the discs for both alloys.

The stainless steel tribopair experienced a change in wear mechanism post-treatment (from plastic deformation to abrasion), and a reduction in volumetric loss. The Kolsterised® cobalt-chromium alloy exhibited finer abrasion grooves, however the treatment did not aid in reducing the volumetric loss.

The Kolsterised® stainless steel tribopair, exhibited less volumetric loss than the untreated cobalt-chromium tribopair, when tested at anodic potentials, as depicted in Figure 1. This makes Kolsterised® stainless steel an eligible candidate for applications which are typically restricted to cobalt-chromium alloys.

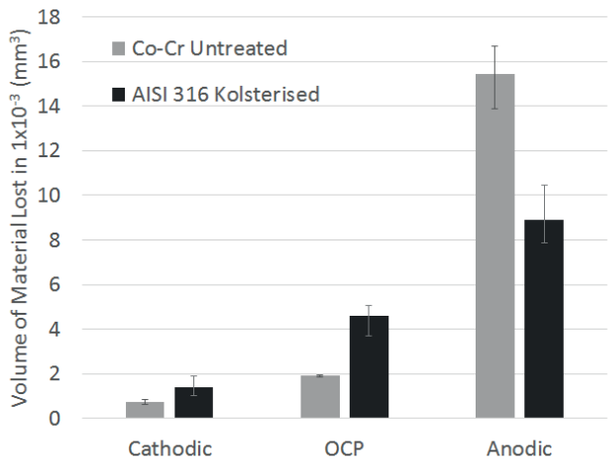

Figure 1: Volume of material lost for untreated cobalt-chromium discs and Kolsterised stainless steel discs

References

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Tribocorrosion of DLC Coated Biomedical Stainless Steel

Student: Miryea Borg / Supervisor: Dr Bertram Mallia / Co-Supervisor: Dr Joseph Buhagiar

Introduction

Tribocorrosion is a material degradation process due to a combined action of mechanical wear and corrosion. Typical components subjected to this type of damage include the bearing surface of hip and knee prosthesis. A plausible way to mitigate such damage and increase their longevity is by surface engineering their bearing surface. This study investigates the tribocorrosion performance of Diamond Like Carbon (DLC) coated biomedical stainless steel.

Project Objectives

This research aims to investigate the tribocorrosion performance of industrial DLC based coatings on biomedical 316LVM stainless steel. Untreated and CrN coated biomedical stainless steel will be used as benchmark materials.

Project Methodologies

Tribocorrosion tests were carried out using a reciprocating sliding tribometer against a 7.94 mm alumina ball counterface material, using a 2 N normal load, frequency of 2 Hz and sliding time of 2 and 9 hours. Tests were carried out in Ringer's solution to simulate the body fluids and under different electrochemical conditions to enable determination of the mechanical and electrochemical contributions to material loss. The resultant wear scars were analysed using microscopy and profilometry techniques.

Results and Achievements

- Uncoated stainless steel exhibited roughening of the scar surface and a total material loss which was two orders of magnitude greater than that exhibited by coated surfaces. Material was lost by both mechanical wear and corrosion.
- CrN coated 316LVM exhibited mild polishing wear together with localised severe damage in the form of coating blistering and delamination due to corrosion at the coating-substrate interface after tribocorrosion testing for 2 hours (Figure 1).
- Very small, often immeasurable damage was noted for DLC based coated 316LVM following tribocorrosion testing. Damage principally consisting of polishing wear and occasional mechanical damage of inherent coating growth defects (Figure 2).
- DLC based coatings were very resistant to electrochemical damage. Localised failure of the coatings as observed for CrN coated 316LVM did not occur even after prolonged (9 hrs) testing.
- The DLC based coating variants displayed a much lower coefficient of friction (~0.1) compared to the untreated material (~0.38).
- The excellent tribocorrosion performance displayed by the DLC based coatings makes them candidate coatings for further investigation as an implant surface treatment.

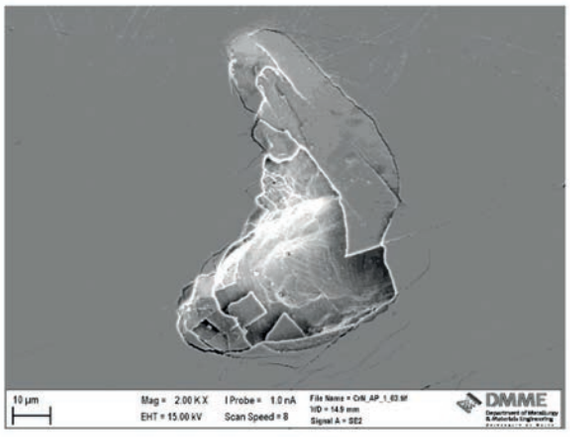

Figure 1: SEM image showing polishing wear and localised damage on CrN coated 316LVM following tribocorrosion testing

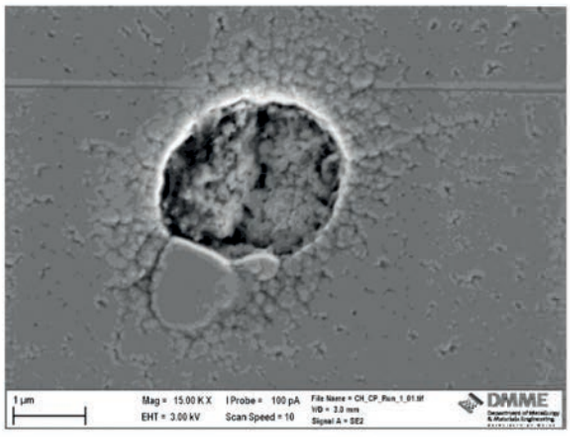

Figure 2: SEM image within the tribocorrosion scar on Si doped DLC specimen containing a coating growth defect

An Investigation of the Mechanical Properties of Transparent Plastic Tubing used In the Assembly of Intravenous Fluid Dispensing Sets

Student: Stephanie Calleja / Supervisor: Dr Daniel Vella / Co-Supervisor: Prof. Ing. Maurice Grech

Introduction

The mechanical properties of extruded PVC medical tubing material used in the assembly of intra-venous sets have been observed to alter with (i) ageing time and (ii) the type of polymer used. This effect is not a desirable one from a manufacturing point of view. In this work the mechanical properties of various plasticized PVC materials containing varying percent amounts of regrind (or recycled) were monitored with ageing time.

Project Objectives

(1) To evaluate the mechanical properties, namely tensile loading and hardness, of as-produced freshly extruded PVC tubing material containing increasing percent concentration of regrind.
(2) To investigate how the stress-strain behavior of the various tubing materials change with time.
(3) To describe any changes observed in (2) in the hope of improving component performance with time.

Project Methodology

PVC tubing materials containing different plasticizers were extruded and allowed to age in a conventional production environment. Standard tube lengths were subject to tensile loading and micro hardness measurements over a period of about 2 months. Specific tubing material was also examined by an infra-red spectroscopic technique in order to determine whether it is possible to monitor plasticizer loss with ageing.

Results and Achievements

Micohardness measurements of the as-produced tubes have shown that the tubing internal hardness is higher than that of external surface, i.e. the tube is softer on the outer surface. This effect was found to be due to a processing issue. Furthermore, the overall hardness of the tubing increases with ageing. The latter is very probably due to plasticizer loss with time. A comparison of the infra-red spectra of as-produced and aged tube material seems to support this fact.

One particular PVC material tested was observed to undergo changes to the stress-strain behavior at > 3200h ageing (Figure 1). A similar material containing the same plasticizer and the same percentage regrind did not show this phenomenon (Figure 2). The curve at 3200h in Figure 1 shows a clear transition point from elastic to plastic deformation corresponding to a well defined yield point (~10Pa). The material appears to be yielding at slightly lower loads, an indication that perhaps it is losing elasticity. Beyond the yield point the polymer chains undergo plastic deformation and align in the direction of tensile stress (the flat part of the curve) [1]. Aligned polymer chains offer more resistance, and the stress is observed to increase.

References

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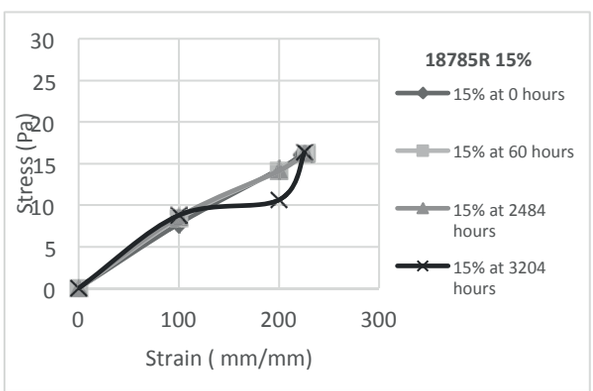

Figure 1: PVC material 18785R with 15% re-grind showing changes to the stress-strain behavior at 3204h

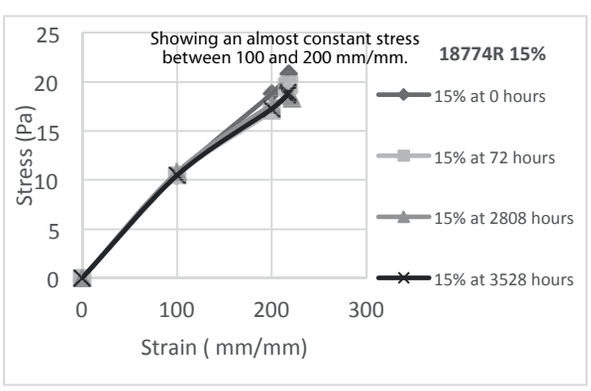

Figure 2: PVC material 18774R with 15 % re-grind, shows no such effect at >3500h

Investigating Welding Techniques to Deposit Hardfacing Alloy onto ADI

Student: Mark Cardona / Supervisor: Prof. Ing. Maurice Grech

Introduction

Manufacturing industries are always seeking materials that can provide them with the required properties. ADI is used in various applications in the industries where wear is a typical problem encountered. Hardfacing is a surface modification treatment used in industries to deposit an overlay in order to improve surface properties.

Project Objectives

The primary objective is to achieve an optimal overlay, free of cracks and satisfying the required properties. Two welding techniques, TIG and MMA, will be investigated as well as the effect of pre-heating and austempering before and after welding.

Project Methodologies

Hardfacing alloy was deposited onto the base material using two welding techniques, TIG and MMA. The flux was removed from the electrode when this was deposited using TIG, as protection will be provided by the inert gas. The electrode was used as-supplied when using MMA. Furthermore samples were subjected to different pre-heat temperatures and was applied both before (pre-austempering welding) and after (post-austempering welding) austempering.
Micro hardness profiling was carried out as this gave indication of the thickness of transformed underlay. XRD, EDS and SEM was carried out at depths in order to determine elements and phases present.

Results and Achievements

The hardfacing alloy was deposited successfully onto ADI by both welding techniques. The removal of flux, when depositing using TIG, resulted in an inferior hardfacing overlay due to the lack of alloying elements. The resulting microstructure consisted in martensite needles in a matrix of retained austenite shown in Figure 1.

On the other hand deposition by MMA resulted in a high hardness coating. The cracking of the coating was investigated and it was concluded that the austempering process after deposition relieved stress from the coating and thus resulted in a crack-free overlay with high pre-heating temperatures. The resulting microstructure consisted of Cr_7C_3 carbides in a FCC and BCC matrix for post-austempering and pre-austempering welding respectively. The pre-austempering welding experienced an increase in hardness when compared to the post-austempering. SEM images and phase diagrams showed that during the austempering the overlay experienced an increase in the volume of carbides and also a third phase, graphite, was formed. Microstructure of the pre-austempering overlay is shown in Figure 2.

Thus it was concluded that pre-austempering welding resulted in a better overlay microstructure both due to the increase in hardness of the overlay and also because the post-austempering overlay is not crack free which would be detrimental if a corrosive fluid is present during application.

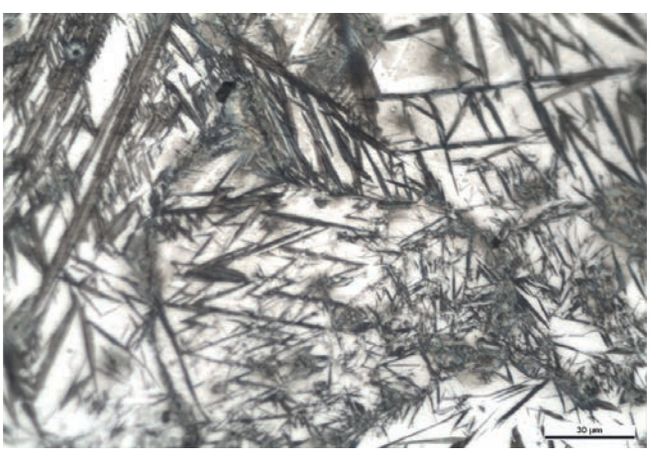

Figure 1: Microstructure of deposited alloy by TIG

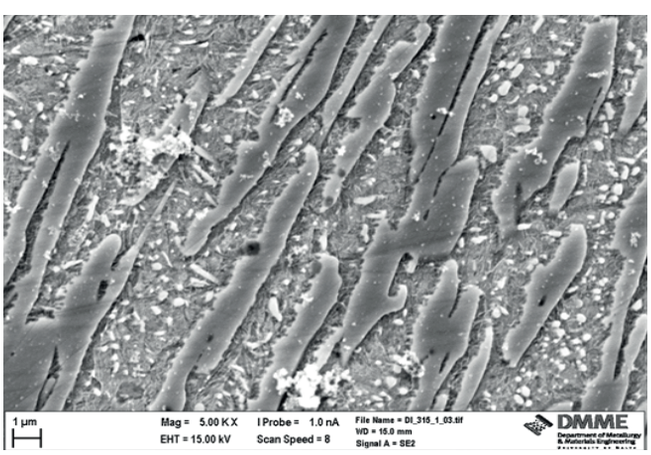

Figure 2: Microstructure of pre-austempering weld

The Development of DLC Coating Techniques on Magnesium Substrate

Student: Karl Joseph Chetcuti / Supervisor: Dr Ing. Stephen Abela

Introduction

Magnesium (Mg) is an ideal implant material due to its low cost and having natural biocompatibility within the body. Fast degradation rates of Mg in body fluid, does not provide enough healing time for natural bone repair, risking secondary fractures. This study aims, to reduce the rate of degradation through surface treatment, by developing DLC coatings.

Project Objectives

Coating techniques tried, were aimed at creating a tribological protective diamond like carbon coat (DLC) barrier on Mg substrate. Carbon coats obtained were identified, assessed for uniformity and hardness. Their protective quality in ringer's solution was tested.

Project Methodologies

Three techniques were tried to develop diamond like carbon coats (DLC). The first was to: deposit DLC on an electrically insulative oxide layer, by an oxide pre-treatment. The second was varied by, depositing DLC without the pre-treatment. The third technique used was: to deposit DLC in the presence of argon (Ar), omitting the pre-treatment again.

An innovative and streamlined plasma ion immersion implantation process (PIII) together with a plasma enhanced chemical vapour deposition (PECVD) process were applied, using a 20kV negative substrate bias, at 20kHz, by a DC pulse generator.

All samples were sputtered for 30 minutes, in Argon (Ar) and Oxygen (O_2) mixture. The precursor gas used for DLC deposition was acetylene (C_2H_2) and an O_2 etchant was used. The etchant served to preferentially remove graphitic-bonded carbon, whilst retaining the diamond-bonded carbon.

This oxide pre-treatment performed was done at a relative pressure of 0.028 mbars in oxygen plasma, for 60 minutes. Other samples were omitted this oxide pre-treatment, where only the intended DLC deposition parameters were used. For the last sample Ar aided deposition of the carbon coat, with a 50% concentration in acetylene.

Results and Achievements

The oxide pre-treatment did not seal the substrate sufficiently. Potentiodynamic tests show a drop in corrosion current for the pre-treated sample, when compared to the bare substrate. A small increase in corrosion potential was observed in the Ar treated sample.

Furthermore, no DLC was recorded as the deposition parameter for DLC using this setup has not yet been identified. What has been achieved is a deposition of graphite and amorphous carbon on the Mg substrates. Some of the coating would spontaneously pitt during or just after deposition due to the build-up of internal stresses in the coating

The C_2H_2 : O_2 ratio for DLC growth lies between 5% and 140%. At 5%, a uniform, non-adherent coat and hardness value of 20.02 GPa was reached, at 140% no carbon coat grew. At C_2H_2 : Ar ratio of 50%, a promising, non-uniform carbon coat grew.

Clearly more work is required to zero in on the parameter window for DLC, but a lot of understanding has been acquired through this work.

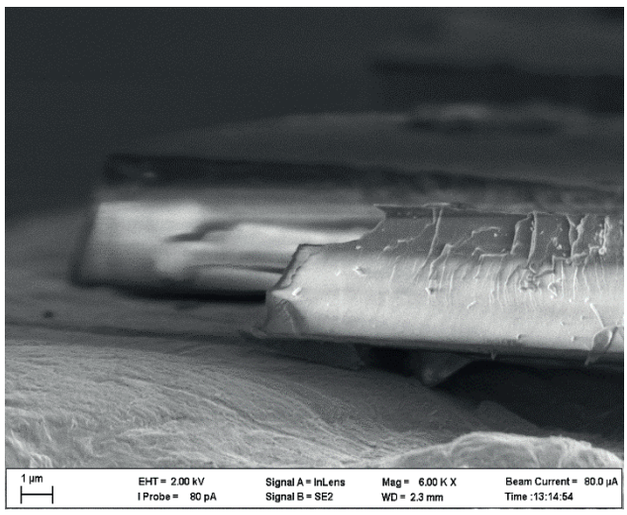

Figure 1: Amorphous diamond coating on pure magnesium substrate

Effect of EBM and EDM Post-Processing on the Microstructure and Mechanical Properties of EBM Parts

Student: Christian Ciantar / Supervisor: Dr Ing. Glenn Cassar / Co-Supervisor: Dr Ing. Arif Rochman

Introduction

Titanium and titanium alloys are among the best metals available for many engineering applications but limitations in the production of parts manufactured from titanium make their use limited and expensive. Electron Beam Melting (EBM) and Electrical Discharge Machining (EDM) are processes which reduce the time and cost of producing titanium parts.

Project Objectives

To manufacture and machine specimens using EBM and EDM techniques according to ASTM-E23 standard for notched bar impact testing of metallic materials.
To investigate the microstructure and impact properties of EDM-machined EBM titanium.

Project Methodologies

EBM was used to manufacture rectangular specimens which were later ground to reduce the surface roughness of the EBM process and achieve the required dimensions. EDM was then used to cut the v-notch required by the ASTM-E23 standard for impact testing.
Samples were prepared for characterization and the impact specimens were tested. The fractured specimens were then observed under optical microscope as well as Scanning Electron Microscope.
Some samples were also annealed to investigate whether heat treatment affected the mechanical properties of EBM-Ti

Results and Achievements

Microstructural examination shows that EBM-Ti has a structure typically seen in conventionally produced titanium parts but contains porosity which can be caused by argon gas [1] or by insufficient melting of the EBM-deposited layers [2].
EDM machining results in surface layers which include a re-cast layer and a heat affected zone. These include un-detached material and a refined structure respectively.
Impact testing and analysis found that like wrought titanium alloys, EBM-Ti is strong and tough. This is also confirmed in the fracture micrographs by the presence of shallow dimples (Figure 2).
Process annealing has little effect on EBM-Ti unless it is carried out at high temperatures both in terms of microstructural modification and in terms of mechanical properties.

References

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[2] [Attar E.], '[Selective Electron Beam Melting]' [Simulation of Selective Electron Beam Melting Processes], pp. [5-21]

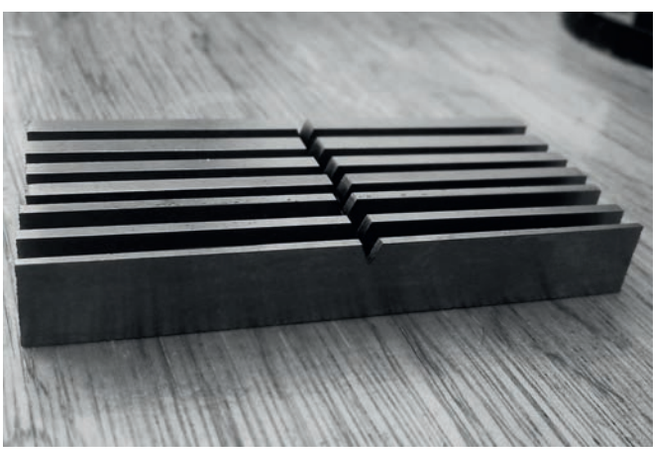

Figure 1: Impact Samples

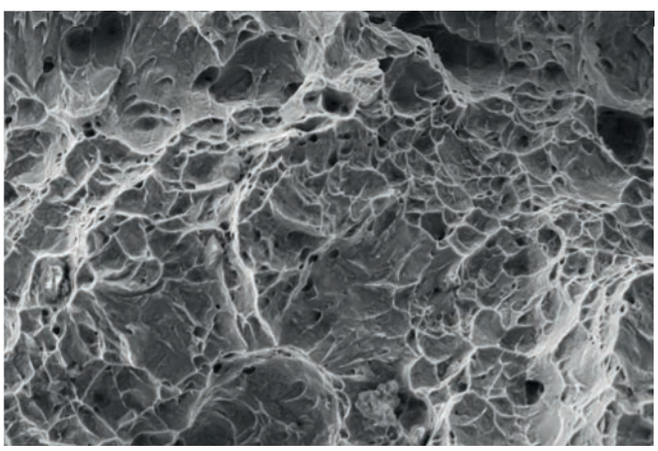

Figure 2: EBM-Ti fracture surface

Material Solutions for Effective Moisture-Gathering from Atmospheric Humidity

Student: Christian Ellul / Supervisor: Dr Ing. John Betts / Co-Supervisor: Ing. Paul Refalo

Introduction

Not all the countries of the world have an abundant supply of rain water, or other sources such as rivers, underground water and lakes, and can suffer from drought in populated areas. Hence it is important to investigate nonconventional techniques for water generation such as moisture gathering from atmosphere.

Project Objectives

Different material surfaces can promote or suppress the condensation and collection of water; thus the right choice of material for the collecting surfaces is critical to the success of the design. The objective of this project was to consider suitable materials and investigate their moisture gathering capabilities.

Project Methodologies

A material selection exercise was carried out to identify which are the best materials to be tested for the Maltese environment, basing on material already used for structures: this identified painted steel to get the best results.

A set of nine passive dew condensers were constructed to test different surface properties of different materials. A total of three material surfaces were tested.

1. Silicone base coated galvanized steel
2. Fatty-Acids base coated galvanized steel
3. Galvanized steel

From the material list one can identify that galvanized steel was used as a base material to eliminate any variables regarding the choice of material. The purpose for using the polymeric coatings was to increase the thermal emissivity of the material therefore giving it the capability to cool faster. The colour of coating chosen was white, to reduce the solar absorptivity during the day therefore reducing the thermal inertia of the passive dew condenser [1].

The Silicone and Fatty-Acids based coatings were used in order to prevent wetting, resulting in increasing the heat transfer capabilities and facilitate the collection of water [1].

Results and Achievements

The contact angle test suggested that the material with the largest water contact angle, the fatty acids-base coating, yielded the largest amount of condensed water. This was followed by the Silicone-based coating, with a 6% difference in yield, whilst the poorest performance was that of the galvanized steel without any coating, with a difference of 80% in condensed water yield compared to the best performance.

Dew (condensation) capture events for both polymeric coatings totaled fourteen over 29 days, whilst for the galvanized steel only five events were registered. A test carried out over nine hours showed that with a polymeric coating the surface of the condenser cooled more rapidly than the galvanized steel surface, which resulted in reaching the dew temperature faster and more frequent.

In conclusion the results obtained in this research helped to recognize the potential of dew collection systems in Malta.

Figure 1: Passive dew condenser array

References

[1] Incropera, F.P., Dewitt, D.P., Bergman, T.L., Lavine, A.A., 2007. Introduction to Heat Transfer. Unites States of America: John Wiley & Sons.

Corrosion Testing: Effect of Different Testing Parameters

Student: Christian Fenech / Supervisor: Dr Joseph Buhagiar / Co-Supervisor: Dr Daniel Vella

Introduction

The lifetime expectancy of surgical implants is increasing drastically with time. Nevertheless the corrosion and degradation of these implants in the harsh body environment remains an imperative issue. BS and ASTM standards were formulated as a guideline in order to help researchers assess the corrosion resistance of biomaterials.

Project Objectives

Using different parameters than those stipulated in the standard will create a degree of variability in the results. It is therefore of utmost importance to understand which parameters have the greatest effect on corrosion testing.

Project Methodologies

A standard procedure was formulated from the BS and ASTM corrosion standards in order to achieve a bench mark test for further analysis. All testing was carried out on a B hler P558 Ni-free stainless steel. Analysis of the effect of varying the scan rate in relation to corrosion results was carried out at three different scan rate speeds (0.17 mVs^{-1}, 1.7 mVs^{-1}, and 17 mVs^{-1}). Further analyses were performed in terms of corrosion with varying surface roughness, testing in acidified Ringer's solution (pH 2), and also carrying corrosion tests in an electrolyte which was de-oxygenated with nitrogen gas for different time periods. Finally Kolsterising® was successfully performed on P558 nickel free stainless steel in order to analyze if the treatment had any effects on the corrosion resistance of the alloy.

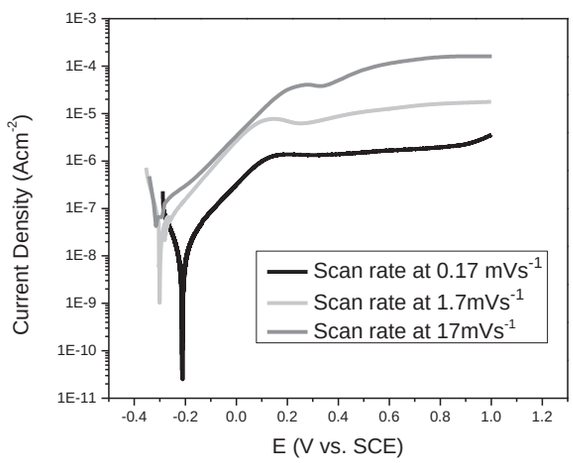

Figure 1: Potentiodynamic curves for Ni-free stainless steel at three different scan rates

Results and Achievements

Results showed that corrosion testing is strongly dependent on the scan rate speed. From figure 1 it is observed that as the scan rate was increase, there was not enough time for the stabilization of the reactions happening on the passive film (charging of the double layer capacitance) [1, 2]. This led to an abrupt increase in the passive current density.

Furthermore it was noted that as long as a surface roughness (R_a) of less than 1 µm was achieved on the testing surface, no significant changes between tests were observed (figure 2). Also it was determined that the right de-oxygenation is important to achieve an adequate repeatable constant testing solution between different tests. An adequate de-oxygenated testing solution was achieved after bubbling nitrogen gas for 15 minutes at a flow rate of 2 $lmin^{-1}$.

The Kolsterising® process improved by far the mechanical properties of Ni-free stainless steel. However no significant improvements were observed attributed to corrosion resistance (figure 2).

References

[1] D. A. Jones, *Principles and prevention of corrosion*, 2nd ed. Upper Saddle River, NJ: Prentice Hall, 1996.

[2] A. Poursaee, "Determining the appropriate scan rate to perform cyclic polarization test on the steel bars in concrete," *Electrochimica Acta*, vol. 55, pp. 1200 - 1206, 2010.

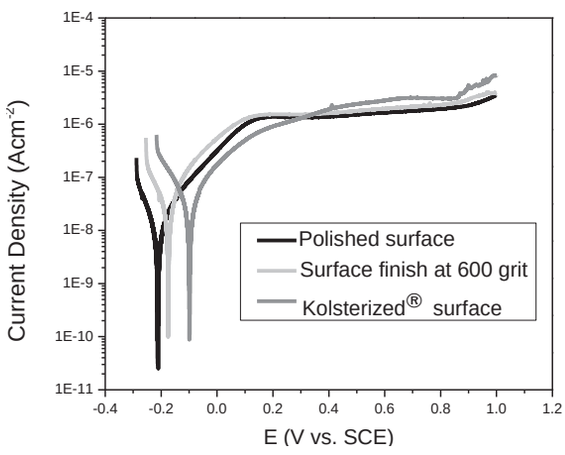

Figure 2: Potentiodynamic curves for Ni-free stainless steel at three different surface conditions

Control of Dissolution Rate of Pure Magnesium

Student: Emanuel Grech Calafato / Supervisor: Dr Ing. Stephen Abela

Introduction

Magnesium is one of the important biomedical materials owing to the fact that it is the fourth most important cation in the human body. However, it degrades at a rate fast enough to compromise the structure of the implant. Many researches have been carried out to increase the corrosion resistance of magnesium alloys for structural and biomedical purposes. Plasma immersion ion implantation (PIII) is one example of such technologies used in the biomedical sector for providing thin protective surfaces ranging from nitrides, diamond-like-carbon (DLC) and oxides. In this study, cylindrical grid-assisted oxygen plasma immersion ion implantation on pure magnesium was carried out at different treatment times and potentiodynamic tests were carried out in Ringer 's solution.

Project Objectives

The aim of this project was to reduce the corrosion rate of pure magnesium in a simulated body fluid (SBF), by modifying the surface with plasma immersion ion implantation and by growing an oxide film.

Project Methodologies

Literature review was carried out on the corrosion mechanisms of pure magnesium, along with surface engineering used for protection of the material including plasma immersion ion implantation. Sample preparation was carried out using abrasive papers and isopropanol followed by 1 m diamond paste. The samples were sputtered for 30mins using Ar and O2. Surface modification was conducted with O2-PIII at pressure 6.04x10-2mbar and -20kV bias voltage. Different treatment times were carried on each sample (60mins, 120mins, 180mins). Characterization was carried out using scanning electron microscopy (SEM), electron dispersive spectroscopy (EDS) and X-ray diffraction (XRD). Cross sectioning was carried out on the samples in order to determine the oxide film thickness. Corrosion analysis was observed under potentiodynamic scans in a 250ml Ringer's solution at a constant temperature of 37 1oC to simulate body conditions. Corrosion product images were obtained with SEM and Nikon optical microscope.

Results and Achievements

The surface modification favoured growth of magnesium oxide in the form of clusters of 0.2 to 0.5 m as illustrated Figure 1. The protective qualities of the surface oxide was significantly compromised by surface damage and arcing. These defects did not induce any superficial stresses or accelerated corrosion in any way. The polarization curves were nobler with treatment time. Increasing the treatment time did not result in improved corrosion protection mainly due to the presence of arc induced defects. However a test conducted on a defect free region showed a significant shift in polarization curve with respect to the untreated sample. In the context of corrosion resistance, such a result was comparable to plasma immersion ion implantation and deposition (PIIID) of Ta on NiTi stents studied for cardiovascular stent applications [1].

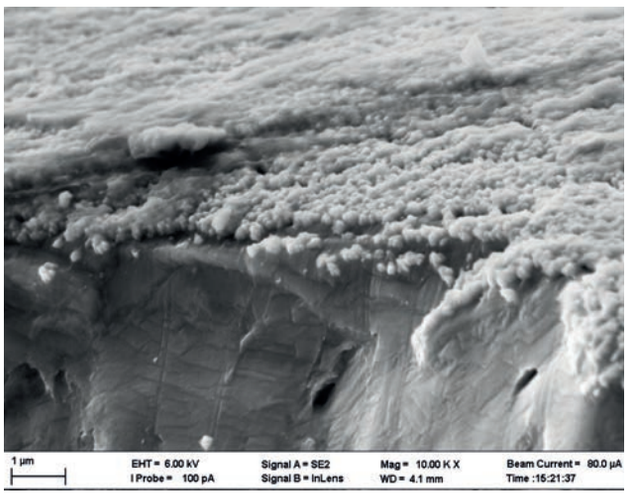

Figure 1: Oxide clusters

References

[1] Zhou Y., Li Y., Cheng Y., Zheng Y F., Xi T F and Wei S C., 'Tantalum coated NiTi alloy by PIIID for biomedical application' Surface and Coatings Technology, 2013, Vol. 228, No. 1, pp. S2-S6

Corrosion-Wear Response of Duplex-Coated Ti-6Al-4V Alloy

Student: Christian Micallef / Supervisor: Dr Glenn Cassar / Co-Supervisor: Dr Bertram Mallia

Introduction

Tribocorrosion is a degradation phenomenon of material surfaces subjected to the combined action of mechanical wear and corrosion giving rise to material loss. The material lost during tribocorrosion is not merely the additive effect of material lost due to corrosion and mechanical wear but the combination of both contributing to a higher (or lower) material removal rate giving rise to synergistic or antagonistic effects respectively.

Project Objectives

In this project four surface-treatments were investigated and compared to untreated Ti alloy - Ti-6Al-4V including, PVD Titanium Nitride (TiN), duplex TPON-TiN, PVD Chromium Aluminum Nitride (CrAlN) and duplex TPON-CrAlN. Triode Plasma Oxidation / Nitriding (TPON) is a thermochemical treatment used for the formation of hard nitrides and oxides, increasing the wear resistance and improving the tribological properties.

Project Methodologies

A ball-on-disk tribometer setup was used to assess the tribocorrosion behavior with a three electrode system consisting of the working electrode, a platinum counter electrode and a Saturated Calomel Electrode (SCE) reference electrode. Each coupon was tested under different electrochemical conditions to determine the behavior of the coupons under pure mechanical wear and corrosion conditions.

Results and Achievements

Under tribocorrosion testing untreated Ti-6Al-4V suffered the most extensive damage (figure 1). Micro-cracks, grain pull-out and adhesive wear were identified within the wear scars under SEM. The contact area of the alumina ball was also extensively damaged indicating the poor abrasion resistance of the titanium alloy.

All the coatings exhibited minimal corrosion due to wear which can be considered as negligible, suggesting that pure abrasion is the predominant mode of material degradation in all cases producing polished wear scars.

An antagonistic effect was recorded in the case of PVD TiN and duplex TiN. This behavior is attributed to the formation of surface features such as the formation of layers which facilitate shear or layers that inhibit corrosion causing a change in the tribological contact.

The PVD CrAlN exhibited the least material loss with polishing wear as the predominant outcome of reciprocating sliding (figure 2). The grinding marks formed during the grinding process, prior to the coating deposition could still be clearly identified after the tribocorrosion tests.

The duplex CrAlN coating was also affected by polishing wear however the degree of polishing was lower than that obtained for the PVD treated counterpart.

Figure 1: SEM Image of the wear scar produced on untreated Ti-6Al-4V

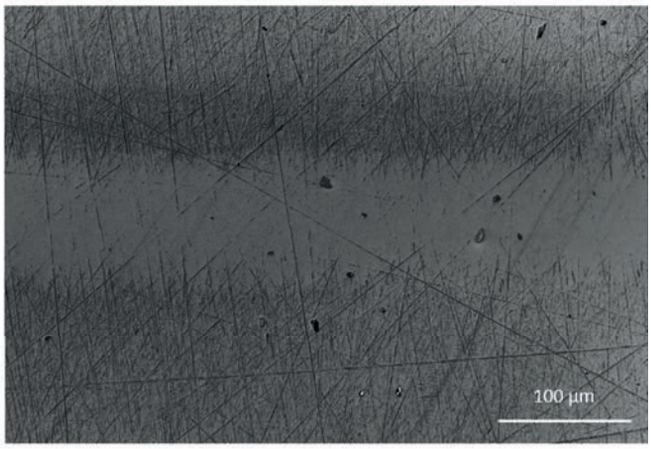

Figure 2: SEM Image of the wear scar produced on PVD CrAlN coating

Recycling of Rubber

Student: Marvic Sultana / Supervisor: Dr Ing. Stephen Abela / Industrial Partner: Pamargan Products Ltd.

Introduction

The extensive use of rubber combined with its longevity resulted in a growing volume of rubber waste. This gave rise to the problem of rubber waste management. The most common method for handling post consumer rubber products is to dispose of the material by dumping it in landfills which however leads to wastage of valuable material and a damage to the environment.

Project Objectives

The primary objective of this thesis focuses on finding a feasible method of recycling scrap rubber generated by Pamargan Products (Malta) Ltd. For this scope, a hypothetical by product was to be chosen and a prototype made out of this rubber material. The design was to be selected based upon a simplified investigation of a potential application for this rubber waste material.

Ageing effects and degradation mechanisms of the rubber were also studied and tested to assess the suitability of two different rubber formulations for this type of service.

Project Methodologies

The project was divided into three distinct phases which cover: the testing of the rubber material and evaluation of its properties, the development of the rubber design and the testing of the physical models.

To tackle this problem, a design approach was followed, starting with the identification of a potential application from a market research study. A series of tests were performed to assess the characteristics of the raw materials used to develop the final products.

Research on existing products on the market was carried out as an initial brainstorming, from which a series of concepts were generated and the most feasible design was selected. The effectiveness of the chosen design was determined by the fabrication of two physical prototypes which were finally tested to assess their performance for the intended application. Product development was concluded with an analysis of the product's potential on the targeted market sector.

Results and Achievements

This project considered the re-use of scrap EPDM rubber as a surfacing material, in particular within outdoor playgrounds with minimal re-processing. The results obtained gave a clearer picture on the feasibility of the rubber product for this application and suggested a sustainable and environmental friendly way of recycling scrap rubber. One of the most significant findings which emerged from this study was that through the proposed design, comprising of a rubber honeycomb sandwich construction, about three fourths of the rubber waste which is currently being generated at the rubber plant can be transformed into useful rubber material.

As per the ageing tests, it was found that changes in material properties were significantly retained after a six month ageing period. Findings also showed an excellent resistance of the rubber material towards moisture absorption, swelling in water, degradation from biological attack, and resistance to high cure temperatures. Stiffness results also confirmed that the two rubber mats created in this project offered sufficient anti-fatigue performance when compared to other surfacing materials.

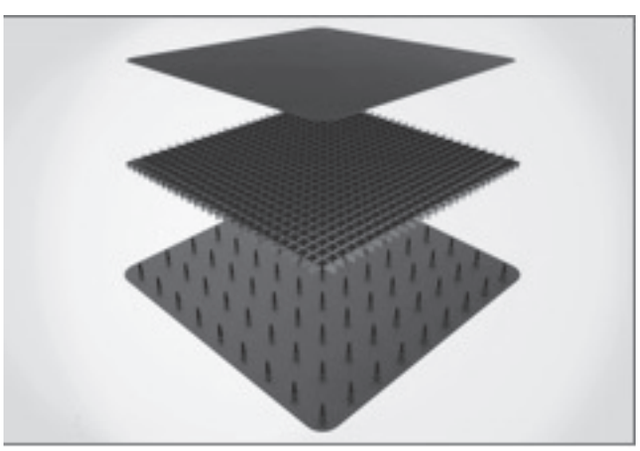

Figure 1: Rendering of rubber mat design on Autodesk Inventor

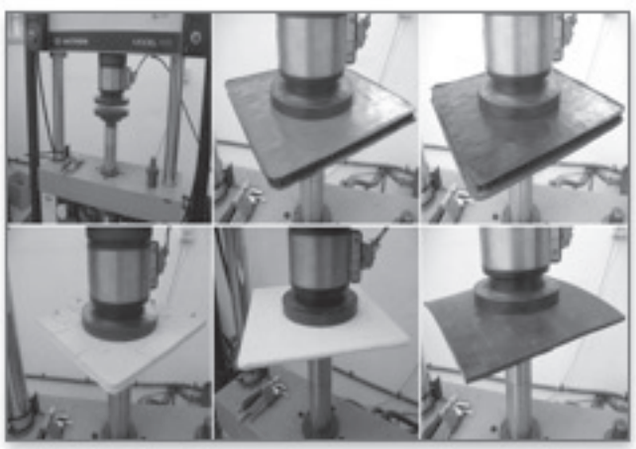

Figure 2: Testing of different surfacing materials in compression

Characterisation and Biocompatibility of Kolsterised® Biomedical Grade Stainless Steel

Student: Michaela Zammit La Rosa / Supervisor: Dr Joseph Buhagiar / Co-Supervisor: Dr Pierre Schembri-Wismayer MD

Introduction

Presently, stainless steels are used in biomedical applications due to their superior corrosion resistant properties. However, their use in load bearing articulating applications is limited due to poor tribocorrosion characteristics. By improving the surface hardness of 316LVM austenitic stainless steel through the application of a carbon diffusion treatment called Kolsterising®, these corrosion-wear problems could be reduced and/or eliminated.

Project Objectives

The objective of this project was to establish whether the biocompatibility of 316LVM austenitic stainless steel was preserved or improved after the Kolsterising® surface treatment.

Project Methodologies

Kolsterising® was performed by Bodycote Hardiff GmbHon 316LVM austenitic stainless steel. This imparted a precipitate free, carbon rich S-phase layer onto the surface of this alloy.

Characterisation tests were performed to determine the presence of S-phase on the stainless steel. Since the surface chemistry and phase of the untreated material was changed by the treatment, the biocompatibility of Kolsterised® stainless steel was also investigated to determine whether the biological properties of the substrate were retained or better still improved by the treatment. MTT biocompatibility tests using a MC3T3-E1 mouse osteoblast cell line where carried out in accordance with BS EN ISO 10993-5.

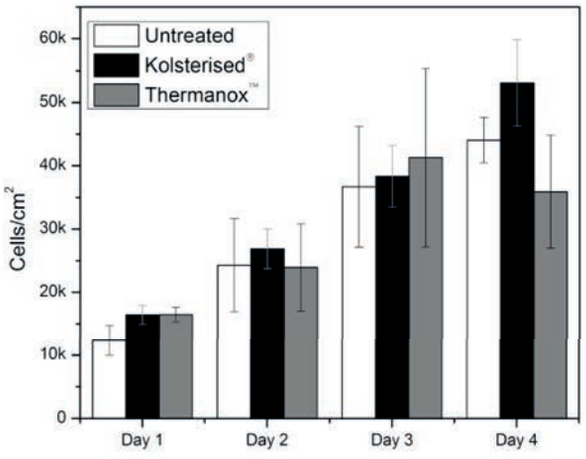

Figure 1: MTT test showing cell growth using MC3T3-E1 cells

Results and Achievements

The Kolsterising® treatment produced a precipitate free, carbon rich layer of S-phase with an average thickness of 40.4μm ±2.1μm. The treatment increased the surface roughness and improved the mechanical properties of the steel particularly the hardness, which reached a maximum of 12.7GPa ± 1.5GPa; an increase by a factor of 5 compared to the untreated stainless steel.

MTT tests using the MC3T3-E1 cell line revealed that the biocompatibility of Kolsterised® stainless steel was not reduced when compared to its untreated counterpart and positive control (Figure 1). All Kolsterised® samples permitted cell attachment and proliferation and representative images after 1 to 4 days are shown in Figure 2. A carbon absorption of 4.0gm^{-2} was recorded in this study. This increase in carbon content [1] imparted by the Kolsterising® together with a change in surface roughness possibly improved the proliferation of cells to the surface of the steel when compared to the untreated alloy [1].

References

1. Buhagiar J., Bell T., Sammons R., and Dong H., "Evaluation of the biocompatibility of S-phase layers on medical grade austenitic stainless steels," Journal of Materials Science: Materials in Medicine, 2011, vol. 22, pp. 1269-1278.

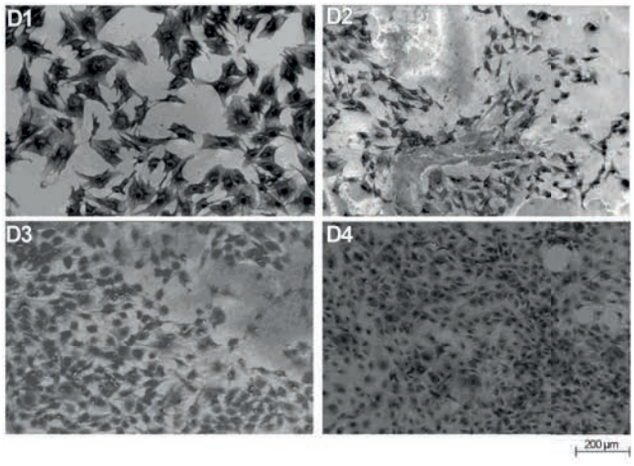

Figure 2: SEM images showing progression of growth over time (D1 = day 1, D2 = day 2, D3 = day 3, D4 = day 4)

Baxter

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