ROYAL NAVAL ENGINEERING COLLEGE POST-GRADUATE PROJECTS 1992–1993

As part of the Advanced Marine Engineering Course (MSc Course in Marine Engineering) at the Royal Naval Engineering College, Manadon, each student spends 17 weeks working at a particular research project. A summary of each project completed by the course of 1992–93 is printed below.

Advanced Marine Engineering Course

Underwater electrical fields associated with cathodic protection
by LIEUTENANT M.R.T. WESTWOOD PGDIP MSC (EUR ING) CENG MIMARE MIMECHE R.N.

Underwater electrical fields and potentials around cathodically protected stylized model hulls were experimentally examined by DACS (Dimension and Conductivity Scaling) physical scale modelling. Various experimental survey methods were compared using both continuous real-time and discrete point measurements. Survey methods included absolute potential measurement with reference to a point remote in the field (a 'virtual earth') and field potential measurement with reference to the hull. The field was also measured directly using miniature electrode pairs on three mutually perpendicular axes. A variety of methods of displaying the potential distribution for interpretation were presented including:

- Potential profiles.
- Contours.
- Vector plots,
- For the first time using DACS, 3D surfaces.

A mathematical model of the system was developed on EXCEL, a powerful spreadsheet, using analytical solutions to LAPLACE's equation which included the boundary conditions in the experimental tank. A good correlation between practical and modelled results was obtained using point source/sink approximations for the anode and cathode areas. The field is best visualised by examining the distribution of absolute potential around the system, characterized by potential peaks around the anodes and troughs around the cathodes. The magnitude of the peaks and troughs are determined only by the system current.

An expression for hull potential, in terms of absolute potential and the ICCP set potential, was derived and validated using the experimental survey results.

The superficial hardening of steel through induction heating
by LIEUTENANT P.D. GILBERT BENG MSC ACGI CENG MIMECHE MIMARE R.N.

This project was carried out at the Ecole Nationale Superieure des Ingenieurs des Etudes et Techniques d'Armement (ENSIETA) in Brest, France. This was the first time that the link between ENSIETA and RNEC involved an exchange of students. The work was undertaken in French and presented at ENSIETA on 23 April 1993. The influence of various parameters on the effectiveness of superficial induction hardening was studied and a single-shot process optimized to achieve a case depth of about 1 mm around the continuously blended region of steel fatigue test specimens with a minimum diameter of 7 mm. The maximum tensile stress increased by over 30% and ductility reduced by over 60%, since the

cross sectional area of the case corresponded to about 50% of the minimum area. The fatigue limit, based on testing up to two million cycles, increased by about 40%, with most failures occurring as the fatigue crack entered the ductile core. The striation spacing, identified in a number of specimens, was approximately constant through the hardened case. The propagation phase was of the order of 1000 cycles, a small proportion of the total life, indicating that the improvement in fatigue life was primarily due to an increase in the resistance to crack initiation rather than to prolonged propagation.

Identification and control of the Tecquipment FH2/3 Mk III arranged as a motor generator set
by LIEUTENANT C.J. SAXBY BENG(HONS) MSC CENG MIMARE R.N.

The elimination of the automatic voltage regulator and governor interaction in diesel-generator systems is considered beneficial to system efficiency, as the cross-coupling effects between speed and terminal voltage may be removed. A motor generator set exhibiting similar coupling or interaction can be modelled as a coupled system, following the application of off-line identification techniques utilizing open-loop steady state and transient characteristics.

The work done describes the identification process used to establish a mathematical model of a bench-top motor generator system. This multivariable system is then satisfactorily decoupled by the use of a pre-compensator, thus permitting the design of single-loop controllers for the machine.

Propulsion design and predicted efficiency package
by LIEUTENANT COMMANDER M.S.LEITE BENG MSC Brazilian Navy

During the feasibility and conceptual phases of a warship design, a very important and decisive task is to define the propulsion system. The choice of a particular configuration involves several technical and operational considerations. A lack of data, combined with the relatively small marine market, means that a database is difficult to construct, and is of little use if a particular design requires deviation from what is previously known. There are several configurations that can be employed to achieve a particular performance for a given hull design, and a broad comparison amongst them can lead to the correct choice.

This project presents the results of the development of a software package that provides the marine propulsion design engineer with important information to help him decide for the most suitable propulsion option to choose. For this particular option the information is presented in terms of the overall efficiency of the propulsion system, its fuel consumption and endurance for various configurations using the same hull, in a user-friendly environment. This technique provides the design engineer with the means to evaluate and compare the through life costs for a wide range of drive systems.

The modularity of the software package will allow the design engineer to easily implement other hull form data. A method to prepare all data necessary for the calculations from data normally found in equipment catalogues or other sources has also been developed, with extensive use of a spreadsheet.

A study into gas turbine combustion testing and mathematical modelling
by LIEUTENANT J.J. MERRITT BENG(HONS) MSC CENG MIMARE R.N.

This project identifies those combustion parameters effected by the reduction in testing pressure, allowing a testing philosophy and redesign recommendations to be proposed for the atmospheric combustion testing facility at the Royal Naval Engineering College (RNEC). It is proposed that atmospheric testing be conducted with inlet temperatures, velocity flowfields and fuel injection characteristics experienced under in-service conditions reproduced under atmospheric conditions. These prerequisites to testing ensure alterations of geometries and jet

locations to produce desired recirculating flowfields may be investigated at atmospheric conditions with confidence that the effects will be echoed under in-service conditions. In addition, the qualitative effect of various changes on emissions, and other parameters not valid at atmospheric conditions, may be observed thus reducing the range of pressurised testing required.

CFD combustion modelling was conducted to assess the capability of the code to model the combustion in the Rolls-Royce TYNE combustor fitted to the test rig at RNEC. Comparison with previous CFD studies gave confidence that results were representative despite the simplified single step global combustion reaction used. Further CFD analysis would permit design modifications to be investigated, predictions being scrutinized in the atmospheric test rig.

A feasibility study into waste heat recovery from gas turbine exhaust utilising heat pipe heat exchangers
by LIEUTENANT K.L. SPICER BENG(MECH) MSC CPENG CENG(U.K.) MIEAUST MIMARE Royal Australian Navy

Exhaust from marine gas turbine propulsion engines offers a source of good quality heat, suitable for recovery and use in auxiliary and domestic ship services. Previous attempts in achieving this using conventional air-to-water heat exchangers were unsuccessful from catastrophic water side failures and the heat exchanger pressure drop hindering gas turbine performance.

The use of heat pipes enables a reliable, high output, compact heat exchanger to be employed. This feasibility study models and analyses the thermodynamic performance of a waste heat recovery pipe heat exchanger designed for use with the LM2500 gas turbine installed on FFG-7 class ships.

A combination of computational fluid dynamics, individual heat pipe performance estimates, and heat exchanger evaluation based on the effectiveness-number of transfer units methods of analysis were utilized, showing that between 440 to 500 kW of waste heat can be recovered from each engine operating in the 3,000 to 20,500 SHP power range.

Heave and pitch motion control of a SWATH vessel
by LIEUTENANT COMMANDER R.E.J. ENGLISH BASC MSC Canadian Armed Forces

Small Waterplane Area Twin Hull (SWATH) ships present an attractive alternative to single hull ships in some naval applications. By the nature of their shape, SWATHs are subjected to significantly smaller wave exciting forces and moments. Thus, SWATHs are subject to notably smaller sea induced movements than similar single hull ships over most conditions. The application of actively controlled fins could reduce these motions even further.

This report describes the design and evaluation of several controllers for the reduction of heave and pitch vertical plane movement in a SWATH. Both quasi-classical and optimal control techniques are explored. Simulations using the MATLAB and SIMULAB software packages were conducted to evaluate controller effectiveness. Estimates of stability robustness are also generated.

This project report concludes that the standard proportional and proportional plus derivative control techniques can be effective with an accurate system dynamic models. It also concludes that even rudimentary linear quadratic Gaussian control can be effective and provide substantial stability robustness with smaller fin motions than those required by classical controllers. The effect of fins dynamics must be included in any future work in this field.

An investigation into using the rudder for lateral force stabilization
by LIEUTENANT S.A FRENCH BENG(HONS) MSC R.N.

A study has been carried out to investigate the stabilization of the lateral accelerations experienced parallel to the weather deck on a Type 22 frigate using the existing rudder system.

This report describes the development of warship and sea state disturbance models to estimate the lateral accelerations by means of a Lateral Force Estimator. A rudder roll stabilization control strategy was used and the lateral force stabilization achieved was assessed. A classical frequency domain sensitivity analysis technique was used to refine the controller designs. Simulation studies are described that quantify the dynamic characteristics of the controlled system.

This study concludes that a rudder roll stabilization strategy using the current rudder system can achieve a degree of roll and lateral force stabilization. The increase in the absolute acceleration component of the lateral force estimator is significantly less from controllers that are tuned to a lower frequency.

The study has concentrated on the Type 22 frigate but the application of the lateral force estimator modelling technique used is suitable to all warships.

Design and construction of a variable mode three-phase Pulse Width Modulated (PWM) drive
by LIEUTENANT COMMANDER M. SYKES BENG MSC CENG MIMARE R.N.

A three-phase inverter and associated firing circuits were designed, to enable future investigations to be undertaken into the optimization of the harmonic content of the output waveform. The inverter used gate turn-off thyristors (GTO's) and utilized a PWM switching regime.

A computer software package was developed to provide the firing circuit trigger pulses. The programme allowed the user full control of the parameters required to generate a PWM waveform. The inverter output frequency was shown to be within 0.5% of the desired frequency, with a sampling accuracy of greater than 0.5 degree of the reference wave.

A spectrum analyser was used to demonstrate the effectiveness and flexibility of the system for the study of harmonics, the results for a number of PWM switching options have been analysed and discussed.

Although the inverter output voltage and frequency could not be controlled in 'real time', the novel approach to the generation of the trigger pulses has led to an outline design for an optimized PWM controller to be proposed. This design has the potential to standardize the controller hardware for the majority of applications.

Exhaust emission evaluation of the Paxman 12RP200 engine using the diesel engine simulation package 'SPICE'
by LIEUTENANT S.M. GRANTHAM BSC(ENG) MSC R.N.

At present no global exhaust emission regulations apply to marine engines. However, there can be no doubt that global legislation will be imposed on marine diesel engines. The Royal Navy currently uses the PAXMAN VALENTA 12RP200 series engine for on board electrical power generation and thus this engine will be subject to future emission legislation.

Bath University's Simulation Program for Internal Combustion Engines (SPICE) was used to model the 12RP200 engine. This model was validated against real engine data for both general engine parameters and emission levels. The validated model was then used to evaluate various engine based techniques for exhaust emission reduction, including variable point of fuel injection, variable valve timing, enhanced intercooler performance, pilot or split injection and injection rate shaping.

It was found that SPICE simulated the Nitric Oxide (NO) emissions from the 12RP200 well, and that the other predicted emissions trends agree with experimental results. Reductions in NO emissions by up to 60% of current levels have been predicted by simulation and these were achieved without resorting to exotic and costly engine and exhaust management systems.

Development of a mount using Electro-Rheological Fluid (ERF)
by LIEUTENANT N. BOYD BSc MSc CEng MIMechE R.N.

The electro-rheological effect whereby certain fluids exhibit solid like properties in a high voltage electric field was discovered in the late 1940's. They have been proposed for use in engineering devices such as clutches, anti-vibration mounts and as valves in fluid power systems. Research on these fluids and devices incorporating them has been undertaken at RNEC for a number of years. This project has used the knowledge and experience thus gained to design, build and test a mounting system for an aerospace application. A number of possible configurations of ERF devices were comparatively evaluated and a multi-plate rotary arrangement was eventually selected. Use of this damper to control steady state and random vibration as well as the response to shock are analysed and discussed. Testing of the damper in isolation produced satisfactory results, with a large increase in damping being observed when the device was energized. Recommendations for future work to produce an operational mounting system are discussed.

The full reports are held at the RNEC Manadon and further information may be obtained from:

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