RN ENGINEERING COLLEGE, MANADON, POST-GRADUATE PROJECTS

The Royal Naval Engineering College provides two MSc courses, namely the Advanced Marine Engineering Course (AMEC) and the Advanced Maritime Defence Technology Course (AMDTC). The officers on each course undertake individual research projects, full time, over some 17 weeks during the final part of their course.

Summaries of projects completed by officers of AMEC 26 and AMDTC 90 are given below. Full reports are held at Manadon and further information may be obtained from the Advanced Marine Engineering Course Officer, Royal Naval Engineering College, Manadon, Plymouth PL5 3AQ.

The Effect of Turbine Blade Erosion on Aerodynamic Performance
by Lieutenant-Commander R. F. A. Findlay, BEng, MSc, Canadian Forces

Development of Equipment Health Monitoring techniques for gas turbine engines is necessary to reduce operating costs and to increase availability. The comprehensive data bases required to analyse equipment trends must be provided by accurate computer models which will predict the changes that occur in an engine's aerodynamic performance as a result of different failure mechanisms.

This project describes the development of a procedure which uses a computer model to predict the pressure loss coefficients resulting from an erosion failure mechanism in the Spey SM1A HP1 rotor blade. This information is used to predict stage and turbine efficiencies which in turn are used to estimate the effects of erosion on the gas turbine engine's overall performance.

A procedure has been developed which will allow the calculation of engine parameter changes based on the aerodynamic predictions of a computer model. The work carried out predicts changes in the fuel flow, power turbine entry temperature and the high pressure spool speed which is substantiated by measurements of an operational gas turbine. Recommendations include development of a fully three-dimensional model, investigation into progressive erosion, and creation of models for other engine faults.

Application of Pneumatic Control Vibration Absorber
by Lieutenant-Commander K. Q. Fong, BEng, MSc, Canadian Forces

Structural modifications and redesign of machinery as a method of reducing unwanted levels of vibration are costly, often time-consuming and at times ineffective. The concept of applying Pneumatic Control Vibration Absorbers

to systems with a single source of excitation was previously investigated and found to be effective. To extend the development of this concept to a multiple excitation system, a Perkins 6-cylinder diesel generator set is selected for the study.

The study begins with a thorough understanding of the IC engine. The theoretical analysis of the sources of excitation of the IC engine as well as the most effective attachment locations for the absorbers are discussed. A mathematical model of the diesel generator is developed based upon modal analysis techniques and is used to study the effect of the vibration absorbers through computer simulation. Finally, the results of engine vibration trials with absorber(s) fitted are discussed.

Trials were limited by the availability of the absorbers and the time constraints of the project. Several observations are made based on measured data and computer simulations. The study shows that vibration reduction of the diesel generator set can be achieved, but the effectiveness of the pneumatic control vibration absorbers is severely limited by the locations at which the absorbers can be attached.

A Parametric Evaluation of the Performance of a Diesel Engine When Running Under Simulated Closed Cycle Diesel Conditions
by Lieutenant-Commander M. G. Lutje Schipholt, MSc, Royal Netherlands Navy

One of the major problems with the closed cycle diesel is the presence of carbon dioxide in the recycled exhaust gases. Carbon dioxide will reduce the thermodynamic properties of a diesel engine's moderating medium unless a counteracting gas such as argon is added to reproduce the properties of 'free air'. If the properties of free air are not reproduced, the diesel engine's power output and thermal efficiency will be affected.

To enable the diesel engine performance to be investigated when running on non-air mixtures the Simulation Program for Internal Combustion Engines (SPICE II) has been modified. This report describes the comparison of predicted engine performance with experimental results captured from a Perkins 4-cylinder diesel engine capable of running on selected non-air mixtures. Selection of the right heat release model within SPICE proved to be of great importance to predict engine performance correctly.

This study concludes that predicted engine parameters and experimental results followed the same trend with good correlation; running both naturally aspirated and with non-air mixtures.

During this study SPICE was also used to predict engine parameters for the Rotterdam Dockyard Company (RDM). RDM, sponsored by the Royal Netherlands Navy, is currently developing a pressurized 600 kW closed cycle diesel system, to be implemented as a hybrid system for future submarines.

The Development and Validation of a Computer Simulation to Enable an Investigation into the Effects of Inverter Induced Torsional Vibrations in Marine Electrical Propulsion Systems
by Lieutenant-Commander M. N. Parker, BEng, MSc, CEng, MIMarE, RN

Variable speed a.c. drive systems are being considered for future warship propulsion. To meet the Royal Navy's stringent low noise signature criteria, the effects of inverter-induced motor torque pulsations on propeller performance must be well understood and controlled.

This report details the design and instrumentation of a laboratory sized practical scale model of a ship's electrical propulsion system used to provide torsional vibration information. A d.c. motor controller was developed so that the motor exhibited the same torque/speed characteristics as a modern fixed

pitch propeller in the transient and steady state conditions. Using Generalized Machine Theory, Park's transformations, an extension of Holzer's transfer matrix theory and MOD-supplied propeller characteristics, a computer simulation was developed to model an electrical propulsion system. This simulation was validated using data obtained from the practical scale model.

The effects of inverter-induced torsional vibration on propeller performance were then investigated. The report's main conclusions are that significant propeller vibrations are created when the inverter supply sideband separation frequency coincides with a shaft system resonant frequency. This torsional vibration is independent of the number of machine poles and the degree of slip. Also, the damping effect of the immersed propeller results in low frequency acoustic energy being imparted to the surrounding sea water, which could significantly increase the ship's radiated noise signature. It is recommended that further research be conducted into inverter-induced torsional vibrations.

Redesign of the 'A' Series J-Mounts
by Lieutenant Commander S. A. K. Sami, BEng, MSc, Pakistan Navy

Resonance problems with 'A' series J-mounts at low frequency prompted this redesign study. Initially, detailed experiments were carried out both statically and dynamically on the existing mounts. A computer-based model of a J-mount was then prepared using 'ANSYS' finite element code. Static load tests and modal analysis of a simulated computer model were carried out to determine the stiffness and natural frequencies of the J-mount under different loading conditions. These results were then compared with mathematically calculated and experimental results and the computer model was validated. Subsequently a linear dynamic transient analysis was conducted. The effects of various parametric changes on the computer model were analysed. Ultimately, in the light of the results, the J-mount was redesigned. Various analyses were carried out to confirm the performance of the redesigned J-mount which exhibited an improved dynamic response. It is recommended that further refinement and analysis of the computer model be carried out using the commercial version of 'ANSYS' software, prior to prototype manufacture and test.

Optimal Controller Design for a Rudder Roll Stabilization System
by Lieutenant T. J. Gulley, MSc, CEng, MIMarE, RN

Considerable research and trials over the last two decades have clearly illustrated the potential and effectiveness of rudder roll stabilization systems. Simulation studies into the rudder roll stabilization control aspects of the Type 22 frigate, conducted at RNEC by Lieutenant S. Braham (1990) using classical frequency domain sensitivity techniques, provided evidence of the potential improvement in roll reduction for this class of vessel using the present rudder system.

This report investigates the use of Linear Quadratic Gaussian (LQG) optimal control techniques for a proposed Type 22 frigate rudder roll stabilization system. Simulation studies are described that quantify the performance of the proposed control strategy and the characteristics of the classical and optimal control solutions are compared.

The study concluded that the optimal rudder roll stabilization control solution provides an improvement in performance over the classical control methodology, particularly in quartering seas. However, it was considered that implementation of an optimal rudder roll stabilization strategy into the present Type 22 system would incur significant technical and financial penalties. Nevertheless, the optimal control solution may provide an attractive option for future ship stabilization systems.

Condition Monitoring of a Turbo-Charged Marine Diesel Engine Using Parameter Estimation Techniques
by Lieutenant P. J. Rangachari, BE(Mech), MSc, Indian Navy

It is well established that condition monitoring of diesel engines increases the equipment availability, reliability, performance and life. With the increased interest in condition monitoring in recent years there have been a number of developments in the techniques that are used. A simple and economical method for on-board implementation was sought.

This project demonstrated the practical viability of a parameter identification technique employed for the condition monitoring of a 6-cylinder, in-line Perkins diesel engine. A comprehensive software package was developed to recursively identify the dynamic characteristics of the engine using four algorithms, namely, recursive least squares, recursive prediction error, recursive maximum likelihood and extended least squares methods. With the fuel rack position as the input and ten parameters of the engine as the output, the software established ten different z-transform transfer function models. The identification of the engine was carried out at several operating points thus forming the 'reference engine dynamics'. A limited number of practical faults was created and the identification was carried out to give the 'fault engine dynamics'. Both the fault and faultless dynamic characteristics were stored as a knowledge base. An expert system was designed to analyse the variations in the parameters and predict the engine health status automatically. It was proved that significant parametric variations did occur in the presence of the faults and with the expert system it was possible to diagnose the incipient fault in the engine.

Proposals for further experimentation with other design parameters of the software and the modification of the expert system for the inclusion of a Kalman filter for analysing multiple faults and overlapping parametric trends have been made.

Prediction of the Thermofluid Characteristics of a Naval Power Condenser
by Lieutenant N. J. Walker, MSc, RN

In attempting to reduce the propulsion signature of a new generation of submarine, a radical change to the condenser configuration is envisaged. This project predicts the thermofluid dynamic performance of such a proposed conceptual condenser. The analysis uses a number of different techniques, including a quasi 3-dimensional computer model. Current predictions of the overall heat transfer coefficient (OHTC) by these different techniques followed similar trends, albeit with a mean spread of $\pm 12\%$. The predicted values of the OHTC are more optimistic than earlier independent results due to the omission of significant physical features in the theoretical modelling of the condenser.

Design of Low Noise Converter Fed Induction Motors
by Lieutenant J. L. Wood, MSc, RN

The Royal Navy is currently considering variable speed a.c. drive systems for future warship propulsion. Little is generally known about the effects on performance of induction motors fed by inverters.

This report compares the performance of a 4·5 MW cage induction motor fed by four basic types of frequency control inverter systems using an induction motor performance model developed by a leading induction motor manufacturer.

From these results the performance of the 12 pulse cycle converter proved to be best suited for low noise applications. This model was validated using practical test data and was also used to optimize the design of the 4·5 MW motor for low vibration.

The largest source of noise in induction motors arises from the radial forces produced by the magnetic flux density waves in the airgap which cause the motor to vibrate and emit noise. Additional fluxes in the airgap due to the phase current time harmonics, produced in the inverter, will react with the fundamental mmf flux and result in significant vibration levels. Reducing the amplitude of these fluxes and increasing the stiffness of the motor are two ways of combating the effects of the time harmonics. It is shown that significant reductions in the vibration levels of large induction motors can be made by increasing the reactance of the motor.

A Neural Network Approach to Target Motion Analysis
by Lieutenant P. E. Gallop, BEng, MSc, AMIEE, RN

This project investigates the Target Motion Analysis (TMA) problem faced by a ship or submarine in estimating the range of a target using 'Bearings Only' information. A Multilayer Perceptron (MLP) was applied to simulated underwater TMA problems and its ability to produce satisfactory estimates of range with a manoeuvring target and inaccurate sonar data is assessed.

Some success was achieved over small problem domains and evidence is presented to show that it would be possible to provide range estimates over larger and more useful problem spaces. However the performance of MLPs was shown to be poor when compared to existing techniques and it was concluded that further investigation is unlikely to be profitable without significant improvements in processing power.

An Investigation into Optimal Search Strategy Algorithms for Examining Zones of Varying Topology
by Lieutenant-Commander T. G. Horne, MSc, RN

Traditional strategies for searching and surveillance use limited search plans based on simple geometry which make little allowance for the topology of the zone being searched, in particular the shadow zones. An alternative is for the search vehicle to decide where to go, based on the scenario, what it has already searched and when. This project investigated optimal search strategy algorithms for examining zones of varying topology.

Initial investigations compared algorithms and established one using a flat sector. The algorithm then proved suitable for searching a terrain with hills and a river, whilst a standard search was unable to achieve 100% coverage. The effect of varying search vehicle height was also investigated.

It was concluded that algorithmic searches will work for any topology. They do not need the planning that standard searches do and yet, unlike standard patterns, they manage to consider the whole area topology together with search vehicle altitude.

Recommendations draw attention to the lack of other studies in this area and suggest several possible paths for further exploration.

An Investigation into a Bistatic System Using Transmissions of Opportunity
by Lieutenant N. G. Oakley, MSc, RN

In an era of diminishing detection ranges, against quieter and quieter hostile submarines, fresh approaches are called for to restore the tactical advantage once enjoyed by the West. One such technique is Bistatic acoustic detection utilizing low frequency active transmissions. The project explored the principles of bistatic acoustic detection where a receiver was widely separated from the acoustic source.

Bistatic detection utilizing transmissions of opportunity is shown to be feasible although, without significant processing gains, detections are short range and limited to the half plane away from the source. Surface reverberation

conditions will dominate when the receiver separation ranges are small. Volume reverberation dominates for greater separation ranges.

Recommendations include the investigation into the efficiency of matched filter realization using the noisy direct path signal as a reference, and the tactical employment of bistatic receivers using Monte Carlo simulation techniques.

An Investigation of Explanation Based Reasoning with Penalty Values for Naval Command and Control Systems
by Lieutenant G. W. Jones, MSc, Royal Australian Navy

Artificial Intelligence Techniques and Knowledge Based Systems (KBS) in particular, are currently being considered as a means to support decision making in the Naval Command and Control (C2) environment. One particular area identified for support is the processing of the vast amount of domain data characteristic of modern warfare. Of the various schemes available, the project investigates an adaption of Explanation Based Reasoning (EBR) developed by R. Hirst, which uses penalty values to resolve domain input inconsistencies.

The conclusion is drawn that, whilst experience can form the basis of a problem solving framework and timely performance of administrative tasks can support the decision process, information cannot be comprehended without first appreciating the original source and the subsequent path to the user. In this respect the technical knowledge base of military equipment has been found considerably inadequate.

The main recommendation is to strengthen the C2 domain knowledge base by studying the operational usefulness of EM models, including their possible inclusion as a support tool for the C2 KBS and the establishment of a comprehensive technical data base of own force emitter characteristics.

Bandpass Sigma-Delta Analogue to Digital Conversion
by Lieutenant I. A. Rawlings, MSc, Royal Australian Navy

Low Pass Sigma-Delta analogue to digital converters are now proven technology commonly used in Compact Disc Players and in certain military sonars. Sigma-Delta circuits are particularly attractive as high resolution converters (greater than 15 bit) due to their quantisation interval linearity and suitability for VLSI (Very Large Scale Integration). The effectiveness of Low Pass Sigma-Delta conversion relies upon bands of input signals extending from DC. For signals with bands existing at higher frequencies Low Pass Sigma-Delta becomes inefficient. Applications such as torpedo and minehunting sonar are examples that would benefit from the high resolution data that Sigma-Delta converters can provide, but have signal frequencies well beyond DC.

This project examines the possibility of realizing a bandpass circuit by identifying suitable circuit filters to give bandpass noise shaping. A simple linear based design method is developed to aid circuit filter choice and operating frequency selection. Simulation of the non-linear circuit is used to identify any unforeseen non-linear effects, and the effect of manufactured component value variation and circuit sensitivity. It is shown that a single loop circuit was unsuitable as an analogue to digital converter while a triple loop circuit is not suitable for VLSI unless a suitable tuning procedure can be developed.
