RN ENGINEERING COLLEGE, MANADON, POST-GRADUATE PROJECTS

As part of the Advanced Marine Engineering Course (MSc Course in Marine Engineering) at the Royal Naval Engineering College, each student spends 17 weeks working at a particular research project. Students on the Advanced Maritime Defence Technology Course (AMDTC) do the same. Those who are successful are awarded MSc degrees.

A summary of each project completed by the courses of 1991–92 is printed below. The 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.

Advanced Marine Engineering Course

Rudder Roll Stabilization for 'Peacock' Class Ships
by Lieutenant T. J. Dathan, MSc, Royal Navy

The PEACOCK Class ships have been the subject of a number of studies to ascertain how their sea keeping characteristics may be improved. Rudder Roll Stabilization offers a cost-effective means of making them more stable. Athough the effectiveness of a Rudder Roll Stabilization system is governed by the slew rate of the rudder, a measure of roll reduction may be achieved using present systems. By interfacing a computer utilizing a digital controller programme with the ships autopilot, it was planned to use the existing rudder system of a ship to demonstrate that roll reduction could be achieved and to quantify to what degree.

This report describes the process of developing a method of assessing a ship's dynamic rudder to roll characteristics and applying these values to various equations in order to ascertain the value of the controller's parameters. By using information available for a Type 22 frigate it was deduced that by applying a sinusoidal rudder demand of varying frequency the natural roll frequency, ω_1, could be evaluated. The remaining parameter values were able to be estimated by applying a step input rudder demand and interpreting the resultant time domain roll response plot. Once all the parameters were known, the rudder to roll dynamics transfer function for the PEACOCK Class could be calculated and values derived for the digital controller coefficients. The digital controller software was then able to modify rudder demand signals to the rudder servomotor to decrease the roll motion. Models for the constituent parts of the system were developed or applied from other authors and an analogue model of a ship was used to test the software and controller.

Ship trials were undertaken after the controller behaved as predicted in the tests. The equipment was successfully installed and tested alongside before conducting forced roll and step response trials at sea. From the results of these the controller was derived and subsequently tested. The results probed the theory as the degree of roll reduction achieved was as predicted.

Investigation of a Motor Vessel Transfer Function
by Lieutenant M. R. Gill, MSc, Royal Navy

The traditional method for obtaining mathematical models of ships has been to build and test scale models and calculate the hydrodynamic derivatives. This

is both time-consuming and expensive. This report investigates two alternative methods of obtaining transfer functions.

One uses standard manoeuvring trials and a theoretical method for obtaining the coefficients to the Bech Equation from these results. The second uses identification techniques to analyse the results from rudder perturbation trials.

From the trial results a transfer function was derived using the identification techniques but due to equipment deficiencies no model was obtained from the other method.

Wide Range Compression Ignition Engine Simulation for Basic Performance Prediction

by Lieutenant Commander S. H. M. Kalimullah, MSc, Bangladesh Navy

A computer-based simulation has been developed for the performance predication of a wide range of diesel engines with minimal operator input and knowledge. This report describes the different processes involved within the engine and the procedure followed for dealing with such processes in a way which fulfills the project requirements of computational simplicity and minimal operator input and knowledge. The program has been developed as a process-based simulation and has been validated against the performance parameters of a wide variety of diesel engines. The primary objective of the program is engine performance analysis, but it can also be used as a preliminary design tool and as a training aid. The program has been incorporated into the propulsion system simulation package TURBO to replace the existing diesel model. TURBO was developed at the Royal Naval Engineering College for the modelling of gas, steam or diesel driven propulsion plants. The new version of TURBO can deal with a wide range of diesel engines with a much reduced level of operator input and knowledge.

Development of a Simulation Package to Model Split Injection on the Paxman Valenta

by Lieutenant Commander G. M. Goonesekere, MSc, AMIMarE, Sri Lankan Navy

A major problem with the on-board diesel engines is the high level of noise and vibration at around half load and below. Combustion excitation is the most important source at low load, being influenced by the high rate of heat released at the time of burning due to the longer injection delays at low load conditions. Most experts agree that the rate of change of cylinder pressure rise, resulting from the rate of heat release, is the critical parameter but some researchers have identified that rate of change of rate of pressure rise and peakiness are more important. There are various methods overcoming this problem. The method investigated in this project is the process of split injection, which has introduction of 5 to 10% of the total fuel injected a few degrees before the main injection.

The MOD has investigated the effect of split injection on the Paxman Valenta 12RPA200 engine as used in the Type 23 frigates, with some success. However, optimizing the process to suit a particular engine is both expensive and time-consuming. To enable the process to be both investigated and optimized it was decided to use the simulation program SPICE to produce a validated basic engine model and then modify the simulation to represent split injection and review the results.

Once the in-cylinder conditions are monitored the most important aspect is to establish the link between the cylinder pressure rise and the generated noise and this is achieved by analysing the cylinder pressure data with the signal processing package HYPERSIGNAL.

This study concludes that SPICE can be utilized as an excellent tool to simulate the Paxman 12RPA200 engine, and also shows the trends of split injection, highlighting the reduced rate of pressure rise in the cylinder, and hence reduced noise and vibration. The link between the shape and levels of cylinder pressure diagram and the frequency spectrum of the combustion noise is established, even though it is time-consuming to convert the HYPERSIGNAL output to familiar engineering units for comparison with empirical data.

A Detailed Study of the Use of Small Diesel Engines for Autonomous Underwater Vehicle (AUV) Applications
by Lieutenant Y. P. Soetens, MSc, Ing AIIBr, CEng, MIMarE, MBSME, Belgian Navy

Advanced underwater non-nuclear power systems with the capacity of higher power densities than the current in-service secondary batteries have been under design and development for the past 30 years. The requirement for such a power system is for increased underwater endurance capabilities. Initially, the impetus was directed towards manned submersible applications. However, the recent developments of submersibles of the unmanned Autonomous Underwater Vehicle (AUV) type has generated a new application. A diesel engine having the capability to operate on its own combustion products is seen as a potential candidate system. All previous non-air-breathing diesel developments have been directed at manned submersibles with engine powers in excess of 150 kW. For AUV applications the required power levels are between 2 kW and 12 kW.

This project was concerned with the identification of suitable engines which could initially meet the power requirement, and which could then be simulated to operate in the non-air-breathing mode. The results of this simulation were then used as the basis for developing a thermodynamic model which would assess the operation of such a system within the constraints imposed by AUV geometry and operating requirements.

A Detailed Investigation of the Performance of a Diesel Engine when Running on excessive Carbon Dioxide Mixtures
by Lieutenant P. C. King, MSc, Royal Navy

The search for alternative power systems to replace the limited energy density secondary batteries used in Autonomous Underwater Vehicles (AUV) has resulted in a number of candidate options. The synthetic atmosphere diesel (SAD) is a short-term, cost-effective alternative.

The overriding problem with the SAD is the effective management of the recycled and surplus exhaust products which in the main are carbon dioxide. Surplus carbon dioxide can be removed by chemical or water absorption and by liquefaction techniques. Alternatively, the surplus exhaust can be directly vented from the system using a compressor.

Current development of this type of system is aiming to recreate the thermodynamic properties of free air by the addition of high specific heat ratio gases such as argon in order to offset the detrimental effects on engine performance due to recirculated carbon dioxide. This study is aimed at detailing the extent of this performance degradation by the operation of a diesel engine under simulated recycle conditions on increasing amounts of carbon dioxide. The advancement of a non-air-breathing diesel engine simulation model, which will predict engine performance under these conditions is investigated.

Application of the Scanning Reference Electrode Technique to the Localized Corrosion of Stainless Steels in the Marine Environment
by Lieutenant Commander A. A Tamimi, MSc, Pakistan Navy

Stainless steels are extensively used in the marine world due to their good corrosion resistance which is mainly attributable to the formation of a chromium oxide film. Any local disruption of this protective film results in localized forms of corrosion attacks, a very common and potentially serious form being pitting corrosion.

The Scanning Reference Electrode Technique (SRET) is a novel approach for the *in situ* investigation into the pitting process. This technique relies on the principle that local potential changes occur in the electrolyte around a pit or a crevice region. The size of this potential variation is indicative of the corrosion activity taking place in the vicinity of the pitted area. By scanning the surface of this area using a fine microprobe, the potential changes can be detected and instant visual display can be obtained in the form of Line Scans or Area Maps (potential contours).

The SRET Apparatus has been developed over the past five years at RNEC. A prototype of the commercial version has been used to validate the equipment in the investigation of pitting and grain boundary corrosion. This project has investigated the feasibility of employing the apparatus for the study of pitting and weld decay of 304 Stainless Steels.

The Initiation of Pitting Corrosion of FV448 Marine Gas Turbine Material
by Lieutenant K. C. Clark, MSc, Royal Navy

FV448 is a 12% Cr steel used as a marine gas turbine material. Its susceptibility to pitting corrosion has led to certain components being prematurely withdrawn from service. Standard laboratory electrochemical and electromicrography analysis techniques were used to investigate the nature and mechanisms of pitting initiation in FV448. It was found that minute quantities of ceramic aluminium oxide inclusions present in the parent metal provide preferential sites for pitting initiation. Laboratory results were compared with analysis of pitting corrosion of in-service material and indicated that the same mechanisms were responsible.

The Effect of Turbine Blade Erosion on Aerodynamic Performance
by Lieutenant H. Hassall, MSc, Royal Navy

Continuous advancement in gas turbine health monitoring techniques is reducing the need for routine maintenance schedules and hence cost. However, their success depends on data availability produecd from modelling or performance trials.

This project investigated the performance degradation, using a general purpose Computational Fluid Dynamics (CFD) package, of the high pressure turbine blade from a Rolls-Royce Spey SM1A when in the eroded condition. The main advancement from previous work was the progress from incompressible to a compressible flow model.

From relevant design data two-dimensional compressible models were constructed for both the eroded and design cases, each consisting of five streamlines, using a CFD package called FLUENT. This information was then used to predict efficiency variation and the associated effect on engine performance.

With the compressible flow model, the performance changes were too small for effective detection using conventional monitoring equipment, although limitations with two-dimensional modelling are highlighted, and hence improvements in modelling techniques are recommended.

Design and Development of a Static Power Motor Generator using GTO Thyristors
by Lieutenant Commander A. R. Green, MSc, CEng, MIMechE, Royal Navy

Motor Generator sets used within the Royal Navy are large, noisy machines with a high maintenance requirement. The prospect of using a static system to replace the current Motor Generator sets is being investigated. This system involves the use of a Gate Turn Off (GTO) Thyristor Inverter utilizing Pulse-Width-Modulation (PWM), together with a digital system for automatically controlling both the voltage and frequency.

The paper describes the problems associated with the design and build of a unit capable of generating AC or DC supplies of variable voltage and frequency. The benefits or otherwise of using GTO thyristors over other available devices, to achieve the aim, is discussed. Closed Loop PWM techniques are employed to produce a supply with minimum harmonic distortion. A computer simulation programme was also written to aid the design process and study PWM inverter current waveforms.

Investigation into the Reduction of Inverter Induced Torsional Vibrations in Marine Electrical Propulsion Systems
by Lieutenant P. E. Jessop, MSc, AMIMechE, Royal Navy

Converter-fed induction motors induce harmonic torque pulsations which are superimposed on the mean output torque of the motor. With the future use of AC propulsion drives for warships becoming more likely, the effects of these torque pulsations on the propeller torque and speed is of increasing concern. Using a scale model of a ship's electrical propulsion system and a previously written simulation programme, the effects of the torque pulsations generated within the motor were established. Using a commercially available PWM inverter and a Laboratory 6-Pulse Cycloconverter, the relative merits and performance of each converter strategy were compared.

The results showed that only low order pulsating torques common to all converters and coincident with the system's natural frequency were significant, high order pulsating torque having no effect. The optimum system for warship propulsion was found to be a Cycloconverter drive.

Laboratory Modelling of Cycloconverter using DSP Techniques
by Lieutenant J. M. Jangir, MSc, Indian Navy

The harmonic spectra of the output voltage waveform of the cycloconverter depends upon various factors, but the method of control of firing instants is the most significant contributor since error caused in generation of firing instants gives rise to significantly higher levels of harmonic distortion in the output voltage.

The analogue method of firing pulse generation has some inherent sources of error, such as filters and transformers which introduce non-linearities in the generation of firing pulses.

This report presents the development of a six-pulse naturally commutated non-circulating type of cycloconverter, using a cosine wave crossing method of firing pulse generation, controlled using PC-based modern Digital Signal Processing techniques. The DSPLAY software package supplied by Burr-Brown has been used for the software control medium. The same system has also been used to simulate the output voltage waveforms of the cycloconverter to establish further the suitability of the software to generate the required control algorithm for cycloconverter.

Software mathematical models of six pulse rectifier, circulating and non-circulating type of the cycloconverters have also been developed to find out the magnitudes of the harmonics in the output voltage under ideal conditions. This allows a comparison between the theoretical and the practical model. Investigations have also been made to establish the similarity between six pulse rectifier and the cyclonconverter.

The investigations carried out suggest that the use of DSPLAY as a software control medium provides effective control of the cycloconverter.

Control of a Submarine Pressurized Water Reactor using Fuzzy Logic
by Lieutenant H. A. Jones, MSc. Royal Navy

The average core temperature (Tave) of a submarine Pressurized Water Reactor (PWR) is controlled by a reactor panel operator (RPO) who uses the control rods to either raise or lower Tave. The amount the control rods are moved depends upon the rod worth of the control rods, the negative temperature coefficient of reactivity and Tave. Due to the subjective nature of the control it was thought that fuzzy logic would be suitable control medium for an automatic controller.

The controller maintains Tave at nominal $\pm$ 2°C during normal operation and prevents Tave exceeding nominal + 10°C during transients. To achieve this the controller uses Tave, rate of change of Tave and reactor start up as inputs, rod movement as an output and two rule bases. One rule base is used for normal operation while the second rule base is only used if rod movement is required to prevent Tave exceeding nominal + 10°C. On completion of the transient this second rule base is deactivated. The controller was tested against a PWR model and the results compared favourably with a RPO controlling the model.

Safety Study for Auxiliary Nuclear Reactor fitted to an 'Upholder' Class Submarine
by Lieutenant C. J. Allen, EurIng, MSc, CEng, MIMechE, Royal Navy

This project, conducted at the Department of Nuclear Science and Technology, RN College Greenwich, has assessed the suitability of marinizing a satellite reactor-generator for use in UPHOLDER Class submarines.

The aim of the project was to conduct a preliminary safety assessment of the reactor-generator system for submarine use. In the absence of a detailed description of the envisaged reactor concept, the study started by investigating a suitable means of retro-fitting the reactor-generator system into UPHOLDER, and defining its likely operating profile in conjunction with the existing diesel electric propulsion plant.

The project then assessed the effects on internal and external hazards on the safety of the reactor-generator system, using classical probabilistic risk assessment techniques against nationally accepted nuclear risk targets based on the Farmer criterion. Only the most significant hazards were investigated, namely fire and collision. The risk from collision is demonstrated to meet the safety target. The risk of fire, especially from the submarine main battery, exceeds the target in the 10^4 Curies Iodine 131 release category and is subject to further analysis.

Advanced Maritime Defence Technology Course

Analysis of Non-Linear Tracking Algorithms
by Lieutenant D. M. R. Chance, MSc, Royal Navy

Anti-ship missiles, capable of enacting terminal manoeuvres in an effort to confuse existing tracking systems, are due to enter service in the near future. These missiles are likely to render conventional tracking systems ineffective. Accordingly there is a need to develop non-linear tracking methodologies which will be capable of meeting this challenge. This project studies the implementation of those strategies that are likely to be the most effective at combating the threat and assesses their relative performance. Recommendations for further research and development are then made.

H_∞ Optimization Techniques Applied to the Design of a Torpedo Depth Control System
by Lieutenant D. Fitzjohn, MSc, BEng(Tech), Royal Navy

In this report, the application of H_∞ (H-infinity) optimization techniques to the design of a depth control autopilot for a torpedo is presented. The results of the simulations for a shallow-running torpedo operating in heavy sea conditions are included. The simulation uses a non-linear mathematical model of the torpedo dynamics and the seaway forces are represented by a simple 'two component' sea state model. It is concluded that an inertial depth can be maintained using an H_∞ controller designed using a linear mathematical model of the vehicle.

Communication Protocols for Packet Switched Radio Networks
by Lieutneant-Commander G. Heløe, MSc, Royal Norwegian Navy

MRR, a new packet switched radio system, is currently under development at the Norwegian Defence Research Establishment. The system was primarily developed for the Army; this MSc project investigates the feasibility of implementing it in the Fast Patrol Boats (FPBs) of the Royal Norwegian Navy.

The project involves development of a simulator, and simulating communications traffic in a typical operational FPB scenario. Message application formats have been created, and estimations of traffic flow requirements have been made. It is concluded that the MRR system appears well suited to meet the requirements posed by the FPBs.

The Application of Neural Networks to Real Time Control
by Lieutenant D. W. Ledger, MSc, BEng, Royal Australian Navy

Several neural network structures have been proposed to control real time plant. Such controllers appear to show promise where robustness is important, and are likely to be relevant to a number of platform and weapon system problems within the defence sector. This report examines a number of neural control strategies and their implementation in the control of a simulated unstable pole-cart system. A performance comparison is made between each control strategy and assessment is made of their potential application to real time systems. Strategies implemented include supervised and unsupervised networks in both single and multilayer form.

Cryptanalysis of Stream Ciphers
by D. C Morritt, MSc

A stream cipher combines a pseudo-random binary stream with plain text to form cipher text. If the cipher produces equi-probable zeros and ones the

characteristics of the message are hidden in the cipher file and so other methods have to be used to cryptanalyse the stream and release the hidden message.

This report starts by examining pseudo-random streams produced by linear shift registers. It finds that the security linear elements offer is limited by the linear equivalence of the output stream. The linear equivalence is a measure of the shortest shift register that can produce a given sequence. To extend the linear equivalence of stream ciphers non linearities have been introduced to the generation process. These non-linearities include multiplication, flip flops and selectors. The report examines a class of these non-linear systems, it finds that it suffers from a cryptographic weakness, the correlation between their simple linear inputs stream and the complex cipher text output.

Four methods of implementing a correlation attack on one of these cipher system are then considered. The implications that these attack methods may have on other elements of stream cipher design are briefly discussed.

To support the ideas in the report, Part II contains listing of software used in support of the cryptanalysis. The software is written in object oriented C, and provides a flexible method of encrypting a plain text file, decrypting linear ciphers with no knowledge of the key, and support when using a correlation attack on a non-linear cipher.

Terminal Manoeuvre Analysis of Anti-Ship Missiles
by Lieutenant A. W. Murdoch, MSc, Royal Navy

This project report contains a description of the background to, the work conducted and the results obtained in an analysis of the effectiveness of terminal manoeuvres in the horizontal plane of a sea-skimming anti-ship missile aiming to penetrate the defences of a surface ship fitted with an Automatic Command to Line of Sight Point Defence Missile System. The amplitude, frequency, phase and profile of the terminal manoeuvre have been analysed in a TSIM simulation model, and the results have been shown to support the postulation that the miss distance in the defending missile can be maximized by careful choice of these parameters in the attacking missile.

An Investigation into the Feasibility of Exploiting Noise Jamming Sources for Passive Target Detection
by Lieutenant M. Walker, MSc, BEng, AMIEE, Royal Navy

A warship in a heavy electronic counter-measures (ECM) environment may be able to detect the presence of an attacking aircraft through the use of enemy jamming noise as an illuminator of opportunity. A passive detection system employing correlation signal processing techniques may well be a possibility. Such a system employing the principles of a bistatic radar has to process a signal containing a very weak scattered (echo) signal and a much stronger direct signal from the jammer transmitter. When correlated, the direct signal masks the echo due to its comparative magnitude. A possible solution is to design a receiver with ultra-low sidelobes, and to use additional sidelobe signal attenuation techniques.