THE MARINE ENGINEERING DAGGER COURSE

BY

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Introduction

Since 1918 the Royal Navy has provided a course for selected officers which will suit them for jobs associated with the design and development of marine engineering equipments for the Fleet. In 1971 the Dagger Course, as it is known, moved from the Royal Naval College, Greenwich to the Royal Naval Engineering College, Manadon. Since that time the course has continued to evolve to take account of developments in the field of warship propulsion and rising standards of first degree education. The continual aim is to provide a course which concentrates on those aspects of engineering which will be of most relevance and value to officers who may be expected to work in the Ship Department and which will demand from students that academic standard which a good honours graduate in mechanical engineering could be expected to achieve after one year of full-time study. The course has been integrated into the College structure so as to take full advantage of available resources while special facilities and a measure of independence appropriate to the students' seniority and the nature of their work are provided.

Course Structure

Courses start in May of each year and last for sixteen months which is four College terms. The first two terms are occupied by a lecture course which culminates in written examinations in December. The last two terms are mainly devoted to project work and the course ends with the oral presentation by each student of his project.

Curriculum

The first week is devoted to a computer course which enables students to take full advantage, throughout the course, of the College's Rank Xerox Sigma 6 computer.

The core subjects of the lecture course are: thermofluids, control and simulation, vibration, and behaviour of materials. Two course options are available. The majority of the students take the Gas-Turbine option which, as the name implies, deals mainly with the gas-turbine cycle and marine gas-turbine design. Officers appointed to the course who have previously taken the Nuclear Reactor Course at the R.N.C., Greenwich, and who are continuing in the nuclear submarine field take the Steam Plant option which deals mainly with the steam-plant cycle, steam turbine, condenser and auxiliaries designs. The control and simulation and the diesel plant, gearing and reliability syllabi are common for both options.

Course Schemes

During the course, students are set Course Schemes which take the form of simplified exercises in design calculations. Twelve such schemes are set covering each main area of the curriculum and their purpose is to amplify and extend the lecture syllabus. The last of these, which students undertake during the period project reports are in type, is a Warship Comparison study which requires students to discover the characteristics and machinery fit of a variety of British and foreign warships and to assess the suitability of each against a fictitious but realistic Outline Staff Target.

Technical Visits

During the course students and staff officers visit about fifteen firms and establishments undertaking work for the Ship Department. During the 'industrial' visits undertaken by Application Courses from the College students have seen a range of manufacturing processes: with 'technical' visits by the Dagger Course the emphasis is on research, development and design. The visits make an important contribution to the course itself and also help officers, when they join the Ship Department, to establish an informed working relationship with the firms with whom they deal.

Projects

During the last two terms of the Course each student undertakes a main project. Projects are undertaken in a wide variety of fields associated with warship engineering and subjects arise from two main sources: staff research, and the Ship Department or Research Establishments.

This article concludes with a synopsis of the projects undertaken by the students who completed the Dagger Course in July 1976. From the authors' names it can be seen that the course is available not only to officers of the Royal Navy but also to officers of Commonwealth and Foreign navies and, of course, the Royal Corps of Naval Constructors (Mechanical). Proposals for future Dagger Course student projects are always welcome and should be forwarded to: The Head of Marine Engineering, R.N.E.C., Manadon, Plymouth.

DIGITAL SIMULATION OF TRANSMISSION BRAKES FOR REVERSIBLE MARINE EPICYCLIC GEARBOXES

LIEUTENANT R. W. ALLEN, R.N.

Reversible marine epicyclic gearboxes offer a means of providing astern thrust from a unidirectional gas-turbine engine. An integral part of this type of gearbox, and the means by which reversal is achieved, is the disc brake attached to each train in the gearbox. Additionally a brake may be attached to the propeller shaft in order to reduce the duty required of the gearbox brakes under reversal conditions.

The aims of this project were to:

(*a*) Conduct a simulation to investigate the parameters which affect brake performance.

(*b*) Produce a simple equation to estimate the brake disc surface temperature.

A simple equation for the brake disc surface temperature was required for inclusion in a much larger whole propulsion system simulation being developed by the Admiralty Engineering Laboratory. Knowledge of the disc surface temperature is required to estimate the wear rate of the brake pads. Computer simulation yielded the torques and energy dissipation rates that the brakes would experience. A model which produced the ship speed/propeller shaft speed thrust and torque relationships was used for the propeller shaft brake which, when coupled with models for the brake, generated the temperature distribution in the disc and the disc surface temperature. A similar technique was used for the gearbox brakes using data from an epicycle gearbox simulation conducted by the Admiralty Engineering Laboratory.

The parameters which affect the brake performance and in particular the disc surface temperature were found to be:

(*a*) The instantaneous energy absorption rate of the brake pads.

(*b*) The disc thickness.

(*c*) The time into the braking period.

(*d*) The disc thermal diffusivity.

(*e*) The area of the brake pads/disc.

(*f*) The area swept by the brake pads/disc face.

(*g*) The bulk temperature of the disc swept volume given by dividing 'energy absorbed' by 'thermal capacity'.

A simple equation giving the disc surface temperature at any time during the braking period was derived. This simple equation was verified against a much larger finite difference model which itself was validated using existing experimental results. It was concluded that the simple equation gives the brake disc surface temperature to an accuracy of within + 10 per cent. of experimental results.

THE CONTROL OF A GAS TURBINE PROPULSION SYSTEM

LIEUTENANT M. P. N. SESSIONS, B.A., R.N.

In spite of recent advances in modern control techniques, few attempts have been made to apply these to gas turbine propulsion systems.

The standard arrangement of an Olympus gas turbine driving a controllable-pitch propeller in a typical destroyer installation was analysed. The equilibrium or steady-state condition of the system was determined using a component-based thermodynamic model. The system's equations in the

model were linearized and the system's eigenvalues (measures of the uncoupled response rate) were investigated for various settings of fuel flow and pitch. The system transfer function matrix was then calculated for several power levels. The transfer function matrix defined the relationship between the system's inputs, engine fuel flow and desired propeller pitch, and its outputs, shaft speed and actual pitch. The transfer function matrix was analysed for stability and dynamic response.

The variation of system eigenvalues with power level was investigated. The eigenvalue associated with the gas turbine's LP spool was found to decrease significantly at low powers indicating a sluggish response. The next stage of the continuing programme of projects in this area will be to validate the initial dynamic model against installed systems and proceed with the design of control schemes.

LOW CYCLE THERMAL AND MECHANICAL FATIGUE BEHAVIOUR OF AUSTENITIC STEEL

MR. C. ADAMS, B.ENG., R.C.N.C.

Using the concept of a strain concentration factor, a design technique is proposed that enables a component's fatigue life to be estimated using properties determined from tensile tests conducted upon the material. The method makes allowance for variations in surface strain fields and the effects of geometric surface discontinuities upon fatigue life.

Experimental apparatus based upon Housefield Type W tensometers was constructed. The apparatus could subject cylindrical notched tensile specimens to:

(*a*) alternating tensile stresses imposed mechanically at ambient temperature;

(*b*) alternating tensile stresses imposed by the repeated cooling and heating of a restrained specimen.

Post-test examination conducted on a mechanically fatigued specimen (27 000 cycles) revealed extensive circumferential cracking in the notch root. Metallographic examination showed that the cracks penetrated deep into the section. Similar post-test examination of the thermally-cycled specimen (10 700 cycles) revealed:

(*a*) severe surface deterioration in the notch root and about the notch walls;

(*b*) evidence of oblique surface discontinuities aligned parallel to the axis of the specimen.

Metallographic examination of the notch root revealed that the thermal cracks did not appear to penetrate deeply into the specimen but rather followed an arc beneath the specimen's surface.

The project revealed the inadequacy of existing theories of thermal fatigue.

SHIP GENERATED SPRAY

LIEUTENANT S. P. C. WESTWOOD., B.SC., R.N.

The aim of this project, sponsored by the Naval Marine Wing of the National Gas Turbine Establishment, was to establish the effect of ship movement on the amount of salt in the air being drawn into main engine intakes. With the advent of gas turbines as main propulsion engines at sea, attempts have been made to establish the probable concentration of salt in intake air. Since the mid 1960s various ships from different navies had taken marine aerosol measurements and the results had been collected at NGTE Pyestock

and formed the basis of a standard Marine Aerosol (a logarithmic relationship between total salt concentration and true wind velocity). It is aerosols to this specification which are used during the evaluation of gas-turbine air-filtration systems.

Previous research carried out on slowly moving or drifting weather ships in the Atlantic Ocean confirmed that the total concentration of salt in air, by weight, was logarithmically related to true wind velocity, but was far lower than that expressed by the Standard Marine Aerosol. A certain minimum true wind velocity was found necessary for sea-salt production. Work in Japan indicated that ship/sea interaction increased the percentage of small-sized salt particles in the marine aerosol.

The aim of this project was therefore to carry out a series of trials on board a steaming ship and measure the concentration and particle size distribution of the marine aerosol. The trials were carried out in H.M.S. *Torquay* during March and April of 1976 using the same type of sampling equipment and method of analysis as used for the Atlantic trials. The trials gave results very similar to those carried out on the weather ships indicating that ship/sea interaction has little effect on the total concentration of the aerosol for most wind velocities, and confirming that the NGTE Standard Marine Aerosol is a pessimistic one. No minimum true wind velocity was indicated as being necessary for sea-salt production, the ship/sea interaction being sufficient to initiate this salt production at low true wind velocities. There was confirmation that the aerosol did have a larger percentage of small particles in the 0-15 micron range. However, although this size band of particles accounted for a larger percentage of the total, it still accounted for less weight than indicated by the Standard Marine Aerosol. It was found that increasing relative wind velocities lowered the total concentration of salt measured in the air entering the intakes.

AUXILIARY BOILER CONTROL

MR. M. R. OWEN, B.SC., R.C.N.C.

The basis of the project was a requirement from the auxiliary boiler section for AMEE Haslar to develop a 10 : 1 turndown ratio version of the AD(S) 4740 boiler for use in the Type 21 frigates. The Standard AD(S) boiler installed at AMEE in the auxiliary boiler test facility was made available for the project. A short period of investigation trials showed that development work was required on the boiler control and fuel atomizing systems. Problems of instability have been experienced in service and AMEE have given much attention to this problem (*J.N.E.*, Vol. 22, No. 2). The result of that work was to introduce a redesigned water by-pass regulator valve profile which cures the problem in the standard boiler. Increasing the turndown ratio appeared likely to result in further stability problems. For this reason a boiler analogue simulation was constructed. No modification was effected as a result of the simulation work since in practice the water by-pass regulator developed by the maker and AMEE for the AD(S) 4740 boiler proved to perform satisfactorily. However, the effect of the water by-pass regulator on boiler stability could be clearly demonstrated. Combustion theory together with experimental results obtained from the AMEE fuel flow facility were used in an effort to develop a wide turndown nozzle, related closely to the existing design. In the event, it was shown that a full 10 : 1 turndown ratio is not possible with the existing basic design of nozzle using a single atomizing air supply pressure. Therefore a simple control system which provides two settings of air pressure was installed. This system combined with a redesigned nozzle was seen to perform satisfactorily over the required range.

These changes, together with minor modifications to the servo control valve which still need to be finalized, enable the boiler to operate satisfactorily over a 10 : 1 turndown ratio.

MARINE GAS TURBINE DUCTING MATERIAL COMPARISON

LIEUTENANT AZHAR HUSSAIN, PAKISTAN NAVY

The aim of the project was to assess the feasibility of utilizing different materials including mild steel, aluminium-sprayed mild steel, stainless steel, aluminium alloy, for the construction of marine gas turbine air intake and exhaust gas ductings. The project included a study of the corrosion resistance, fabrication techniques, availability and life-cycle costing for the several materials.

A comprehensive literature survey was carried out to obtain basic information on the utilization of various materials, their corrosion behaviour, fabrication processes and availability. To study the ambient aqueous corrosion behaviour of appropriate intake ducting materials, natural sea-water spray-fog testing was conducted on specimens of mild steel, aluminium-sprayed mild steel, stainless steel and aluminium alloy. A hot corrosion test rig was set up to simulate the marine gas turbine exhaust gas environment. Mild steel, aluminium-sprayed mild steel and stainless steel specimens were tested in this rig. Specimens from both the tests were observed under optical microscope and scanning electron microscope and corroded surfaces examined. An approximate life cycle cost analysis of the appropriate corrosion-resistant materials was then carried out to find the most suitable materials for the application. Aluminium-sprayed mild steel for air intake ducting and stainless steel for the exhaust gas ducting are recommended for the required duty.

SYNTHESIS OF AN ACTIVE DAMPER

LIEUTENANT B. S. RANDHAWA, INDIAN NAVY

Vibration isolation systems using passive components (springs, dashpots, viscoelectric mounts, etc.) are effective only when their natural frequency is lower than the frequency of excitation. The use of soft suspensions can ensure that the isolator natural frequency is well below the excitation frequency but the resulting large static deflection may pose installation problems. In the case of a single-degree-of-freedom system, the addition of damping in the isolator reduces the vibration amplitude at resonance but impairs the high-frequency isolation. Active force generators utilizing feedback control used in conjunction with suitable passive mounts can yield isolation systems possessing low static deflection, low natural frequency, low vibration amplitude at resonance and good high-frequency isolation thereby fulfilling conflicting requirements.

This project has utilized 'Modal Synthesis' techniques to design such a vibration control system. An electrodynamic vibrator is used to perform the function of an 'Active Damper' when energized by a control signal generated by a transducer attached to the vibrating structure. An isolation system incorporating modal controllers can be made to exhibit specified dynamic properties without physical alteration of the system hardware. Experimental results obtained bear close agreement with the predicted theoretical values. Besides vibration isolation, such schemes offer possibilities for varying the vibration signature of ship-borne equipment.