MARINE ENGINEERING

An investigation into a marine flywheel generator
by LIEUTENANT M.T.W. BOLTON, BENG, RN

The use of a flywheel as a means of storing energy is not a new idea, in fact it is an ancient technology of which the potter's wheel is a particularly good example. Energy is stored in the form of kinetic energy, which is proportional to the mass of the rotor and the square of its speed. A resurgence of interest in recent years may be attributed to the advent of modern, high strength composite materials which have enabled flywheel speeds to be dramatically increased, and hence the total energy stored. In addition to the manufacture of the flywheel rotor itself there are several associated design issues which rely on the development of emerging technologies. Despite this, flywheel devices have been proposed for a diversity of applications, from electrical utility load levelling to satellite power supplies. This project reviews the current state of flywheel energy storage technology and assesses the prospect of marine applications. A Marine Flywheel Energy Storage System is proposed and suitable electrical machines and power electronic drives are considered. The integration of flywheel energy storage technology into a ship's electrical power system is investigated and the performance of such a system is modelled using computer simulation techniques.

An investigation into the operation and performance of a matrix converter using simulation techniques
by LIEUTENANT K.P. DOHERTY, RN

The characteristics, practical considerations, advantages and disadvantages of a matrix converter were investigated, in order to comprehend the most suitable control strategy for simulation on a MATLAB toolbox, SIMULINK.

The model provided a graphical display of the matrices involved in the synthesis of the resulting waveform. This was either the output voltage or the input current. A mathematical proof for a common operating condition employing all the parameters was carried out, enabling the limitations of the technique to be established. The model was developed to include additional output phases, a requirement for Transverse Flux Motor control, and the theory behind this identified. Output voltage waveforms at various switching frequencies were developed, and the simulated matrix converter was loaded with an induction motor equivalent circuit for 3 phase operation, and an R-L circuit for the 4 phase operation, to show the resultant effect upon the output current. The experience of the matrix converter architecture was finally used to produce an assessment of its feasibility in a naval environment.

Thermodynamic modelling of a marine steam plant
by LIEUTENANT E.M. GIBBS, RN

There are still many large merchant vessels using steam propulsion in service, and these are likely to remain for some years. The efficient operation of these plants can be monitored using a steam heat balance. A previous report detailed how a steam plant heat balance for the vessel LEPETA could be

modelled on a Personal Computer (PC), enabling calculations to be carried out quickly and easily. The model was implemented on an Excel spreadsheet and was linked to a database containing steam tables. This model, however only enabled calculations to be made at maximum design powers with any degree of accuracy, and was not truly representative of the complete plant.

This initial model was modified to include part load efficiencies for most of the major components. It also included pipe and heat losses throughout the system. The calculations were based largely on the Society of Naval Architects and Marine Engineers Technical and Research Bulletin 3-11, *Marine Steam Power Plant Heat Balance Practices*. This resulted in a more realistic model and established the techniques to be used for the later stages. The spreadsheet calculated the speed of the vessel, the fuel flow rate, the cost to operate per day, the cost per nautical mile, the specific fuel consumption and the overall, all purposes thermal efficiency.

The model was now altered to include all of the components and losses normally associated with a marine steam plant. The calculation was expanded to consist of 2 stages to eliminate circular references and ensure greater accuracy. With this model working satisfactorily a parametric survey was now carried out. This established that the model produced realistic results.

Finally the spreadsheet was altered to allow the user to isolate either the feed heater, the de-aerator or the steam air heater in order to simulate defects. These components could be isolated either singly or together. The full power results of these isolations were then recorded.

Fire detection systems on ships
by A.I. KALLINIKOS, Private Student Greece

Fire at sea remains the most frightening and catastrophic accident, regardless the type of vessel (merchant, cruise liner or naval). Even in recent years, the number of vessels that are lost through fire or explosion persists to be significantly high.

Therefore, there is a primary need for all types of ships to be equipped with the most effective, efficient, reliable and up to date fire detection systems. These systems are divided into two categories:

- Fire detection and alarm systems.
- Fire equipment and systems.

The aim of this project is an extensive research on fire detection systems that are used on ships.

Chapter 2, analytically describes all the different types of fire detectors. Operating principles, advantages, limitations and specific fields of use, for each different type, are also included.

Chapter 3, integrated fire detection systems are examined. Different system designs, current trends and developments, both in detectors devices and design philosophy are contained in this section.

Chapter 4, final conclusions are made, involving all the basic considerations that must be taken in account for developing and installing the optimum fire detection system to fulfil the specific environmental and operational requirements.

Chapter 5 (with reference in Chapter 6 - Appendices) includes the current frame of rules and regulations that international authorities and classification societies have imposed, and covers the installation, maintenance and operation of fire detection systems on ships. The second part of this chapter contains suggestions that can be future amendments in todays legislation.

Fault Tree analysis and Reliability Centred Maintenance analysis applied to marine vessels
by LIEUTENANT J.C. LOWE, RN

This thesis is submitted as part of an MSc in Marine Engineering. It is a study into the application of Fault Tree Analysis (FTA) techniques to marine vessels in an attempt to quantify reliability and availability over different mission lengths.

A spreadsheet was used to produce a tool which assesses the reliability performance of three different vessels - two Combined Gas and Gas plants loosely based on ships currently in service with the Royal Navy, and a notional single engine merchant vessel.

Reliability studies are only ever as accurate as the reliability data on which the calculations are based, for this reason a significant amount of time was devoted to pursuing accurate and up-to-date reliability data for marine engineering machinery.

It concludes that the application of FTA with the aid of a spreadsheet provides a simple and useful method for assessing whole system reliability performance given on reliability data for the component pieces of machinery.

Alternating Current stress measurements in steels
by K. MANARA, Private Student Greece

There is now an increasing interest in the determination of stress as a Non Destructive Testing (NDT) technique.

It has been known that stress is a significant factor affecting the magnetisation of ferromagnetic materials such as mild steel. To investigate such an affect in steel, proven and established NDT equipment was used. This was done bearing in mind its possible industrial applications, so fine adjustments could be made to the present technology enabling it to embrace the addition of stress measurements.

The equipment in this project used Alternating Current Field Measurements (ACFM). As such the concept behind the stress measurements is the effect that stress has on the ACFM technique.

In ACFM a constant current is made to flow across the area under investigation. The skin effect causes the current to flow only near the specimen surface. This current has an associated magnetic field, and depending on whether it is parallel or perpendicular to the applied stress (Position A and B), the 90° or 180° domain walls will contribute to the permeability.

Two different types of probe were used. One was found to obtain better responses from the steels. This was attributed to an offset between the sensing and inducting coils within this probe.

The steels were tested both in tension and three point bend. While the responses obtained from these two different loading conditions were not exactly similar, they were comparable.

When the readings taken in Position B are divided by Position A, the ratio approximates to Poisson's ratio. This implies the readings are in fact a measurement of strain. So, rather interestingly, in the quest for stress measurement, we have attained strain measurement.

Ship impact of exhaust emission legislation
by K. Manousou, Private Student Greece

The world's atmosphere has deteriorated over the last 30 years. It was then decided that it was time to clean the air we breathe, by means of reducing exhaust emissions from road transportation, industrial sites and marine engines. New world-wide limits for exhaust emissions are now being introduced, and certain operating areas as in California or Sweden, already have

much stricter limitations imposed. The new legislation for diesel engines and gas turbines has a significant effect on the design and operation of vessels.

The first aim of this report (Part A) is to give an indication of how exhaust emissions are formed, as well as the effects on human health and environment. A section covering the proposed or current legislation on regional/international level, has also been included. Secondly, a survey of emission control methods for diesel engines and gas turbines can be found in Part B and C respectively. Finally, these methods are assessed in part D of this report, both new and old vessels are considered.

The author concluded that the assessment is more complicated than originally thought, and consequently, there is not an easy solution in the quest for a cleaner environment.

Assessment of alarm levels for acceleration, velocity, and bearing defect energy of vibration for the vibration monitoring system of the main engine turbochargers operating in container vessels

by I. MARAKIS, Private Student Greece

The project described in this report was concerned with vibration data obtained from rotating machinery in six large container ships. The purpose was a comparison of the data with existing alarm levels and the recommendation of new limits where it was thought necessary. The report is divided into two parts:

Part 1 contains a presentation of condition monitoring principles, a description of the induced defects and methods of analysis of rolling element bearings, the source of most of the data, and a brief outline of the Vibration Monitoring System used by Lloyd's Register.

Part 2 consists of the main analysis of the vibration data.

In the beginning of part 2 a categorization of the engine room rotating machinery in appropriate groups is presented. From these groups the vibration data of the main engine turbochargers were chosen to be examined first as the time available for the project was limited. A presentation of the turbocharger and the vibration parameters recorded at each measuring point is given before the main analysis of the data.

The analysis of the vibration data aims to establish alarm limits through an appropriate probability distribution function which will match the actual distribution of the vibration data. There are two approaches for the estimation of the alarm limits given by two different probability distribution functions, namely, the Weibull distribution and the Extreme value distribution.

Before the recommendation of the alarm limits, an investigation of specific trends in the vibration data for two cases of bearing failure is presented. This includes examination of which parameter is more indicative of the failures, correlation of turbocharger speed with the level of vibration, and the event of high vibration readings without failure.

The recommendation of alarm limits takes into account the number of false alarms and the performance of these limits in the cases of failure. Finally, a comparison of the recommended alarm limits with the Lloyd's Register guidance notes on acceptable vibration levels and their measurement is presented, before the concluding remarks of the project.

The impact of marine pollution regulations on the design and operation of oil tankers

by P. MAVRAGANIS, Private Student Greece

The sea transport of crude oil and other petroleum products is considered as the most economical and efficient way of moving large quantities of cargo. These products, however, pose great safety and environmental risks,

due to their flammability and potential of causing harm to the marine environment by poisoning the marine life.

As a result of the increasing number of marine accidents - mainly oil spills - during the 1980s and early 1990s, the period 1990-92 has seen considerable changes in maritime regulations. The aim of this report is to assess the impact of such regulations on the design and operation of oil tankers, especially those in the Very Large Crude Carrier Class (VLCCs).

Great focus was given to various tanker design proposals, to possible methods of reducing both exhaust and vapour emissions, as well as other aspects of marine pollution prevention, such as tank washing, cargo and ballast water handling, waste disposal, and sewage treatment. Furthermore, a discussion assessing all proposals, along with their cost and operational implications, is presented.

After the investigation, it became evident that no one design performs perfectly against the risk of accidental oil pollution, each behaving in a different manner under various scenarios. As far as exhaust emissions are concerned, technological advances have proved that considerable reductions are feasible, but with the penalty of increased investment and operational costs. In addition, an area of great importance for the maritime safety, the problem of crewing standards on ships, has to be reviewed and stricter legislation must be imposed, in order to ensure that quality ships are manned by properly qualified personnel.

Finally, with regulations unable to stop all marine accidents, shipowners and operators have a legal and moral obligation to take all safety precautions when handling oil on or near the marine environment.

Integrated ship roll stabilization using fins and rudders
LIEUTENANT D. MCCUE, RN

A Roll stabilization system in ships is needed to reduce the otherwise excessive roll motions that may result from sea conditions. Such motions can cause discomfort to crew and damage to equipment. In the commercial world the requirement to steer an alternative course to reduce motions would increase operating costs, whilst warships have the need for a stable weapons and helicopter landing platform. Traditionally, active stabilization systems have taken the form of tanks and fins. Since 1956 every combatant ship built for the Royal Navy has had an active stabilization system fitted. In recent years there has been considerable interest in the use of the rudder as a roll stabilizer. With this technique, roll motion induced by rudder displacement is used to counteract the roll motion resulting from sea disturbances.

This project begins by looking at existing published work on ship roll stabilization systems, with the emphasis on Rudder Roll Stabilization (RRS) and Integrated Systems. It proceeds by using the PAT 95 suite of seakeeping programmes, at DRA Haslar, to generate data from forced fin and rudder trials, for a frigate sized warship. These programmes are also used to produce data for the ship motion in various sea conditions. This data is then processed and analysed to infer transfer functions to describe the ship responses. The transfer functions are used to build a mathematical model of the ship's responses in SIMULINK in MATLAB. The ship motion data is used to generate sea disturbances to input to the simulation model. A cost function is introduced, and used in conjunction with the model to optimise fin and rudder controllers. The potential for improving current RN fin controllers and the benefit of RRS and Integrated Systems are examined. The relative performances of controllers optimised for different conditions are compared, and the advantages of adaptive controllers discussed.

All of the computer files referred to in the following text, or listed in the Annexes, are available on disks accompanying this report.

156

Application of reliability analysis to ship's systems
by LIEUTENANT COMMANDER B.D. MURRAY, Canada

This report introduces the principles of application of reliability analysis to ship's engineering systems. The basic terminology and concepts are described together with the use of the mathematical theory within the systems studied. The specific area in which the reliability analysis was applied, together with present difficulties and limitations, are discussed.

Attention is focused mainly on the use of reliability analysis in the marine engineering system of main propulsion, although, it can equally be applied to any system within the ship or even the ship itself.

There are 5 annexes and 7 appendices:

Annex A, B and C demonstrates the calculations associated with the main propulsion analysis carried out for Full, Cruise and Any Power respectively and their associated Fault Trees.

Annex D shows the Full Power Sensitivity Analysis calculations.

Annex E shows the System Data Base used within this report.

Appendices 1–7, give the Functional Block Diagrams, System Description and Operation, Fault Tree Calculations and Initial Fault Trees used within the analysis conducted.

Methods to control the proliferation of micro-biological contamination in marine distillate fuel systems
by LIEUTENANT COMMANDER R.L. PERKS, Canada

Microbiological Contamination (MBC) of hydrocarbon fuels is a problem that is increasing in both occurrence and severity. This is particularly true in the marine environment where water, which is essential for microbial growth, is invariably present in shipboard bunkers. When conditions are favourable, the metabolic products associated with microbial proliferation can facilitate fuel spoilage, extensive corrosion, blockage/poisoning/coking of fuel and combustion system components, and ultimately, catastrophic failure of engines. Middle distillates are most susceptible to microbial attack, hence gas turbine and high speed diesel engine users are particularly vulnerable. This includes most navies, and to an ever increasing extent commercial operators. In the Canadian Navy, MBC of shipboard fuel systems has resulted in millions of dollars of equipment damage and reduced availability.

This paper attempts to consider the problem in very broad terms from a marine engineering perspective. The chemistry, and microbiology of fuels is developed, as required, so as to provide a basic understanding of the underlying causes of MBC. The effects of severe infestations on fuel system and engine components, on ship operations, and the necessary remedial activity are significant (as demonstrated in a Canadian Navy case study), and advocates the requirement for a suitable overall controlling strategy. Methods by which micro-organism proliferation can be controlled are reviewed from literature and are used in the development of such a strategy aimed at limiting or preventing microbial growth. The use of anti-microbial physical fuel conditioners in preference to anti-microbial chemical agents in the Hierarchical Control Strategy (HCS) implementation plan, champions increasing concerns associated with the use of toxic chemicals in terms of health, safety and environmental protection. The HCS lends itself to the development of some basic design considerations so that improvements, with respect to increased resistance to MBC, may be realised in future marine fuel systems.

This paper reflects the views and opinions of the author. Although the author is a serving Naval Officer, these are not necessarily the views of the

Canadian Navy. Its purpose is solely in support of the fulfilment of academic requirements.

Condition monitoring of electrical equipment within a Reliability Centred Management strategy
by LIEUTENANT M.F. ROSE, RN

Technological advances have resulted in a range of rapidly developing condition monitoring equipment, each having a dedicated application and varying degrees of sophistication. Such diverse availability within a changing naval maintenance strategy, demands an investigation into the applicability of such tools.

Its relevance to electrical machines and ancillary equipment is given raised significance, with the current investigations into the concept of Integrated Full Electrical Propulsion (IFEP). This paper commences with an overview of the rationale behind condition monitoring in warships and how future applications may be influenced with the present interest in electrical propulsion. A survey of available techniques is conducted and their applicability within a Reliability Centred Maintenance (RCM) methodology is investigated. An overview of condition monitoring techniques for electrical machines, presently being researched is included. The report closes with a hypothesis on an integrated multi-condition monitoring tool application to an IFEP arrangement.

Mapping stress intensity factor weight functions
by LIEUTENANT A.M. STEWART, RN

Stress intensity factor solutions for an angled step in a finite width strip under tension loading have been produced using experimental and analytical methods. This geometry is applicable to a wide range of engineering components, including T-butt welds and screw threads. The experimental solutions were produced by fatigue testing of specimens with a range of angled steps. The analytical solutions were derived by geometrical mapping of published constituent solutions.

The methods used are described and the results presented. The solutions produced by the different methods are compared and their validity and utility discussed. The mapping technique offers considerable potential for the efficient production of stress intensity factor solutions. The experimental method developed can be adapted to validate existing solutions or to investigate new cases.

LR5K submarine rescue submersible simulation system
by LIEUTENANT COMMANDER G.E. WALTERS. Canada

The current LR5K Simulation System was developed by the Control and Robotics Group of Technical Software Consultants (TSC) for Slingsby Engineering Limited (SEL). This program successfully meets the contractual requirements of a foreign navy, who recently acquired the LR5K submarine rescue submersible. This project involves evaluating the present simulation programme, producing a list of prioritised improvements and implementing some of the proposed amendments in a MATLAB program for future inclusion by GRL in an improved version of the program.

The aim of the project is to transform the program into a more powerful instruction tool for the training of the submersible pilots. Even though the LR5 is approaching 20 years old, the validity of constructing and improving a simulator system is justified by allowing the operator to become intimately familiar with potentially dangerous situations, while under the direct supervision of an instructor. Although a simulator can not completely replace the

requirement for hands-on experience, the simulator develops the operator's systems knowledge and creates an instinctive response to emergency situations in a cost effective manner. The proposed improvements to the Version 1.10 software enables an increased number of emergency procedures to be exercised with the added ability of combining the evolutions in escalating complexity. These combined evolutions would otherwise be deemed to have an excessively high degree of risk to be conducted at sea, dived. The end result is a safer and more reliable operator through simulator training.

Although the author is a serving member of the Canadian Navy, the views and opinions stated in this report do not necessarily reflect the policies of the Canadian Forces and as such serve only to fulfil academic requirements.

An investigation into mechanical properties of technical ceramics
by C. WARDLE, MoD UK

There is no doubt that ceramics will play an increasing part in modern engineering development where special materials' properties are required. Ceramic materials have improved wear properties and are particularly suited to high temperature applications. These characteristics are being exploited and new materials to utilise such properties are always being developed. This report covers two aspects of the use of ceramics, firstly, the report forms an investment appraisal into the establishment of a ceramics testing facility at UCL. Secondly, the literature survey phase of the project has formed an investigation into the correct and standard tests to be carried out in the facility, and a list of data already supplied by other sources.

This report should be of interest to those involved in the mechanical testing of ceramic materials and establishing a facility for carrying out those tests. Secondly, it will be of interest to those wishing to get nominal values of material data for selected ceramic materials.

A investigation into the current and future use of titanium in the offshore and shipbuilding industry
by LIEUTENANT N.S. WRIGHT, RN

Titanium is the fourth most abundant element having structural possibilities in the earth's crust and at present the intense interest in titanium shows that many people believe it has great commercial potential. This belief is based upon three factors; abundance of the element, the location of the ore and the unique and attractive mechanical properties and excellent corrosive resistance of the element.

The aim of this report is to produce a single source of information for designers and engineers in the offshore and shipbuilding industries covering all significant aspects of titanium's mechanical properties, corrosion data, chemical composition of alloys, fabrication routes, weldability and applications. The report also includes a feasibility study based on replacing steel structure and components with titanium in current design study of a trimaran area air defence destroyer.

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

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