UNIVERSITY COLLEGE LONDON
MSc NAVAL ARCHITECTURE DISSERTATION
ABSTRACTS – 2001

Design – Seakeeping and High Speed Ferries
P.J.ANCERIZ, Private Student, France

The fast marine transport industry has grown substantially over the past twenty five years, approximately doubling in size every five year period. This rate of growth and the increasing speed of the vessels have created a need for a change in traditional naval architecture and shipbuilding. Indeed, numerous new high-speed hull forms are now in service and it is essential for operators and designers to assess the seaworthiness of such vessels in terms of passenger comfort and cost.

This report summarizes an investigation carried out on the seakeeping performances of high-speed hull forms used for civilian high-speed transportation. Three typical hull forms are analysed using Trimo-Shipmo, a strip theory based program developed by Maritime Research Institute Netherlands (MARIN).

The three hulls, monohull, catamaran and trimaran are made comparable in terms of payload, displacement and size. A number of seakeeping criteria are assessed against existing standards and the results of the three vessels are compared.

An investigation into the necessity of the Box Structure of Trimaran ships to meet the Stability Requirements of NES 109
A.G.BACHTIS, Private Student, Greece

In trimaran designs, the most commonly used connecting structure is the box shaped one, which has a similar construction to a conventional ship's double bottom, leading to a very heavy structure. As the bottom of the box may receive significant slamming loads, replacing the box structure with alternative connecting structures offers weight savings and increased seakeeping performance.

This study investigates the necessity of the box structure to stability in order for trimarans to meet the stability requirements of NES 109. A series of models of varying displacements, varying side hull separations and a constant Metacentric Height of three metres was analysed. The intact and damage stability of all models was analysed with and without box structure, assuming twenty one metres flooding.

The study is grouped into two major categories. The first category consists of models with the same form and displacement but different transverse metacentre and centre of gravity, denoted as the original model category. Within this category, three different displacements of 1,500MT, 1,800MT and 2,300MT were investigated. Within each of the consequent subcategories one of the models has the same transverse metacentre and centre of gravity as one of the models of the other two. The research on the above models revealed that the 1,500MT models without box structure were most unstable. The study extended in improving the stability of the 1,500MT model without box, with a vertical centre of gravity of 5.812m. In improving the stability of the model, eight different models and the improved models category were created. The models within this category have the same main hulls, but different side hull form, for a constant transverse metacentre and centre of gravity. The installation of ballast water and foam were also investigated within the latter category.

The study concluded that replacement of the box with an alternative structure is possible. Five different models without box passed all NES 109 requirements. However, modifications in the side hulls will have to be made. The 3 models with longitudinally stepped sides behaved best. It was observed that side hulls should have low displacement, small separation and full above water waterplanes, especially in the forward compartments. Alternatively, the required stability may be achieved by installing ballast water or low density foam in the side hulls.

The effect of Tumblehome on modern warship design
J.M.BRYARS, MOD UK

Tumblehome has long been associated with adverse stability characteristics for warships. As such, tumblehome was dropped for major vessels in the early 20th century, but not before severe loss of life. With the requirement to build 'stealthy' warships however, there is a movement back towards tumblehome because of the way in which it reflects radar beams. This report is directed at studying the implications of including significant amounts of tumblehome and the modifications needed to gain satisfactory stability.

A large amount of computer models were generated and tested looking at features such as:

- Angle of tumblehome.
- Beam of the vessel.
- Total (from the waterline) and semi-tumblehome designs.
- Intact and damage stability.
- Bulkhead optimization.
- Effect of tumblehome angle on Radar Cross Section.

The results indicated that tumblehome has severe implications, especially for damage stability. These can be overcome by adopting design measures such as increasing the beam of the vessel. Overall it was found that there was little benefit in adopting severe angles of tumblehome.

Quasi Static Stability Standard Development
G.MAILER, MoD UK

Current stability regulations fall into two broad categories: Military and Commercial Regulations. In general, ships are either designed to one or the other of these codes. Recently, however, ships such as RFAs and Hydrographic survey ships have had to be designed to both sets of regulations. Sea Technology Group (STG) of the MoD propose to investigate adoption of a unifying, baseline set of stability criteria that can be bought up to the appropriate level of safety for military vessels by applying 'owners enhancements' that are of a similar form to the baseline criteria.

This paper investigates the various stability regulations that a RFA would be required to meet, both in a theoretical form and via a limiting KG analysis, in order to determine the limiting criteria.

Based on this information a modified set of stability criteria for the 'weather criteria' are proposed. These criteria are derived from the original theory used by the IMO to produce its rules, yet represent a level of safety similar to the current NES regulations.

Various problems were encountered via the project that prevented a full analysis being carried out. These are detailed, as are the proposals for future work based on results of this project.

Improving Combat System Survivability
A.MARTIN, QinetiQ UK

This report investigates potential solutions that are aimed at improving the survivability of combat systems on surface ships.

The main problem addressed is that of centralization of combat system equipment. Areas of particular concern are the concentration of radar functions into a single computer driven command position.

Alternative combat system architectures are suggested and their technical feasibility examined. The vulnerability of each architecture is investigated using a 'presented area method' applied to a generic future frigate. Vulnerability values are compared to establish which solutions are most 'battleworthy'. Each solution has important implications for the overall arrangement of a warship, the position of masts, sensors and accommodation.

It is found that it is possible to reduce vulnerability through a variety of measures including:

- Creating a second fire control system for the surface to air missiles sited on a different mast from the MFR.
- Using developing technology to allow a second, remote command position crewed by the off-watch command team.
- Fully integrating co-operative engagement capability with the ship's combat system.
- Adding a stand-alone weapons system such as Raytheon SEA RAM.
- Dividing the surface to air missile silo, placing some cells in a different zone.
- Distributing fixed radar arrays about the ship's structure.

High Speed Ferry Trimaran Hull Optimised for Low Wake Wash
J.MELILLO, Private Student, Malta

One of the major problems to effect high speed ferries these days is the generation of wake wash which causes beach and river erosion. Accidents have also been reported such as the capsizing of small craft after the passage of high-speed ferries. The aim of this thesis is to design a trimaran ferry that is optimized to reduce the wake wash generated from it. The trimaran hull form has been selected for the ferry design because it is claimed to combine the resistance and seakeeping characteristics of the monohull with the wide deck areas and stability of the catamaran.

A FORTRAN program to calculate the wave resistance of the trimaran was written. Wave resistance is directly linked to the energy of the waves generated by the ship and is therefore a reliable indicator of the wake wash that will be produced after the ship. An initial sizing exercise for a large trimaran car-carrying ferry was undertaken to obtain values for displacement and dimensions that could be used to generate a hull form that would result in a competitive ferry design with adequate resistance, seakeeping, manoeuvring, stability and payload carrying characteristics.

Once the initial sizing was carried out a number of hull forms were generated and tested using the FORTRAN program. Initially the main hull parameters were varied while the side hulls were kept constant. The results indicated that a long, narrow and shallow main hull produces the least wave resistance. The correlation between main hull displacement ratio and stability was also investigated. A high main hull displacement ratio results in less wave resistance but also a decrease in GM.

The side hull was extensively tested for a wide range of parameters. The separation of the side hulls from the main hull and the position of the side hulls amidships or aft of the ship were also varied. The results showed that it was difficult to predict any trends in the wave interference and cancellation effects. In optimizing a trimaran for reduced wake wash one needs to test extensively and vary the parameters involved over a wide range of values in order to obtain the best results.

The final tests showed that thin side hulls about 40% the length of the main hull, positioned aft and as close as possible to the main hull produced the least wave resistance. Another interesting aspect to emerge from the results was the fact that deep side hulls were best for reducing wave resistance. Side hulls deeper than the main hull were also tested and these produced a further reduction in the wave resistance.

The final results show the configuration of the trimaran hulls that are needed to produce the least wave resistance and wake wash for a high-speed ferry with a displacement of 4,701.4 tonnes and a service speed of 40 knots.

Optimum GM for Trimaran Seakeeping and Stability
L.K.ONG, Private Student, Singapore

One of the key issues the designers of trimaran ships face is the choice of Metacentric Height (GM). High GM is necessary for stability but is bad for seakeeping. Therefore it is unclear whether a trimaran should have GM closer to a catamaran or a monohull. It is also unclear if there exists an optimum GM which is ideal for both seakeeping and stability.

This report is the result of an investigation carried out to find the optimum GM for both stability and seakeeping for a frigate sized trimaran. The scope of this investigation includes determination of the effect of KG and overall beam, appendages and the side hulls on the stability and seakeeping of a trimaran. Stability calculations are carried out using GODDESS CASD Suite and stability assessments are carried out using NES 109 stability criteria for warships. Seakeeping calculations are carried out using the frequency domain based strip theory program, TRIMO. Further seakeeping assessments are also carried out using three human factor based criteria;

- Lateral Force Estimator (LFE).
- Motion Sickness Incidence (MSI).
- Subjective Magnitude (SM).

It was found that trimarans designed using current design methodology need a GM much higher than a monohull for stability. This will, however, result in poor roll motion behaviour and lead to the degradation of performance that is unacceptable. Adding appendages do not have a significant effect on the roll motion behaviour since a large moment is required from the appendages to counter the large roll motion generated by the side hulls. This requires a fairly large appendage area which do not argue well for resistance.

It was also found that the GM of a trimaran could be lowered when the side hull length increases. This improves the roll motion behaviour of the trimaran and increases the effectiveness of the appendages. Increasing side hull length is also beneficial for wave making resistance. It seems that by modifying the side hull, an optimum GM (lower than the current GM recommended) for the trimaran is achievable and desirable. This not only gives adequate stability and much improved seakeeping, but also generates other benefits which are not offered by the current trimaran design methodology.

Numerical Simulation of 2D Sloshing Waves in a tank using FLUENT
N.POLLOCK, Private Student, UK

A study has been carried out to investigate the use of the CFD code FLUENT to model fluid sloshing waves in partially filled tanks subjected to motion. The aim of the project was to validate the results generated using Fluent against accepted results for the fluid sloshing problem. The scope of the study was restricted to the development of a working two-dimensional model within FLUENT and the validation of the results.

The experience and results gained demonstrated that FLUENT was:

- Difficult to operate.
- Difficult to create realistic conditions.
- Produced unrealistic surface wave profiles.

The results did not behave in the way described for the accepted results against which the FLUENT results were compared.

The effect of changing air density and surface tension coefficient were also explored and found not to improve the quality of the results.

It is the conclusion of this project that the Navier Stokes' computation method used by FLUENT is not suited to modelling the fluid sloshing problem. This is due to the minimal influence of viscosity in the fluid sloshing problem.

MSc MARINE ENGINEERING DISSERTATION ABSTRACTS – 2001

Advanced Control Systems aiding Manning Reductions in RN Warships
LIEUTENANT S.T.AUSTIN RN

The use of advanced control system is proliferating in new build ships. These control systems has several advantages such as improving the effectiveness of individuals and allowing a reduction in manpower. The Merchant Marine has included advanced control systems in their new build ships. The control systems used by Shell Liquid Nitrogen Carriers (LNG) was assessed with similar systems used in the P&O Cruise Liner *MV Auriana*.

The requirements of the warships were compared with the in service experience on the LNG Carrier and the Cruise Ship. The aim was to establish if the existing advanced control systems of the merchant marine were appropriate for use in warships.

It was found that if the manpower savings were to be achieved in operating the propulsion plant then the Unmanned Machinery Space (UMS) policy used in a LNG would need to be implemented. The Cruise Ships are unable to adopt UMS due to Flag Authority Regulation. The watchkeeping burden was directly

comparable to that of T23 frigate. It was recognized that the role of a warship will not allow constant UMS. It was thought that UMS would be viable at a cruising state supplemented with additional personal at states of higher readiness.

The Distributed Control System of the Cruise Ship was found to be more suitable for RN use due to the gradual degradation and more fall back options in the control system in the event of system fault or action damage. The Integrated Control System philosophy of the LNG was predicted to be more reliable but in the event of action damage the loss of control functions would be more severe.

It was found that advanced control systems similar to those in existence would be appropriate for RN use.

Application of Fuel Cells for Naval Marine Power Generation
LIEUTENANT M.R. BOYES RN

Marine vessels have traditionally employed some form of heat engine to provide an auxiliary electrical supply, with diesel engines coupled to electric alternators the most common method. With the move toward Integrated Full Electric Propulsion systems (IFEP) these are likely to be superseded in specialist areas, such as naval applications, where the advantages offered by gas turbines are perceived to outweigh their additional costs and complexities. With increasing limitations on emissions and a desire to reduce cost, the development of both diesel engines and gas turbines is continuing, but as these are relatively mature technologies, any improvement is expected to be gradual and of limited effect.

Fuel cell technology is therefore increasingly seen as a logical progression in marine power generation due to its low emissions, noise and vibration, and part load performance characteristics. As the development of fuel cells is in relative infancy when compared to the competing technologies, consideration of their limitations must be made before committing to it as the power generation solution for the future. The few studies that assess the marine fuel cell market potential within commercial shipping have identified a market below the 2.5 MW power range. The aim of this paper is to assess the application of fuel cells for naval use in auxiliary electrical generation or as part of an IFEP system.

A literature search was conducted and companies actively engaged in fuel cell research were contacted to identify suitable technologies, their current state of progress and highlight any difficulties as yet unresolved. Using this information a naval market and application analysis was conducted with system dimensions and capabilities estimated to enable comparisons to be made. This identified fuel cell systems to be a suitable alternative for power generation, given some allowances, and these are discussed with comment on possible solutions. Marine Gas Oil derivatives are identified as suitable fuels as they offer the minimum impact to ship design and fuel supply infrastructure, despite increased system volume and technological difficulties. The most suitable cell type depends on the specific application and operating philosophy considered. For near term applications (10 to 15 years), Proton Exchange Membrane and Solid Oxide Fuel Cells have the potential for use, yet systems designed around either type will require a compromise in performance when compared directly to the current technologies.

Novelty Detection in Condition Monitoring Data
LIEUTENANT S.N.DAY RN

The ability to analyse and draw useful and timely conclusions from the condition monitoring, operating and control data of engineering equipment is essential as the industry in its entirety progresses towards ever tighter margins of time, cost, maintenance and personnel.

Techniques and algorithms for novelty detection and pattern recognition within data are manifold, widely researched and reported. Key areas of research in this field, outside of engineering, include medical diagnosis formulation, imagery analysis and character recognition.

Drawing from these themes, the principal aim of this project was to discern the characteristics exhibited by a data set of parameters, taken from an operating Marine Diesel Engine. Further, to identify methods whereby these characteristics could be extracted and utilized to indicate the operating state of the machine. The key underlying thrust throughout this work has been a desire to move away from the traditional warning, alarm and protection signals issued in response to an individual parameter's fluctuation. This essentially requires a more holistic approach that encompasses the whole or pre-determined sub-sections of the range of data captured by a control or condition monitoring system.

These objectives were tackled by a detailed literature search, yielding broad analysis of the subject areas and techniques available. The compilation of this data led to an initial selection of 3 methods to actively pursue, representing a cross-section of techniques:

a. Supervised Statistical Method – K-Nearest Neighbour.
b. Unsupervised Statistical Method – K-Means.
c. Unsupervised Neural Network Methodology – Self Organizing Map.

Implementation, programming and testing of these methodologies was conducted using the MATLAB suite of programs and public domain shareware, modified for this purpose. Their responses were compared and analysed using data modified to simulate interaction between individual and groups of parameters that would likely be experienced by this type of machine. This manipulation of data was also conducted on the premise that the simple mathematical functions used are likely to be exhibited as the building blocks of parameter fluctuation in the event of a fault condition occurring.

Podded Propulsor Pull Configuration Load Calculation and Analysis Method Study

MR. A.K. GALIATSATOS, Private Student, Greece

During project evaluation and model testing carried out in the last decades, it has been shown that the power requirements of the integrated electric propulsion system, involving a sufficient number of pods, can be reduced up to 15% in comparison to the conventional mechanical option. This level of reduction in the power requirements can offer to the ships that employ Pod Propulsors a significant optimization of the through life operational cost.

However, not all has been smooth running with Podded Propulsors. Malfunctions in the propeller bearing systems have been occurred. The ships that the malfunction occurred on were forced to be dry-docked, and while the malfunction was repaired the causes of it are still unknown.

The aim of this project is to offer an understanding of the loads that acting on the entire pod system in order the behaviour of the Podded Propulsors under various operating conditions and vessels configurations to be highlighted.

For the purposes of the undertaken project various assumption are to be made. The pod structured geometry is to be simplified in order the propeller performance and its interaction to the pod structure to be defined. Suitable equations that govern the behaviour of the system are to be presented and a load calculation software will be developed and its validity will be assessed by conducting a parametric survey.

Furthermore, the hydrodynamic loads generated on the pod structure are transmitted to the ship hull and consequently to the entire ship structure via the slewing ring and bearings. Therefore, this project endeavours to assess an analysis method for the loads acting on the slewing bearing and the corresponding structures.

The load analysis method will take under consideration the requirements for slewing torque generated by the steering angle of the ship.

In order for the above to be performed, the problem is to be divided into two sub-categories.

1. To investigate the loads generated by the propeller operation
2. To investigate the loads acting on the entire propulsor due to the geometry of the pod structure, in respect the areas inside and outside the slipstream that is generated by the rotation of the propeller.

For the calculation of the results, a computational program developed in Lloyd's Register Technical Investigation Department was modified by the author and adjusted on the under consideration study. The obtained results are to be discussed and evaluated.

Pollution Transport in the Marine Environment – Gravity Currents and Waves
MR. C. KASTRITSEAS, Private Student, Greece

Understanding how pollution is transported and spreads in the sea is particularly important for determining effective ways to treat oil spillages. In addition, it can provide a means of assessing environmental risks associated with shipping and discharges into the sea.

Such flows can be modelled and approximated by lock-release gravity currents. A gravity current is a wedge of fluid intruding laterally into an ambient body of fluid and is produced when fluid of one density is released into fluid of a different density at a horizontal boundary. The density difference causes a variation in buoyancy force along the boundary and produces a horizontal pressure gradient, which drives a flow along the boundary.

A considerable amount of work has been done on gravity currents and their characteristics. However, little consideration has been given on the way gravity currents behave in the presence of waves, i.e. in conditions that better approximate reality.

In this experimental investigation, a newly built, transparent water tank (LxHxB = 2,955 x 495 x 150 mm) was used. A lock gate was fitted to it, so the lock-release case could be performed. In this case, two fluids of different densities were contained in the tank, initially at rest, and separated by a vertical barrier (lock gate). When the barrier was withdrawn, the dense fluid flowed along the floor of the tank underneath the less dense fluid, forming a gravity current.

The dense fluid was formed by adding amounts of salt to the water at one side of the gate. A simple food colour was also added to allow for good visualisation of the flow. Different salt concentrations of the dense fluid were employed and the height (or depth) of the water in the tank was varied. The experiments were recorded using a video camera and the recordings were then analysed using suitable computer software to assess the degree of propagation of the gravity current along the tank floor at various time periods.

Two sets of experiments were performed: the first without the presence of waves and the second in the presence of different wave patterns. A simple, suitable, manually-driven wave generator was designed and built for this purpose.

The results were compared against theoretical calculations and conclusions were made about the behaviour of gravity currents in the presence of waves.

Introduction to Propeller Design. Finite Element Method in Blade Stress Analysis.

MISS R. MIGUEZ, Private Student, Spain

In the 19th century, for the first time, theoretical methods were used in marine propulsion, resulting in successful designs like those proposed by ERICSSON, Francis P. SMITH or MONSIEUR DOLLMAN.

The design of a marine propeller is developed nowadays by the introduction of new technologies, together with the study of propulsion hydrodynamics, which offered the base to a new philosophy in the design of propellers.

The procedure developed from the cantilever beam, base of classification societies regulations regarding blade thickness, assumes that a blade flexes about the neutral axis of the root section, which is either cylindrical or a straight section. In the case of the cylindrical section procedure, the adopted root section is located at twenty five per cent of the propeller radius or alternatively just clear of the fillet radius. The method evaluate stresses of a given section at the point of maximum thickness, assuming thrust and torque can be substitute by equivalent loads at their centre of action.

More recently, the use of beam theory techniques for propeller blade stressing, base of the classification societies regulations in this field, has been superseded by the development of numerical analysis methods. These use as input data the propeller geometry together with the results of pressure calculations and combining these with an appropriate finite element mesh structure. The main advantage of computational methods over the traditional is that they study stresses and strains over a greater area, assuming the hydrodynamic blade loading is defined.

The software used is Props2, a numerical package for propeller flow and blade stress analysis in which three modules, Propeller Steady Flow, NASTRAN, and Finite Element Modeling and Post-processing, are included.

The use of fluidization to lay pipes in the ocean: Experimental

Mr. D.PAPAMICHAIL, Private Student, Greece

Industry today uses pipes to transport fuel oil or other petroleum products, natural gas and fresh water through long distances. If the pipes pass through the sea it is usually desirable to bury them one meter or more below the seabed. This procedure is done for the following reasons:

1. To protect them from destructive wave action.
2. To avoid any damage from boat or ship anchors.
3. To avoid instability due to bottom currents.
4. Eliminate the risk of any hazardous to the marine environment.

One of the methods that are used to submerge the pipelines is the fluidization technique. Jets placed in front of the pipe are used to fluidize the seabed and the pipe sinks due to its weight as it is being dragged. Then during the backfilling process the arising soil settles on the seabed and the pipe gets buried.

The aim of this project was to gather information and investigate the current technique that is used in industry and try to improve the design. Therefore in order to visualize and understand the motion of the pipe that occurs in reality an apparatus was designed that is able to represent the behaviour of the pipe. Using

this model and varying the number of jets the behaviour of the bed and of the model was observed. This procedure was repeated for different type of particles since the soil of the seabed has different size of particles. During the experiments, for different heights of the bed, the critical flow rate was recorded during erosion and fluidization states when the model was kept in different fixed positions and when it was freely to move in a vertical motion. From the experiments that were established it was estimated that the critical flow rate is independent of the height of the bed and from the size of the pipe. Also by increasing the number of jets the value of the flow rate is reduced significantly. Furthermore it was observed that having a large number of jets, evenly placed around the periphery of the pipe, the portion of the seabed that is fluidized is not spread far away from the source. This means that the amount of particles that settle along the pipeline after fluidization is larger, and as a result the pipe will be fully protected. Therefore the use of backfilling equipment may not be required.

Investigation of performance and integration issues associated with Marine Gas Turbine Alternators

MR. R. PARTRIDGE, Private Student, UK

The use of marine gas turbines has diversified from almost exclusive mechanical drive application to more sophisticated applications in vessels using integrated power and propulsion systems and converter-fed electrical drive systems.

This new application of marine gas turbines may provide tangible benefits to the operator in terms of better utilization and reduced number of prime movers, and critically leaner manning levels. Considerable cost of ownership savings are anticipated. Also, significantly, Single Generator Operation (SGO), where the threat-risk and geographic location permit, will offer further cost and ARM benefits.

The requirement for a reduced marine engineering watch-keeping compliment implies much greater reliance on automation, and in particular, machinery control and surveillance as part of an integrated Platform Management System (PMS).

Modern turbo-intercooled diesel engines, which must be considered as the conventional marine generator prime mover solution, are more or less immune to maximum power output reduction up to at least 45°C ambient air temperature. However, gas turbines are more susceptible to power reduction at elevated climatic conditions, the effect of which was demonstrated using a 25MW simple cycle gas turbine performance model. The effects of compressor blade fouling and turbine tip seal wear were also illustrated, which will often have significant impact on maximum achievable power. A number of case studies, using definitive climatic data, provided an indication of the maximum engine power output achievable at specific geographical locations. The results, coupled with a limited insight into some of the problems encountered in early sea-going experience of Gas Turbine Alternators (GTAs), provided a compelling case for a high level of integration between the Engine Control System and the Electrical Power Management System. In particular, in SGO the need for a high level of automation to adjust electrical load level by shedding and re-applying the sacrificial portion of the load would enable the platform to more fully realize the benefits on offer.

A small number of different ECS/EPMS performance management methodologies are briefly reviewed, with observations on their relative merits and shortcomings.

The primary conclusion is that treating a GTA as a DG is simply not good enough in the context of sophisticated vessels requiring the ability for SGO. Careful attention should be paid to both performance issues associated with the gas turbine, and integration of the systems within the integrated PMS hierarchy using a

more joined-up approach. This would avoid any nasty surprises, and provide a combination of optimal prime mover utilisation and integrity of essential electrical supplies.

Air Independent Power Systems for Submarines
LIEUTENANT E.R. SHARKEY RN

Submarine Air Independent Power (AIP) systems may be divided into three categories:

- Nuclear.
- Thermal (closed cycle heat engines).
- Electro-chemical.

Whilst nuclear power is the ultimate AIP solution in terms of submerged endurance, mobility in three dimensions and high speed it has certain disadvantages such as excessive costs, demanding infrastructure requirements and stringent safety standards. A lower cost option, the non-nuclear or conventionally powered variant also provides a quieter and stealthier submarine that is more suited to certain missions such as littoral operations. However, the submerged endurance of the traditional conventional submarine is limited by the relatively low capacity of its lead acid battery, which is used to supply power for both propulsion and hotel electrical loads.

As a result, there has been extensive research and development work on a range of different AIP systems to enhance the submerged endurance and operational flexibility of the conventional submarine.

The primary objective of this thesis is to review the different AIP systems and discuss their limitations. The systems are examined against key submarine integration factors and the ability to meet a range of operational profiles. Additionally, the application of AIP systems in nuclear powered submarines is also discussed.

The limited amount of energy (fuel and oxidant) that can be stored onboard the submarine is a critical factor that restricts the endurance of all the AIP solutions. However, fuel cell technology within the automobile sector, in particular fuel storage systems, may be exploited in a submarine fuel cell system. This thesis investigates the different fuel options and storage methods that are available to determine their application in submarines and potential for development.

Fuel Cells for Merchant Marine applications
MR D. SPERTOS, Private Student, Greece

This project investigates the use of fuel cells for marine applications. The development of fuel cells is a major step in the transportation technology towards the implementation of energy systems being more efficient and environmentally friendly. Major research has been done on the use of fuel cells in the automotive industry, and this project will be considering the use of fuel cells on board of ships for propulsion and other applications.

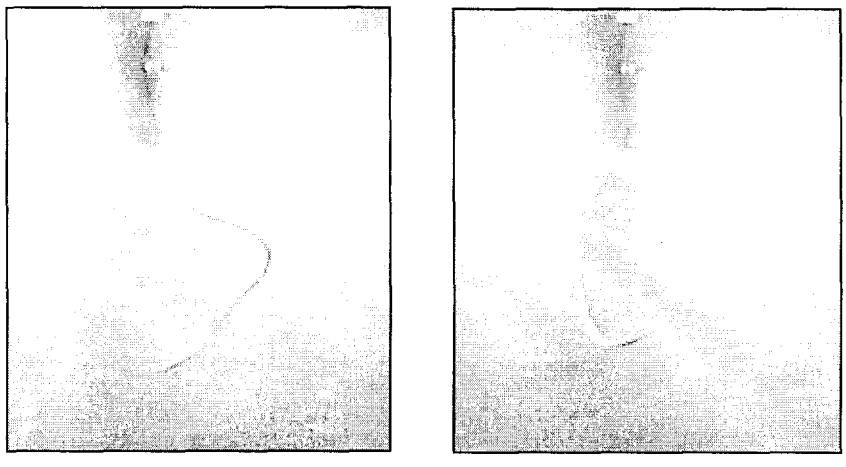
A fuel cell is an electrochemical device that converts a fuel's energy to electrical energy. Fuel is supplied to the anode (negative electrode) and oxidant to the cathode (positive electrode), and the fuel cell then operates like a continuous battery. In this way, the fuel cells chemically combine the molecules of a fuel and oxidant without burning, surpassing the inefficiencies and pollution of conventional combustion.

The aim of the project is a research, based on literature review and contact with companies that are developing fuel cells, on the feasibility of the use of fuel cells for marine applications in the near future. Four different types of fuel cells that can be used in marine applications (molten-carbonate, solid-oxide, polymer-electrolyte and phosphoric-acid fuel cells) are investigated for the case of an inland waterway ship with a power demand of 200-400 kW output. The research is also based on information on applications where the fuel cells are being used now (such as submarines).

The next step is a research on the possible fuels to be used with the fuel cells, such as hydrogen, methanol or natural gas. This is done in comparison with an investigation on the use of diesel fuel and predictions of its use and cost in the next 20 years. As the fuel is the most important running cost of a ship throughout its operation, an economic study is done based on fuel costs.

Whipping Modes of Elastic Tubes
MR. S. TSIPIDIS, Private Student, Greece

All flexible connecting elements in modern fluid power and fluid conveying systems are required to sustain high pressures and stress levels. These connecting elements such as elastic tubes and plastic hoses are required to perform in harsh environments were corrosive fluids, large temperature differences and high pressures tend to wear them down and eventually damage them. When a pressurised elastic tube is severed, the jet of fluid released from the open end will exert a thrust on the tube. The result of this continuous thrust will be to initiate a rapidly accelerating rotational movement of certain displacement causing the tube to oscillate unstably, a phenomenon otherwise known as pipewhip. This unstable phenomenon can pose great threat to any objects or humans found exposed inside the zone where pipewhip occurs. Therefore an investigation of the size of the exposure zone, the speed of movement and the identification-categorization of the motions occurring, was found to be essential.



This paper is concerned with the study of the above phenomenon for a system, which is constrained to move in the vertical axis. Different features of this phenomenon were investigated experimentally by varying the flow rate of the discharged liquid and the length of the elastic tube for both cases of the tube being surrounded by air or water. Additionally, an attempt was made to construct a theoretical model, using a rigid plastic beam model incorporating the tube twisting motion and the tube weight, in order to directly compare the experimental and theoretical data.

The results obtained helped in categorizing the different types of motions occurring during the pipewhip phenomenon of a vertical elastic tube, while simultaneously helped identifying the size of the pipewhip hazard zone. Additionally, the speed of the tube-end was determined, which helped visualizing the effect that an impact between the tube and an object in the hazard zone might have. Moreover, from the theoretical analysis it was determined that the effect of tube twisting is analogues to the weight of the tube and the flow rate of the conveying fluid. Finally, all the results obtained were found to be applicable not only for elastic tubes but also for rigid pipes conveying high-pressure fluids.

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

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