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Contents

1. Study Objectives

Improving the competitiveness, safety and security of European shipping is a major objective of the European Maritime Transport Policy (Ref 1). This study will review ship technologies which could contribute to improved safety and efficiency of maritime transport as well as its environmental performance.

The main goal is to provide information for stakeholders on current state-of-the-art and on the emerging technologies and techniques becoming available for use on-board ship, in the short term and longer term, which will support improved efficiency (cost/ton-km) and quality of maritime transport services (reliability, safety, security and environmental performance). The study will highlight key technologies that will impact the achievement of co-modality transport in Europe. Selection of appropriate state-of-the-art technologies will need to take into account whether they will be supported throughout the life of a ship in order to avoid early obsolescence and unsupportable systems.
The availability of new technologies for marine applications could have considerable effect on current operational procedures, marine regulations and health and safety standards. This aspect will be taken into consideration when evaluating potential technologies for application on-board-ship.

2. Target Stakeholders

- Ship technology providers who wish to examine new developments affecting their product development plans
- Ship operators who wish to evaluate their technologies and identify alternative technology options to increase the efficiency and quality of their services
- Freight integrators that are designing specific supply chains
- Policy makers interested on the impact of emerging technologies on sustainable transport

3. Glossary terms

- *Co-modality* was introduced the Mid-Term Review of the 2001 Transport White Paper[1] to signify optimal use of all modes of transport singly and in combination.
- *Ship efficiency* can be measured by the average ship running cost per km. The design factors influencing ship efficiency are propulsion efficiency, propeller efficiency and hull efficiency measured in operational terms by specific fuel consumption and ship speed. Operational factors affecting ship efficiency include port turnaround times and efficiency of loading, maintenance, crewing, regulations compliance.

4. Overview of ship technologies

4.1 Key drivers for enhanced ship technologies

Increasing fuel prices and strong environmental concerns (regulations and cargo carrier demands) have changed the competitive landscape. A ship that was state-of-the-art and leading the competition 5 years ago is now expected to fall far behind competition in another 5 years with detrimental loss in asset value; the changing competitive environment has rekindled interest in improving ship efficiency and sustainability performance (Ref 2).

To meet the changing commercial market and economic environments, new vessel designs will be required with longer lifespan, with more flexibility in their design and which will be more energy efficient and cost effective to operate (Ref 3). These new vessels will require the latest enabling technology and their integration with ship/shore infrastructures will need optimization.

The need to minimize operating costs is paramount in order to be competitive. The current oil fuel based energy source, at recent high prices, can result in fuel costs as high as 50% of operating costs (Ref.4). Hence choosing the most appropriate energy source is vital. Alternative energy sources for power generation (e.g. LNG, fuel cells, nuclear) are now being considered by many companies. Energy consumption for purposes other than propulsion can also contribute significantly to fuel costs (e.g. hotel services in passenger/cruise liners) and these factors should be factored in designing optimised solutions. It has been claimed that the benefits of employing a common electric power system for both propulsion and ship's

[1] "Keep Europe moving – Sustainable mobility for our Continent" (COM 2006, 314)

services can, in an optimised merchant ship installation, allow Running Cost savings of up to 25% (Ref 5). Hence the benefits and limitations of each type of system will be assessed.

Apart from the hull and propulsion efficiency, optimisation of ship running costs and quality of services depends on the performance of operational systems and processes such as voyage management, loading, maintenance and compliance automation. Such systems will be only briefly covered in this study.

Key areas to be addressed:

1. *Ship design development trends*
    a. Efficient hull forms
    b. Improvements in Propeller Efficiencies
    c. Long Lifetime Design to increase the useful life of ships and reduce degradation effects
    d. Designs to promote intermodal transport services.
2. *Propulsion technology development trends*
    a. Energy Sources with specific reference to fuel cells
    b. Diesel engine developments
    c. Gas Turbines
    d. Hybrid Propulsion Systems
    e. Podded Propulsion
    f. All Electric Ship
    g. Wind Assisted Ships
    h. Shore-side Power Supplies
3. *Ship operation systems and processes*
    a. Ship shore communications
    b. Condition monitoring systems
    c. Integrated Platform Management Systems

It is anticipated that enabling technologies emerging in the areas listed above will contribute to the following EU goals:

- Increased safety at sea and of personnel and passengers
- Reduction in the effects on the environment due to increased safety

- Improved working conditions/job satisfaction
- Increased competitiveness due to improved efficiencies
- Easing/smoothing the intermodal interfaces
- Reducing bottlenecks and congestion

References

Key Publications

1. Maritime Transport Policy – Improving the competitiveness, safety and security of European Shipping – issued by the European Commission (ISBN-42-79-02947-9)
2. Tor E. Svensen, Environmental Footprints of Ships and the Future Asset Value OSLO SHIPPING FORUM, 10 June 2008
3. Waterborne TP – European Technology Platform supported by the European Community under the ‘’Sustainable Development, Global Change and Ecosystems’’ programme (2003-2006) – Strategic Research Agenda Overview
4. Saving fuel oil to improve business performance, DNV Leaflet
5. THE ELECTRIC WARSHIP VI by C G Hodge and D J Mattick OBE A paper for the Institute of Marine Engineers (12 December 2000)

Key projects

FP5 INTERMODESHIP It provides a flexible and more profitable door-to-door waterborne solution, including the transport of 'swap bodies"

Key journals, conferences / events

International Conference on Ship Efficiency - The German Society for Maritime Technology http://www.ship-efficiency.org/

5. Ship Design Development Trends

In an industry where there is an increasingly keen competition on a global scale, the key to survival is designing, building and operating ships more efficiently than is the case with the majority of current vessels. A ship can be considered to be efficient if it is profitable, environmentally compatible and if it complies with the safety, health and environment policy of the owner. However, experience to date has shown that current ageing vessels are almost always uneconomical in operation and environmentally unacceptable when compared with modern vessels.

Much of the existing fleet of cargo vessels is ageing, uses outdated and energy intensive technology, and will only have about a further 10 years of life; there is also currently a shortage of capacity in the SSS sector- a situation that may change under the current economic climate. There is therefore, a need for a new generation of vessels which will meet these requirements.

5.1 European Scenario

The aims and objectives of the European Maritime Transport Policy and the IMO is to ensure that future shipping is safer, more secure, more energy and fuel efficient, and more environmentally friendly. These requirements will also, in the not too distant future, generate a need for a new fleet of vessels capable of meeting these requirements for sustainable transport.

In addition, the European White Book promotes Short Sea Shipping (SSS) and associated intermodal transport modes. A stated aim is to move cargo from road transport to more environmentally friendly modes of transport and in particular coastal transport to SSS where there is already a shortage of capacity. Key policies aim to support improved ship emissions, wastes and "end of life of vessels". It is likely that new vessel designs, compatible with these requirements, will be required, capable of operating in both deep sea and in the shallower coastal and inland waters.

The criteria to be considered in the decision process when drawing up the requirement for new vessels include capacity, redundancy, environmental influence, maintenance and repair, manning, noise/vibration, but the main criteria in future will be fuel efficiency, environmental performance and direct investment cost.

The European Commission has placed great importance, when funding R&D projects on the following aspects of ship design:

- hydrodynamics and stability
- efficient hull forms and structures
- power plants and propulsion

Some of these development trends are discussed in the following Sections.

5.2 Efficient Hull Forms

5.2.1 Hydrodynamics and Stability

The recent increase in information technologies dedicated to optimal design, associated with the progress of the computational fluid dynamics tools for predicting ship hydrodynamic performances, has resulted in significant improvement in ship design and over the last 15 years and the development of more stable and efficient hull forms has accelerated.

Aspects which are taken into account in determining the performance of a vessel in different sea conditions etc include:

- the type of vessel and its role
- prevailing operating conditions and the performance required (speed, stability etc)
- port limitations, narrow routes
- sea conditions (states, slamming/vibrations etc.)
- structural requirements
- draught, shallow water

The European Commission has funded a three years European R&D project, FANTASTIC (G3RD-CT 2000-00096), with the goal to improve the functional design of ship hull shapes The principal objective of FANTASTIC is to improve ship design by applying parametric shape modelling and state-of-the-art CFD analysis tools to predict ship hull performance. These functional aspects are integrated in an optimisation environment (Ref 1).

References

Publications

1. Towards optimal design of ship hull shapes j.j.maisonneuve, s.harries , j.marzi, h.c.raven, u.viviani, h.piippo

Project

1. EC funded Project FANTASTIC, G3RD-CT 2000-00096, a R&D project on ‘Functional Design and Optimisation of Ship Hull Forms’.

5.2.2 Hull Structural Design

Structural design of a ship is one of the few areas of the marine platform process where the latest design techniques are being employed. These techniques fall into the general category of computer aided design/engineering. A specific example of such techniques is the use of finite element analysis to establish the stresses in the platform hull and superstructure. This technique enables the hull and superstructure to be configured in an optimized way to better withstand platform operational stresses and yet have weight which is less than that of earlier designs. This, in turn, can reduce construction costs and because the platform structure weighs less, increases the capacity and hence operational efficiency.

Ship structural design tools must be capable of taking into account all the modern material such as composites which are increasingly being considered due to their strength, lightweight, resistance to corrosive degradation and environmental benefits. Equally, such tools must have the capability of dealing with a variety of new hull concepts and multihulls (e.g. catamarans, trimarans, pentamarans). Several such tools are becoming available; an example is provided in the reference documents (Ref 1).

5.2.3 Future Hull Shapes

Existing cargo vessels are characterized by a U-shaped hull requiring a draft of between 4-6 meters which is a limitation in terms of access to small ports and shallow channels. The requirement for new and competitive vessels has generated the need to investigate other hull forms such as multi-hull vessels to provide improved stability while having a shallow draft and the potential to operate without ballast, (the average usage of vessels around the world is only around 50-60%, with many ships spending too much time running in ballast.).

References

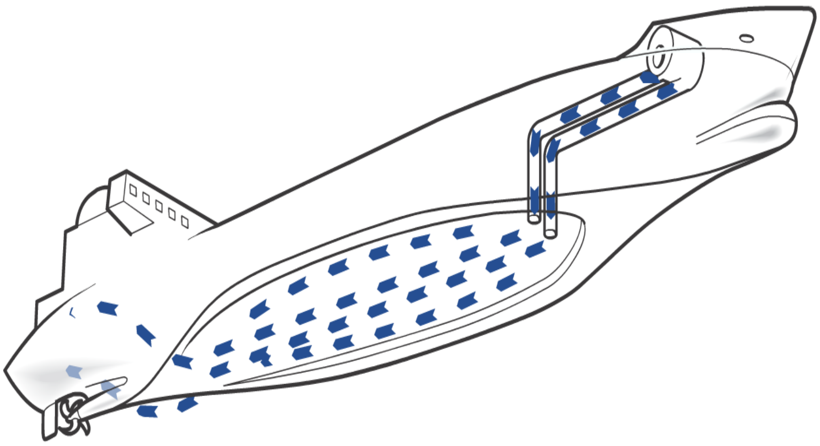
1. Unified first-principles ship structural design based on the *maestro* methodology Dr. Robert S. Dow and Professor Owen F. Hughes

5.2.4 Air cavity ships ACS

There are several methods of adapting a vessels's hull to improving performance, reduce fuel consumption and lower emissions such as optimizing the hull shape, dimensions, displacement and block coefficient to reduce the vessel's resistance to movement through the water. Air cavity ships utilize air to reduce the drag and frictional resistance of a hull. The method involves injecting air into a specially designed air cavity in the underside of the hull which effectively reduces the hull wetted area and frictional resistance of the hull surface.

The idea of Research on drag reduction was proposed by Laval and Froude in the 19th century but with little success. The Research Institute in St Petersburg contributed significantly in the 1960s by Butuzov and later applications by I. Matveev (Ref 1). Research in Europe, USA, Japan, Korea and Australia has been conducted recently.

Air-cavity ships (ACS) are advanced marine vehicles that use air injection at the wetted hull surfaces to improve a vessel's hydrodynamic characteristics.It has been estimated that typically less than 3 per cent of the total ship power is needed to support the air cavity total power requirement.
'At sufficiently high speed and with suitable hull lines, a boat can glide over the water surface. Air can be injected under the bottom, significantly reducing wetted hull area and consequently hydrodynamic resistance'. This type of ship corresponds to the ACS, and the phenomena of generating a gas layer at the submerged hull surface is called artificial cavitation or air lubrication.



Air Cavity Ship. Source: DK Group

The idea of drag reduction aims primarily at high speed vessels but reduction of hydrodynamic resistance is also applicable to relatively slow vessels, such as cargo vessels and tankers but with a different arrangement of air cavities. The larger size and weight of these vessels require several air cavities (up to 7-8) built into the underside of the vessels (Ref 2). For conditions of semi-displacement, most of the hydrodynamic resistance comes from waves, making ACS not so effective; calm water is ideal condition.

The Danish-Dutch DK Group has patented the ACS technology (Ref 3) and calculations carried out by the Group indicate that ACS reduces a ship's friction by approx. 10%, which gives fuel savings of 10-15% for bulk carriers and tankers, while for container ships the figure is just under 10%. If the ACS technology is combined with more effective propellers and helm systems, as well as better re-use of waste heat, the fuel savings, and thus the reduction in CO_2 emissions, can be as much as 30%[2]. Other benefits are: improving the safety by shortening emergency stopping distance by 50%, improve manoeuvrability, payload increase and speed increase. The DK Group has built a ship demonstrator and concluded full-scale sea trials on the 2,550 dwt, 83-metre MPV which has undergone a first set of trials in Norwegian waters in 2008. The trials were conducted in association with Germanischer Lloyd, FORCE Technology and Lyngsø Marine. As a result Germanischer Lloyd, a German classification company, has approved the Air Cavity System (ACS) of the DK Group for commercial shipping, and has entered into an agreement with DK Group (Ref 4) for the development of energy efficient ship designs and the joint development of a 200,000 deadweight tonne (dwt) bulk carrier design (announced in September 2008)

References

1. Matveev, K.I., 2005, Application of Artificial Cavitation for Reducing Ship Drag, Oceanic Engineering International, 9(1), pp. 35-41[3]
2. Matveev, K.I., Air cavity ships are ready for a wider market, http://docs.hydrofoils.org/SAS03.pdf
3. THE UNIQUE AND INNOVATIVE TECHNOLOGY BEHIND THE AIR CAVITY SYSTEM ,DK Group, http://www.dkgmt.com/Default.aspx?ID=64
4. Agreement Between DK Group and Germanischer Lloyd[4]

5.3 Improvements in Propeller Efficiencies

5.3.1 Overview

Over the years, a variety of propeller designs has appeared and been manufactured. Each design has its own benefits, characteristics and drawbacks. These designs have been refined with experience and with the emergence of new design tools. Operators have their own

[2] http://www.investindk.com/visNyhed.asp?artikelID=20615
[3] http://www.hydrofoils.org/Abus/mar.html

4 http://www.competence-site.de/1779/presse.nsf/4b4cbfb4df7542cdc1256a0d003a534f/a5e26d06ea5f8dfcc12574d40033e311!OpenDocument

preferred types of propellers. Some consider three bladed propellers to be more efficient than four bladed propellers and have cited improvements in fuel consumption as a result of changing.

For example, ferry operator Stena changed the four-bladed propellers on its ferry *Stena Germanica* in 2005 for three-bladed replacements supplied by Rolls-Royce and reported 10% less fuel consumption. It immediately repeated the exercise on two more ferries, *Stena Scaninavica* and *Stena Nordic* and saw savings of 12% and 17% respectively[4].

Some of the most relevant propeller designs are briefly described below:

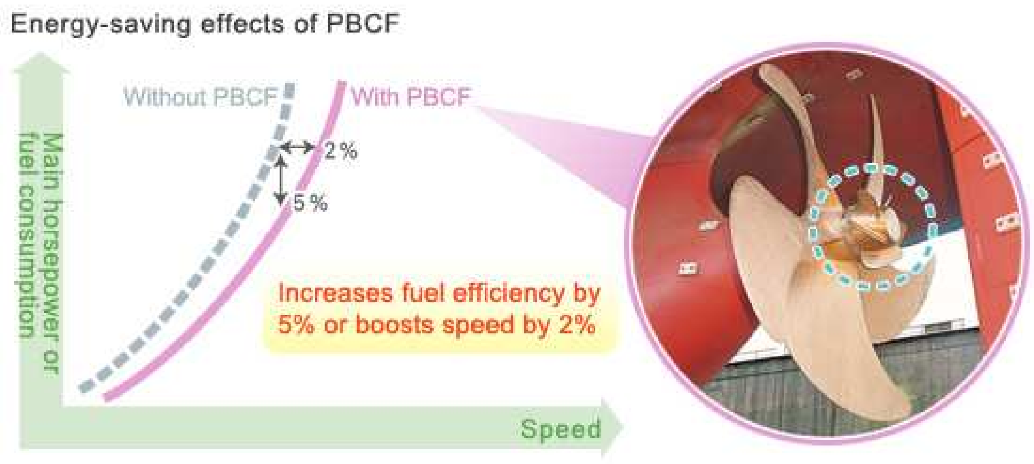
- Fixed Pitch Propeller (FPP) -This covers the major proportion of propellers and design types and sizes, ranging from propellers for small powerboats to those for large tankers and bulk carriers. These propellers are easy to manufacture
- Controllable Pitch Propeller (CPP) - This is more flexible than a Fixed Pitch Propeller due to flexibility of its control and ability to change blade pitch rather than propulsion efficiency. It has found most application on ferries, tugs, trawlers, and fisheries because of the improved manoeuvrability compared to that provided by a FPP. However, its manufacturing cost is higher than that of a FPP. It also requires more maintenance.
- Ducted propeller – These consist of two components, an annular duct having an aerofoil cross section and a propeller inside the duct. The presence of duct reduces the pressure forces induced on the hull; the duct also protects the propeller against damage. Propeller efficiency is increased depending upon the propeller loading and improvements of between 1% and 5% compared to an open propeller are quoted
- Contra Rotating Propeller (CRP) - This kind of propeller has two coaxial propellers sited one behind the other and rotating in opposite directions. It has the hydrodynamic advantage of recovering part of the slip stream rotational energy which would otherwise be lost to a conventional single screw system which leads to an energy saving about 15% in power. A more detailed description of this propeller configuration is given later in this Section

5.3.2 Propeller Boss Cap Fins (PBCF)

Propeller Boss Cap Fins are small fins fitted to a propeller's boss cap and are made of the same material as the Boss Cap; they can be easily installed in the same way as the Boss Cap

[4] The Naval Architect, Magazine of the Royal Institution of Naval Architects

and have been available since the late 1980s. The PCBF was developed jointly by Mitsui OSK. Lines, West Japan Fluid Engineering Laboratory Co. Ltd. and Mikado Propeller Co. Ltd .They have been fitted on Mitsui OSK Lines vessels. Actual measurements on over 60 ships have shown benefits of 4-5% in fuel saving and an increase in speed of about 2% .
The fins are intended to reduce the energy lost into the hub vortex .Without the fins, the flow of water around the propeller generates a hub vortex that wastes almost 10% of the engines energy; the fins help to reduce this effect. Other benefits include a reduction in stern vibrations, reduction of propeller noise and acoustic equipment. The latter makes them particularly suitable for oceanic research vessels. The fins can also be installed on controllable pitch propellers are used on fast ferries and RoRos which benefit from the reduction in fuel consumption and increase in ship's speed.
More than 1,500 ships had been fitted with Propeller Boss Cap Fins up to 2008[5]..



Source: Mitsui OSK Lines website)

5.3.3 Kappel Propellers

Propulsion efficiency of a marine propeller can be increased with tip fins. A five year EC funded project under the BRITE-EURAM Programme (BRPR970458) investigated the potential of a concept applied to aircraft wings to improve the performance of marine propellers. The KAPRICCIO project, entitled 'The Kappel propulsion concept –improving energy efficiency and reducing the environmental impact' was completed in 2002. The cost increase in production over a conventional propeller was estimated to be about 20% and the

[5] MOL Group Environmental and Social Report 2008, 9th Edition, April 2007-March 2008 Page7 http://www.mol.co.jp/csr-e/environment/management/technologies/index.shtml

mathematical and physical modelling carried out in the project indicated that it is realistic to expect fuel savings of up to 7% compared with a well designed conventional propeller.
A number of commercial airliners now feature non-planar wings and have winglets at the wing tips giving increased performance from the airfoil wing resulting in improved fuel consumption and a greater operating range. The unique feature of the KAPPEL propeller is that the theory of non planar wings and winglets has been applied to marine propellers and applied to a propeller concept where the propeller blade and "winglet" are designed as one integral curved blade to reduce the energy losses inevitably present at the ends or tips of airfoil devices.

(Source: Stone Marine Propulsion (propeller supplier) website)

The illustration above shows the 14 tonne Kappel propeller unit fitted to the “Nordamerika” of Norden A/S just prior to trials that demonstrated savings of 4% .

5.3.4 Contra Rotating Propellers (CRPs)

Contra Rotating Propellers are becoming accepted as the propulsion device capable of giving the highest efficiency in several fields of the marine industry and are being fitted in various system configurations to such vessels as:

- Large RO/Ro Ferries
- Large Container Ships
- LNG Carriers
- Research Vessels, Offshore/Deepsea Floating Platforms requiring dynamic positioning

The main benefits and shortfalls of contra rotating propellers are:

- Recovery of rotating energy loss originating form a propeller through the use of a contra rotating propeller
- Improves propulsion efficiency by10% to15%
- Reduces cavitation
- Benefits mainly at cruising speeds
- Complicated design and higher costs

Relevant Documents:

1. Development of Electric Propulsion Chemical Tanker with Contra-Rotating Propeller (CRP), IHI Engineering Review Vol. 40 No.2 2007, FURUTA Tetsuya : Manager, Ship & Offshore Basic Design Department WATANABE Manabu : Ship & Offshore Basic Design Department, NAKAI Genta : Ship & Offshore Basic Design Department, MIYABE Hiroaki : Manager, Project Engineering Department, Engineering Division, all of IHI Marine Inc
2. IHI Engineering Review, Vol 40, No 2, 2007
3. Contra-Rotating Propellers – Combination of DP Capability, Fuel Economy and Environment, Hannu Jukola *Steerprop Ltd., Finland*, Teuvo Ronkainen *Steerprop Ltd., Finland, Dynamic Positioning Conference)ct17-18, 2006* *http://www.steerprop.fi/products.htm*
4. Azipod® & CRP Azipod® Propulsion, Sales Literature, ABB Marine
5. Advanced Machinery Solutions for RoPax Vessels
   Oskar LevanderM.Sc. (Nav. Arch.), Project Manager, Product and Application Development, Wärtsilä Corporation, May 26th, 2004

5.4 Long Life Design and Lifecycle Considerations

5.4.1 Long Life Designs

In the increasingly competitive global shipping market, ship owners need to keep competitive prices. Owners, when considering the investment cost in a new vessel, must consider the initial capital cost, the annual operating cost and the expected service life of the vessel.

By extending the life of a vessel, the capital cost can be amortised over more years. Provided that the vessel remains efficient and its performance does not deteriorate, the annual operating costs will, therefore, be lower. There is thus an incentive, with the current high capital cost of vessels, for owners to increasing the lifespan of a vessel.

The capability of designing a vessel to last a long lifetime such as 30 to 40 years exists. The vessel will need to be built to a better quality than current vessels and as a result will likely cost significantly more than vessels designed for a shorter more conventional lifetime due to the more detailed design investigations needed, better quality materials and equipment installed etc.

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Other factors which must be taken into consideration are:

- The rapid pace of technology may result in the vessel's equipment becoming obsolete requiring costly refits
- The likelihood of the vessel becoming inefficient, less environmentally friendly have high running costs, in comparison with later vessels, particularly after say 30 years
- Changes to regulations and standards over the vessel's lifetime may render it obsolete unless major work is undertaken

IACS, in its submission to the IMO regarding goal based design has defined design life as 'the nominal period that the ship is assumed to be exposed to operating and/or environmental conditions and/or the corrosive environment and is used for selecting appropriate ship design parameters'. In terms of the hull structure, the paper addresses the effects of structural strength, corrosion and wastage, and fatigue (which results in cracking) on the design life. Time of exposure affects all these parameters and therefore the lifetime of the vessel.

Those elements of the vessel's hull/structure more prone to aging deterioration and damage must be identified early in the design process. Inspection and maintenance plans can then incorporate the appropriate operations to ensure that work is carried out to ensure that degradation is minimized and the design lifetime of the hull and structure is achieved.

In terms of the systems and equipment, machinery and electrical systems, fire safety, life saving equipment etc fitted on board ship there are well proven inspection and maintenance plan/routines. For these systems and equipment, many components are routinely replaced and consequently the concept of design life is different.

5.4.2 Design Lifecycle

As part of the process of developing a new generation of vessels, new design tools and techniques have to be perfected. Software tools are now becoming available which enable a more efficient and quicker ship design process and to create advanced ship designs with increased efficiency and in shorter time. The ultimate aim is to establish a set of tools to cover the whole lifecycle of a ship from initial concept, through design, development, operation, and final recycling at end of life. A main criterion which must be taken into account is the sustainability aspect; ships should be designed such that environmentally friendly and recyclable materials are used wherever possible and that the ship emissions during its operational phase are minimized In terms of the latter, the use of Life Cycle Assessment (LCA) tools in the ship design process may help the designer to optimise energy use and emissions over the entire ship life span.

The European Commission has funded several projects with the aim of developing tool sets for the design of future ship's to meet the efficient and environmentally friendly requirement such as The Efficient Ship Project, FANTASTIC and VR SHIPS – ROPAX 2000.

The "Energy Efficient Ship"-project funded by the European Commission produced tools to assist the designer in reducing not only the energy consumption during the entire life span of a ship, but also important environmental aspects. The tool is developed for design of fast ferries, containerships and fishing vessels.

FANTASTIC: - Focusing on geometric modelling and hydrodynamic analysis as the two decisive components, a new "functional design" process will be introduced which allows the efficient generation, systematic variation, effective flow analysis and rational evaluation of ship hull forms. Aiming at hull form optimisation at both the early and the refined design stage, innovative parametric modelling techniques will be developed, established numerical simulation methods will be enhanced and existing optimisation procedures will be supplied. An open and modular system integrating all necessary tools will be implemented and applied at model basins and shipyards.

VR SHIPS – ROPAX 2000:- VR Ships, completed in Dec 2005, produced a generic virtual platform including elements of integration, shared common model, virtual interaction, consistency management, process control, simulations and performance analysis. One of the advantages of this approach is that lead times are reduced as are lifecycle costs.

Structural design and computational fluid dynamics tools form the basis of ship designers toolset as described in the previous section. Simulation and visualization techniques are currently used to generate a 3D model of a vessel which can be used to derive all information necessary for the production (drawings, part list etc.) and to assess maintainability and operability. The simulation is also used throughout the design process in an iterative way to assess the implication of any changes and potential improvements to the design and to assess the vessel's performance under various sea conditions and while manoeuvring.

In terms of the actual equipment fitted on vessels, marine engineering practices and design methodologies have in the past relied on a 'bottom-up' approach based on the availability of standard equipment and vessel design has been carried out on a piece-meal basis. This has often been accompanied by a lack of adequate project management and configuration control techniques. The increasing requirements placed on marine platforms of all types have resulted in ship systems of increasing complexity often utilizing sophisticated computer technology/software packages which require integration into an overall efficient functional system. To achieve this, there is a need for a comprehensive set of design, integration and project control tools which provide a more efficient and lower risk method of design. Simulation tools and virtual platforms will be increasingly used to assist in the design, performance assessment and risk reduction related to specific designs. Knowledge management is also playing an increasingly important role not only for the design, development and construction phase but throughout the lifecycle

An important aspect in the design of new vessels is the use of new environmentally friendly materials, obsolescence and the recycling aspects when a vessel reaches end of life. In this respect the design aims should include:

- Minimize use of hazardous materials and environmental contaminates.
- Maximize use of recycled and recyclable material.
- Minimize waste and scrap.
- Maximize use of rapidly renewable and regional materials.
- Minimize air emissions.

- Minimize energy use.
- Minimize discharges to water.

It is expected that there are a number of benefits which can accrue to commercial shipyards, ship owners and operators resulting from adopting an integrated approach to the design and construction of new vessels and the use of the latest design and construction tools such as:

- .reduction in the design/construction time and hence a reduction in costs
- reduction of costs associated with design risks
- reduction in overall equipment costs due to more accurate specifications
- reduction in installation time due to more efficient integration techniques
- reduction in commissioning/test due to the use of simulation techniques
- more efficient hull forms, improved stability and fuel efficiency
- improvements in vessel operating efficiency due to better design
- more environmentally friendly vessels

Sophisticated modelling and simulation reduces the risks associated with design, saving both time and money as well as making a ship designer/builder more competitive.

Relevant Documents

1. Goal-based new ship construction standards -Design life and related lifecycle design parameters, Submitted by the International Association of Classification Societies (IACS**)**, MARITIME SAFETY COMMITTEE 80th session, MSC 80/6/9, 14th March 2005
2. Long lifetime design – Does quality make sound business sense? Broder Hinrichsen, Flensburger Schiffbau-Gesellschaft mbH & Co. KG, Flensburg/Germany
3. Green Vessel Design Environmental best practices, B.W.King, R Roberts, J Payne, *C.Villiott, Elliott Bay Design Grou; Published in Proceedings of The Marine Safety and Security Council, USCG*
4. Tool for Environmental Efficient Ship Design, Ellington, Fet, Aanondsen; Efficient Ship Project, *ENSUS 2002, Newcastle, UK, December 16.2002*

Projects

1. EC funded Project, FANTASTIC, G3RD-CT 2000-00096, a R&D project on ‘Functional Design and Optimisation of Ship Hull Forms’.

2. EC funded Project, The Efficient Ship
3. EC funded Project, VRSHIPS – ROPAX 2000

Website:

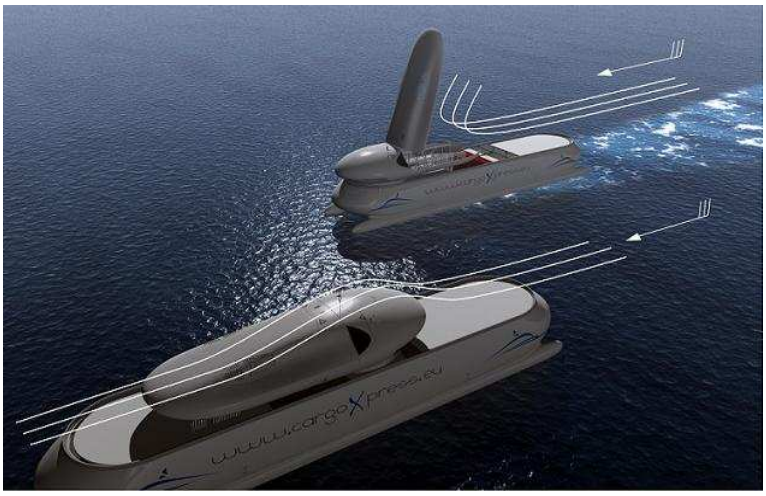
www.uscg.mil/proceedings

5.5 Designs to Promote Intermodal Transport Services

The plans and actions of the European Commission to move a substantial part of road transport towards SSS marine links will require vessels which are capable of operating not only in the large ports which can service trans-ocean cargo vessels but also in small and medium ports. A significant proportion of the cargo to be transferred is currently carried by trucks on coastal roads. The current large cargo vessels are unsuitable, require costly facilities (such as cargo handling systems) not available in medium/small ports; they also cannot compete on a cost and time basis.

The design of future vessels to meet the above must take into account the fact that such vessels must operate in small ports with poor facilities and maneuvering restrictions, in shallow waters and narrow channels whilst still being capable of operating in heavy seas and swells. This will require innovative concepts, the use of novel hulls and materials and must result in a cost effective safe and efficient environmentally friendly vessel. High tech. design and production methods will be essential to achieve this.

The EC have recently approved funding under FP7 for the EU-CargoXpress project (Ref 1) which specifically addresses the above requirements. The project has put forward a vessel concept which it will address during the project with the intention of building a full scale experimental prototype which will also be used for demonstration and evaluation purposes.
The concept vessel is a patented Catamaran style Container Ship with on-board loading equipment and very low fuel consumption.



The next step would see the construction of a real-scale experimental prototype to set the bases for a new European Standard Freighter. Large scale production should start after 2010. The goal is to serve small and medium size European and African Ports with reliable routes and provide feeder service to the Mega-Terminals and River-Ports.

The main features of the concept vessel include:

- Multi-hull to improve stability without ballast allowing access to all ports
- Superstructure with bridge and crane, revolving and mobile along the length of the freighter – it will not need shore carnage
- Covered cargo-bay over the whole ship length with on-board loading equipment
- use of wind propulsion in adequate meteorological conditions,
- use solar energy by covering part of the very flat surface of the superstructure and
- the loading bay enclosures for solar collectors
- superconducting energy conversion and propulsion to reduce energy loss and weight
- Fuel tanks within the catamaran's bodies.
- Steel structure with a fibreglass and polyester deck.
- Bridge and personnel facilities at the head of the superstructure, with electric lifts to access the dock or the loading bay.
- Innovative equipment for the train/truck port interfaces

Another concept vessel, the E/S Orcelle Green Flagship (Ref 2), represents a vision for zero-emission car carrying as it may be performed in 2025.

The idea combines fuel cells, wind, solar and wave power to propel the vessel, that will need no oil or ballast water. It will not release any emissions into the atmosphere or into the ocean and is proposed by Wallenius Wilhelmsen. The vessel will have an optimum cargo capacity of up to 50% more space than today's modern car carriers and will be capable of transporting up to 10,000 cars on eight cargo decks. Three of the decks will be adjustable to accommodate cargo of different heights and weights.

Compared to today's vessels, its pentamaran hull shape and its utilisation of energy from renewable sources will help optimise the cargo carrying capacity of the vessel. The E/S Orcelle will be 250 metres in length, have a maximum deadweight capacity of 13,000 tons and weigh 21,000 tons much like today's car carriers. Yet the E/S Orcelle will be capable of carrying approximately 3,000 more tons of cargo, thanks to the use of lightweight materials and the elimination of ballast water.

References

1. Greening of surface transport through an innovative and competitive CARGO-VESSEL Concept connecting marine and fluvial intermodal ports: Proposal under the FP7-SUSTAINABLE SURFACE TRANSPORT (SST)-2008-RTD-1 AREA 7.2.5.2 Competitive surface transport products and services, SST.2008.5.2.1 Innovative product concepts (website:www.cargoxpress.eu)
2. http://www.2wglobal.com/www/environment/orcelleGreenFlagship/index.jsp

5.6 Conclusions

- The future requirement for more efficient, environmentally friendly and sustainable vessels is a stated requirement by all major European stakeholders involved in the shipping industry.

- Ship designers will continue to seek improvements in the design of conventional technologies such as propellers and also to research and develop novel concepts such as air cavity ships in order to improve efficiencies and to meet increasingly demanding environmental requirements.

- The rapid advances being made in IT and the availability of large computer processing power is enabling the development of efficient and rapid ship design tools. These include optimised hull design tools using computational fluid dynamics techniques capable of coping with a variety of complex hull shapes and finite element analysis tools for the calculation of hull/structural strength.

- Future European development trends in the design of marine vessels will concentrate on aspects which will provide sustainable and green transport. Ship designs for intermodal applications will be based on low resistance hull forms, materials to lower the weight of the vessel and designs which will enable the vessel to operate in a variety of a sea conditions, in shallow waters, small ports and restricted waterways. The trend towards ballast free operation to enable vessels to be designed with shallow drafts and to operate in shallow waters will gain importance for SSS.

- The concept of lifecycle design will gain importance both in terms of extending the operating life of a vessel and in terms of wastage. Vessel designs and the choice of materials will take into account obsolescence, recycling/wastage at end of life, in addition to operational requirements.

- The automobile industry has, for many years, produced concept designs for futuristic vehicles; much of the technology is appearing in today's vehicles (electric/hybrid-electric cars, fuel-cell buses, recyclable car bodies/parts). This trend is now being seen in the shipping industry, the E/S Orcelle Green Flagship being the first example.

6. Propulsion technology development trends

The need to minimise operating costs and to achieve a reduction in emissions bring with them the need to ensure that the most appropriate energy source and propulsion system is chosen to ensure that they are optimised for the operating profile of a vessel.

Methods of reducing fuel consumption and reducing emissions include:

1. the use of alternative fuels
2. renewable energy sources such as solar, wind and fuel cells
3. availability of new improved propulsion systems
4. the possibility of reducing ship speeds

For the foreseeable future, fossil fuels will probably continue to be the predominant source of power for the majority of the shipping industry.

While renewable energy sources may have their place in helping to meet some ancillary requirements onboard ships, they are unlikely to provide sufficient power to operate ships' main engines. Fuel cells may be a possibility for new ships in the very long term, although they are currently too limited in range to offer a viable solution. Nuclear propulsion may be a potential solution in the longer term.

6.1 Energy Sources

6.1.1 Hydrocarbon Fuels

It is likely that the main fuel available and used in shipping for the foreseeable future will be conventional heavy fuel oil often referred to as Residual Fuel Oils as they represent blending of what remains after from the refinery processes after all the distillate or lighter fractions have been removed. RFOs are characterised by variable quality and many classification societies offer bunker fuel oil analysis services.

Alternative hydrocarbon based fuels are being researched and developed which could supplement current fuels when these become scarce. They include biodiesel, based on vegetable oils, synthetic fuels derived from methane or coal, LNG etc all of which can be used to derive the hydrogen for fuel cells.

6.1.2 RFOs

Residual fuel oils are characterised by high density and viscosity which means that need to be pre-heated and relatively high content of water and catalytic fines (hence importance of on

board treatment plants). Also contains pollutants, particularly sulfur, which forms sulfur dioxide upon combustion. However, its undesirable properties make it very cheap.
Variants of RFOs available include Low Sulphur Heavy Fuel Oil (SHFO) which helps to reduce the emission of sulphur dioxide; this fuel in conjunction with engine modifications to reduce nitrogen oxide helps to meet the IMO requirements. Other hydrocarbon based fuels include marine diesel oil and marine gas oil.

6.1.3 LNG

Liquid natural gas (LNG) is considered to be a very clean fuel which results in very low emissions when used in marine vessels. It is believed by some marine experts that in 5-10 years time, the majority of ships contracted for short sea trades will use LNG as a fuel[6]. NOx, SOx and particle emissions are almost negligible from prime movers using this type of fuel. Even levels of CO2 - emissions will be lowered by 30% compared to diesel fuels.

Natural gas reserves are significantly higher than the remaining oil supplies which could run out in about 30-50 years. Hence, given the infrastructure (which the MAGALOG project is studying) LNG could become the favoured fuel.
Engine manufacturers are already working on modifications to enable current engines to work on LNG or dual fuel and there are already some ships in operational service which use LNG as fuel.

6.1.4 Biofuels

Biofuels might conceivably provide a possible alternative to conventional fuel. However, conversion of the shipping fleet to biodiesel would give rise to a requirement for vast quantities which may well exceed the availability especially if land transport demands were high. The environmental effects and the economic viability would also need to be assessed before undertaking conversion of prime movers. Biofuels could form the basis for obtaining hydrogen for on-board fuel cells.
There are a variety of sources for biofuels such as vegetables or animal fats which can be in solid, liquid or gas form for use as fuels. Marine engine manufacturers such as Wartsila have been researching biofuels and their application to marine engines together with the engine modifications required and likely engine performance[7]. Wartsila has concluded that liquid

[6] project MAGALOG http://www.eu-magalog.eu EC funded project under the Intelligent Energy Programme
[7] Alternative fuels for medium-speed diesel engines, Kai Juoperi, and Robert Ollus, Wärtsilä
www.wartsila.com - Wärtsilä website

biofuels could be well suited to its medium speed diesel engines and would result in very low emissions, particularly sulphur dioxide compared to a conventional fuel.
A range of alternative fuels have been developed based on using different percentages of biodiesel and conventional diesel fuel for use in marine engines..
Synthetic fuels suitable for diesel engines could be produced from methane or coal, there still being substantial amount of coal still available.

6.1.5 Fuel Cells

Fuel cells are increasingly regarded as an alternative fuel to meet emission reduction targets. Reducing emission of CO_2 and the zero emission of NOx and SOx provide value in alleviating the environmental impacts from ships.

A fuel cell is a clean, silent, efficient and reliable method of producing electricity, making it a highly attractive option for commercial power production and is particularly suitable for maritime and naval applications. It is a device which generates electricity by converting the chemical energy of a fuel and an oxidant to electrical energy and heat. Most fuel cells use hydrogen at the point of energy conversion but this can be reformed from conventional fuels such as gasoline, natural gas or methanol. Unlike conventional combustion engines the fuel is not burnt and therefore the fuel cell is more efficient and environmentally friendly.
Fuel cells are already used in marine applications such as small boats and in submarines. The German Navy has four Class 212A submarines, built by HDW, in service; these use hydrogen fuel cells for the propulsion and power system. The Greek Navy will have four updated submarines (Type 214) and South Korea will also have four all utilising fuel cells for their propulsion and power systems. This sector is likely to provide an early market for marine fuel cells as it can stand the higher cost for leading edge performance; spin-off into the commercial marine market should then follow.

Unlike conventional diesel generators, fuel cells are more flexible in terms of their positioning and can be distributed throughout a vessel giving flexibility in vessel design and distribution of power. Fuel cells are approximately 50% more efficient than a conventional engine, are silent in operation and vibration-free which makes them suitable for passenger vessels such as cruise liners providing for increased passenger and crew comfort as well as better working environment for the crew.

There is strong interest in Europe, Japan, and the United States in developing shipboard fuel cell technology for both powering shipboard equipment and ship propulsion. The most likely early market ship application is as an Auxiliary Power Unit (APU) for sea going merchant ships (approximately 9,800 EU owned and large ferries commuting within the EU (approximately 500). Such ship fuel-cell systems will be in the power range of 500 kilowatts to 1 Megawatt and need to be designed for long endurance. Growing demand for on-board electricity and the increasing request for clean power generation in harbours can also be satisfied by fuel-cell APU technology. These power levels can also be used for propulsion systems for small vessels such as fishing vessels. Compatible updated electrical technology in the form of electric power management, power electronics and efficient electric machines will be required to maximise the benefits of fuel cell technology. Mass market transport applications of fuel cells are expected to be achieved by approximately 2020. However, in the short term the fuel cell system will most likely use marine diesel fuel which will require reforming on-board.

Relevant Documents:

1. Fuel cell for future power – MER November 2007
2. European Hydrogen and Fuel Cell Technology Platform - Strategic Overview (June 2005)
3. European Hydrogen and Fuel Cell Technology Platform - Strategic Research Agenda (July 2005)
4. European Hydrogen and Fuel Cell Technology Platform – Deployment Overview (August 2005) http://ec.europa.eu/research/fch
5. FCSHIP Final Report – FCSHIP GRP-CT-2002-00823 DTR-5.2-0.6.2004
   www.hfpeurope.org -European Hydrogen & Fuel Cell Technology Platform
   www.fcship.com – European Commission funded Fuel Cell Ship project

6.1.6 Nuclear

Nuclear power has been used in naval submarines for many years and the associated electrical conversion technology is available. However, it has not been taken up in surface vessels. Its use on land has been restricted to large nuclear power stations. While nuclear propulsion is technically possible, the support infrastructure costs would prove a serious drawback to its use in merchant ships as would the regulatory and safety requirements. However, it may have limited application and be a contender in the very long term.

6.2 Developments with diesel engines[8]

The low-speed diesel engine is the dominating prime mover for ships, representing about 70% of installed power. Increasing ship size favours the large two-stroke low speed diesels, whereas demand for more flexible and smokeless operation in cruise business favours the 4-stroke engines particularly with common rail fuel injection[9].

Following significant advances in the 90's in response to rising fuel oil prices during 70's and 80's which speeded up engine efficiency improvements and development of heavy fuel engines, during the last decade, diesel engine manufacturers have made steady progress with:

- increasing the performance of the engines (specific fuel consumption)
- ensure the highest level of safety and reliability for the different types of applications on vessels
- reduce emissions especially of NOx

The emission legislation has been one of the main drivers to develop clean engines with novel technologies for fuel injection and combustion control. Electronic control systems are becoming standard and the common rail technology is optimized for new two-stroke and four-stroke engines. The common rail technology has established clear performance benefits for ship-owners like smokeless operation, reduced fuel consumption, lower noise and lower, stable running speeds.

Most new engines can meet IMO's Tier II legislation by Internal Engine Modifications. These entail controlling better the combustion process using new fuel systems, adjusting the

[8] A diesel engine is an internal combustion engine that operates using the diesel cycle with highest thermal efficiency approaching 60%; manufactured in two stroke (low speed) and four stroke (medium or high speed) versions

[9] Common rail direct fuel injection on diesel engines features a high-pressure (over 1,000 bar/15,000 psi) fuel rail feeding individual solenoid valves, as opposed to individual fuel pumps feeding unit injectors. Modern common rail systems, whilst working on the same principle, are governed by an engine control unit (ECU) which opens each injector electronically rather than mechanically and are specifically addressing in maritime propulsion IMO's Tier II emission requirements.

combustion chamber volume and the scavenge air pressure; a specific approach is the application of the Miller cycle controlling the intake valve closing time.

Electronically controlled fuel injection, exhaust gas valve actuation and turbo charger control have shown to provide the key to future improvements.

Another key development will be to develop new systems for sealing piston rods of two stroke engines to prevent contamination of system oil and making them capable of burning gas as a proportion fuel.

The following techniques have been investigated for over the last 20 years and apart catalytic redetection methods, they are all essentially aimed at reducing combustion temperatures:

1. Exhaust Gas Recirculation,
2. Water fuel emulsification before injection
3. Humid Air Motors (HAM) - uses heated charge air enriched with evaporated seawater which replaces the conventional engine air inter-cooler
4. CASS – Combustion Air Saturation System- pressurized water is added to the intake air after the turbocharger compressor
5. Direct Water Injection - freshwater is injected through a valve to cool the combustion chamber before combustion commences
6. Selective Catalytic Reduction.

It should be emphasized that what is needed for substantial reduction in emissions is an overall design optimization approach which should include ship design, engine design, waste heat recovery and optimised operational practices.

Relevant Documents

1. Improving the NOx-BSFC Trade Off of a Turbocharged Large Diesel Engine Using Performance Simulation Ki-Doo Kim and Dong-Hun Kim Hyundai Heavy Industries Co., Ltd.
2. EU Service Contract on Ship Emissions Task 2b – NOX Abatement, Entec UK Limited August 2005
3. Wärtsilä - The EnviroEngine Concept
4. Thompson R.V. and Katsoulakos PS (1982) The application of emulsified fuels in diesel engine designs. Trans IMar E, Vol. 10, Paper 10

5. Katsoulakos, P, et al. *“Assessment of the combustion performance of RFOs”*. CIMAC. Oslo. June 1985
6. Katsoulakos, P, et al. *“Integration of a fuels characterisation Expert System with Diesel Engine Simulation”* CIMAC. Warsaw. June 1987

6.3 Gas Turbines

Gas Turbines have some important advantages over conventional diesel engines such as their high power-to-weight ratio. In addition there is also a significant reduction in the amount of routine maintenance required when compared with diesel generators; hence their application in hovercraft and other vessels where weight restrictions are important. Another significant factor is the low emissions. However, they do have some limitations, for example, for maximum efficiency they need to be run at steady full power for substantial periods. This leads to their being used in combinations with smaller conventional diesel engines or small gas turbines for cruising.

Higher-Efficiency Gas Turbines with greater efficiencies than the conventional gas turbines currently used in ships have the capability to substantially reduce the consumption of ship fuel use depending on the operating profile of the ship. Such engines are becoming available; two of these are produced by Rolls Royce based on its gas turbine based aero engine.

The company is supplying the MT30 gas turbine, the most powerful available in the marine market today, for naval and other applications. The latest engine is the WR-21 intercooled recuperated (ICR) gas turbine engine, which was jointly developed between 1991 and 2000 by the U.S, UK, and French governments for potential use on future warships and based on the RB211 aero engine.

Compared to the equivalent simple-cycle gas turbine engine, the latest high efficiency engines are more expensive to procure, but could reduce fuel use significantly compared to a mechanical drive system.

6.4 Hybrid Propulsion Systems

Hybrid propulsion, using diesel-electric technology, is well proven and has been used in shipping for many years, where the mechanical drive for the propellers has been replaced by electrical connections to electric motors which in turn drive the propellers; spare electrical capacity is made available for hotel requirements. These highly efficient and reliable hybrid propulsion systems have been the driving force for years in cruise liners, specialized ships, such as offshore supply ships, patrol boats, ice breakers and research vessels.

Incremental improvements in fuel consumption and emissions continue as improved technology becomes available, particularly in terms of power electronics and electrical machines. Diesel-electric systems are often combined with podded propulsers (described in next section) for maximum efficiency and manoeuvrability.

An example of a hybrid propulsion system applied to smaller vessels which combines both mechanical and electrical propulsion system is one where the propellers are driven by a prime mover such as a diesel engine (which also drives an electrical generator) or by an electric motor or possibly both. Such a system has great flexibility and can result in optimised and efficient propulsion system because the most appropriate drive can be selected for a particular mode of operation. There is also the possibility to minimise emissions while keeping fuel consumption low. Such a system is suitable for applications which require high and low load operation. Wartsila has developed such a system for small vessels and will be fitted to high powered anchor handling tugs, 20 of which are scheduled for delivery between 2008 and 2011. Siemens (Ref 1), Alsthom and other suppliers also offer similar systems.

A new EU project HYMAR is aimed at investigating an "optimized and fully integrated" marine hybrid-electric drive providing:

- Fully integrated marine hybrid drive system for commercial and recreational craft up to 24m
- Zero emissions to air and zero discernible noise and vibration in harbour
- An increase of 50% in the lifetime kilowatt-hour performance of lead-acid batteries in marine hybrid applications
- Full compliance with European Commission Directive 2003/10/EC (Merchant Shipping and Fishing Vessels Control of Noise at Work Regulations 2007)
- Propeller efficiency increased by 5% at full load and >15% at "off design point" operation
- Reduction of overall fuel consumption by 20%, tending to >90% on long distance sailing boats
- CO2 reduction of 20% in all "off design point" applications such as fishing boats, pilot boats and small commercial ferries

Hybrid LNG systems

Liquefied natural gas, or LNG, is natural gas in its liquid form. When natural gas is cooled to minus 259 degrees Fahrenheit (-161 degrees Celsius), it becomes a clear, colourless, odourless liquid. LNG is neither corrosive nor toxic. Natural gas is primarily methane, with low concentrations of other hydrocarbons, water, carbon dioxide, nitrogen, oxygen and some sulphur compounds. During liquefaction, natural gas is cooled below its boiling point, removing most of these compounds. The remaining natural gas is primarily methane with only small amounts of other hydrocarbons. LNG weighs less than half the weight of water so it will float if spilled on water.

LNG[10] is transported in double-hulled ships specifically designed to handle the low temperature of LNG. These carriers are insulated to limit the amount of LNG that boils off (BOG) or evaporates. This boil off gas is sometimes used to supplement fuel for the carriers. Hybrid LNG systems combine diesel engine propulsion and auxiliary electrical propulsion as well as re-liquefaction system and gas combustion system in the propulsion plant and BOG treating plant, respectively. Such system was adopted for the first time for a ferry boat built by MHI and put into service in June 2004 is considered to be a suitable propulsion system for high-speed vessels and high-powered ships such as next-generation high-speed container ships[11].

References:

1. Hybrid propulsion systems for AHTS ships, Marine Engineers Review, June 2008 Siemens paper

Websites:

2. www.converteam.com – Converteam (Alsthom) website
3. www.wartsila.com – Wartsila website
4. www.sam-electronics.de – SAM Electronics website
5. www.siemens.com/marine - Siemens website
6. www.rolls-royce.com/marine/ – Rolls Royce website

[10] Liquefied natural gas, or LNG, is natural gas in its liquid form. When natural gas is cooled to minus 259 degrees Fahrenheit (-161 degrees Celsius), it becomes a clear, colorless, odorless liquid. LNG is neither corrosive nor toxic. Natural gas is primarily methane, with low concentrations of other hydrocarbons, water, carbon dioxide, nitrogen, oxygen and some sulfur compounds. During liquefaction, natural gas is cooled below its boiling point, removing most of these compounds. The remaining natural gas is primarily methane with only small amounts of other hydrocarbons. LNG weighs less than half the weight of water so it will float if spilled on water.

[11] http://www.mhi.co.jp/technology/review/pdf/e416/e416322.pdf

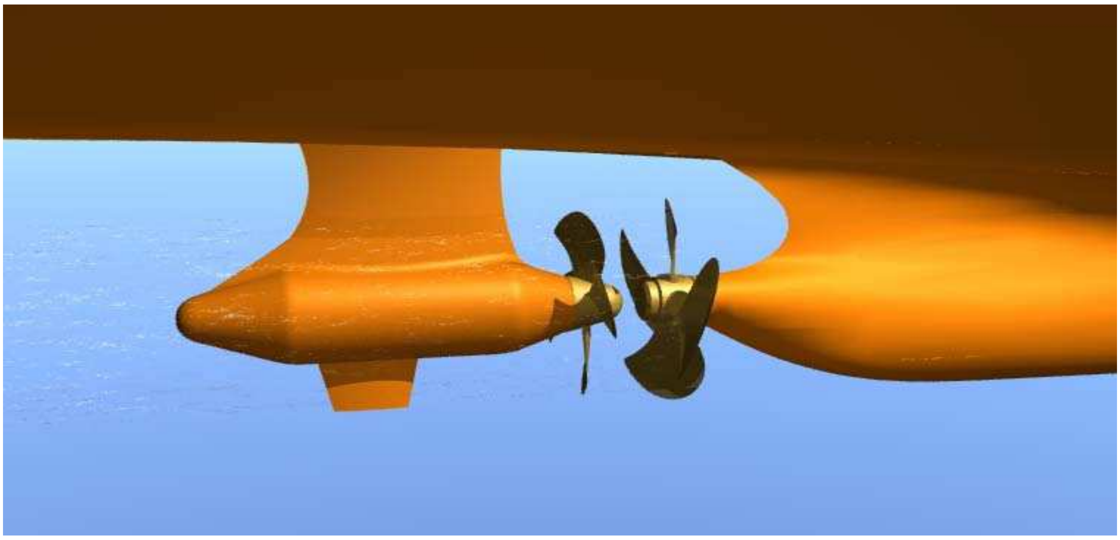
6.5 Podded Propulsion

A podded propulsor is essentially an electric motor/propeller combination in a podded housing which can rotate through 360 degrees in azimuth. This autonomous unit is fitted outside the hull of a vessel. Such systems by nature are easy to install and can be installed quite late in the building process. The major advantages of pods include a great deal of flexibility in the arrangement of machinery installations, the relatively little space they require on board ships, and the fact that they provide very good vessel manoeuverability compared to traditional propellers and rudders. Podded propulsion is also more fuel efficient than conventional propellers and could provide a savings of around 10-15 per cent compared to conventional propellers

Podded propulsion was first employed in the 1980's and many pod propulsion systems have been supplied over the past few years to a variety of vessels, such as cruise ships, ferries, supply vessels and ice breakers. The main suppliers are ABB (Azipod System), Rolls Royce (Mermaid System) and Siemens (SSP); STN Atlas also supplies the Dolphin system. The available power range is typically 0.5-30 MW per propulsion unit.

Although the initial large market was for cruise liner applications, podded propulsion is finding application in many other areas and pods in the range of 0.5 to 30 MW are available. Applications include naval vessels, RO-ROs, Tankers.

There are a variety of configurations of podded propulsors being fitted to ships from the use of a single propulsor unit, twin propulsors, twin propulsors and a main axial propeller depending on the role of the vessel. One interesting configuration is that of a single propulsor fitted immediately behind the main axial propeller to provide a Contra Rotating Propeller (See Section 5.3) configuration as shown below:



(Source: Advanced Machinery Solutions for RoPax Vessels**)**

This configuration has the benefits provided by the CRP mode of operation while also providing the enhanced maneuverability in ports and confined waters. The use of two propulsion systems provides improved redundancy and power sharing between the two systems. Efficiency gains of up to 15% are quoted (Refs 1 and 2).

References:

1. The First Hybrid CRP-POD Driven Fast ROPAX Ferry in the World, Mitsubishi Heavy Industries, Ltd. Technical Review Vol. 41 No. 6 (Dec. 2004)
2. Advanced Machinery Solutions for RoPax Vessels, Oskar Levander, Wärtsilä Corporation 26th May 2004

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1. www.abb.com – ABB website
2. www.marinelog.com - Marine Log Journal
3. www.rolls-royce.com/marine/default.jsp - Rolls-Royce website
4. www.siemens.com/marine. Siemens website
5. www. wartsila.com Warstila Corporation Website

6.6 All Electric Ship

Much has been written about the concept of the all-electric ship, the associated technology and systems. There are annual conferences on this topic held by such organizations as the IEEE and the IMarEST. Both the naval and commercial shipping sectors are very interested in the concept. Electric ships are anticipated to provide significant advantages in speed, manoeuverability and in hull space utilization and are expected to deliver significant improvements in efficiency and fuel consumption.

The UK Navy, in conjunction with the French Navy has an Electric Ship Technology Demonstrator (ESTD) based at the Alsthom Power Conversion Limited premises in Leicestershire. This utilizes current state-of-the-art equipments and integrates them into a combined propulsion and power distribution system while the European Commission is funding the Pose2idon a 23 MEuro project starting in January 2009, led by BMT and involving a consortium of 30 partners which will investigate electric ship technology.

The use of Integrated Full Electric Propulsion (IFEP) which involves the use of a common power system for both propulsion and ship's services is becoming standard commercial practice for the cruise liner market with the aim of increasing efficiency and profitability. In an all-electric ship, all hydraulic, mechanical and other non-electric means of operation are converted to being electrically operated.

Compared to a traditional mechanical-drive propulsion system with two separate sets of prime movers (one for propulsion, the other for generating electricity for shipboard use), an integrated electric-drive propulsion system can reduce a ship's fuel use by permitting the ship's set of prime movers to be run more often at their most fuel-efficient speeds. The benefits of employing a common power system for both propulsion and ship's services can, in an optimised merchant ship installation, allow running cost savings of up to 25%.

Cruise liners tend to cross the seas at a leisurely pace, making calls at a large number of ports and putting in the occasional sprint in between. The power requirements for on-board hotel functions are also variable. These vessels therefore need a variable form of propulsion power. The all-electric concept is well suited to this type of application.

The main barriers to the introduction of all-electric systems across the range of marine vessels are the size and weight limitations of the electric machines and prime movers. However, the technologies supporting the Electric Ship concept continue to move forward on an incremental basis together with associated advances in efficiency and operational effectiveness. There are also new technologies emerging which are likely to make significant contributions such as the use of rare earth permanent magnets/high temperature superconductivity in rotating machines and the use of wide band gap semiconductors operating at medium voltages and multi-megawatt power levels in the power electronics used in conversion equipment.

High Temperature Superconductor technology offers numerous advantages for modern shipbuilding. The conductors of the rotor windings carry a current density 100 times greater than that in conventional copper windings. As a result, significant weight and volume reductions are possible. In addition, there are no electrical losses with HTS, so that means greater efficiency. Such a motor has been developed by Siemens Corporate Technology and others aimed at all electric ships.

Relevant Documents:

1. Beyond the electric ship, Commander J M Newell Royal Navy and Commander S S Young Royal Navy, A paper for the Institute of Marine Engineers, 24 October, 2000

2. Electric Ship VI, C G Hodge and D J Mattick, OBE, A paper for the Institute of Marine Engineers. December 2000
3. Pose2idon E2SM – Power Optimised Ship for Environment with Electric Innovative Design on Board – EC Funded project on electric ship technology/environmental studies

websites

1. www.ieee.org – Institute of Electronic and Electrical Engineering
2. www.imarest.org - Institute of Marine Engineering, Science and Technology
3. www.bmt.org – British Marine Technology Limited –Pose2idon Project
4. www.naval-technology.com – Naval Technology – website for the defence industry – navy re high temperature superconductors

6.7. Wind Assisted Ships

6.7.1 Overview

Shipping companies seeking immediate answers to soaring fuel prices are simply slowing down. It has been estimated that slowing down a large bulk carrier by 10 per cent can lead to a 25 per cent reduction in fuel use. This would be equivalent to a reduction from about 22 knots to 20 knots on long haul ships.

Higher fuel costs and mounting pressure to curb emissions are leading some in the shipping industry to investigate the use of wind power which has the capability to assist with both objectives. Shipping was excluded from the United Nations Kyoto Protocol to slow climate change, but may well be included in the successor to Kyoto, post 2012. Consequently the environmental impact of shipping, until recently considered low, will gain importance.

The long-haul bulk trades, traditionally not in need of express service, have been identified as the most appropriate application for wind assisted propulsion because the principal bulk trades run more or less in a north-south direction in parallel with the globe's principal wind systems. Wind power has also been applied to cruise ships.

Three approaches, Flettner rotors, wing sails and kite sails are the most favoured. The first two are fitted on the ship while the latter is tethered to the ship. These approaches are described briefly in the following sections.

6.7.2 Flettner Rotors

Spinning vertical rotors installed on the deck of a ship can convert wind power into a thrust in a perpendicular direction to the direction of the wind. This effect is known as the Magnus effect. The effect causes a side wind to be converted to forward thrust propelling the vessel in a forward direction.

Anton Flettner first successfully demonstrated this capability in1924 when he had an experimental vessel built equipped with two large cylinder rotors at Germania shipyards in Kiel. Such rotors are now known as Flettner Rotors, The price of fuel at that time was so low that there was insufficient interest in pursuing the use of wind power any further.

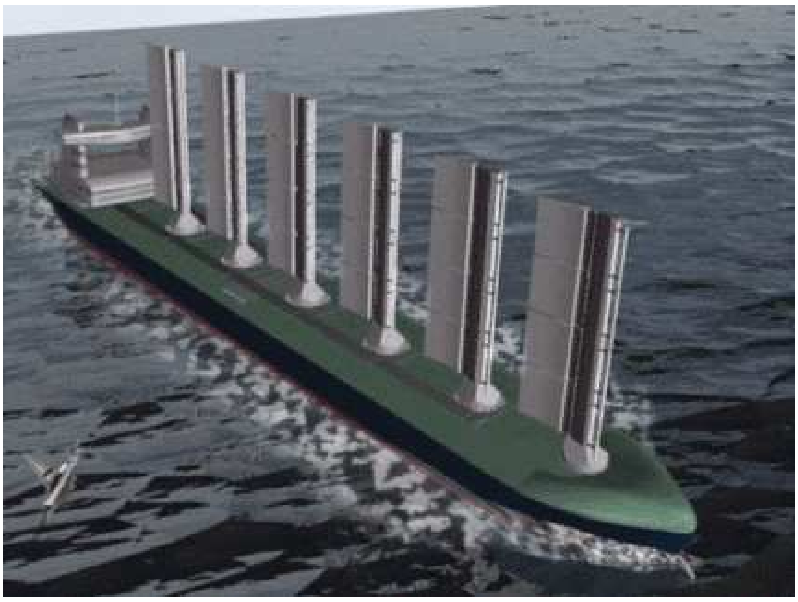
The current price of fuel and the increasing interest in global sustainable development together with the need for environmental improvements has generated considerable interest in the use of Flettner Rotors to reduce fuel consumption and associated CO2 emissions.

ENERCON GmbH, a German company which is one of the world's leading manufacturers of wind turbines and which has already installed more than 13,000 wind turbines in over 30 countries, is having an energy efficient ship built to carry its products to its global customer base. A large portion of the energy required to propel the ship will be supplied by four Flettner rotors 25m tall and 4m in diameter. (ENERCON Press Release – 1st August 2008). Construction of the 130m long and 22.5 m hulled vessel is now planned to be completed by the end of the 2009 - *Lloyd's List 23 January 2009.*

(Source: ENERCON Press Release}

6.7.3 Wing Sails

The illustration shown below is that of a prototype commercial 50,000 ton product carrier using a wingsail system developed as a result of a project funded by the Danish Ministry of Environment and Energy in 1995.



Source: CRS Report to Congress: Navy Ship Propulsion : Options for Reducing Oil Use – Background for Congress, Dec 11 2006 (RL33360)

A UK company, Shadotec plc, is involved in developing a wingsail in conjunction with a Norwegian marine consultancy and a Norwegian shipping company with the objective of investigating wingsail propulsion for commercial ships. The project is funded by the Norwegian National Research Council. The complete system will consist essentially of one or more computer controlled wingsail thrust units mounted on a vessel. Initial design considerations indicate that fuel savings and emission reductions of greater than 5% can be expected from the prototype system on a research vessel.

There are some major disadvantages to wingsail systems such as:

- In unfavourable winds, large masts create a lot of drag and could cause ships to heel, sometimes dangerously
- Masts and their pivoting sails take up valuable container space on the deck.
- Loading and unloading is more expensive, since the cranes that lift containers must work around the masts.

- The cost of retrofitting a cargo ship with a row of masts, and strengthening its hull and deck to dissipate the additional stress, could take several years to recoup in terms of fuel saved

6.7.4 Kite Sails

Kites have some major advantages, they:

- Can be added to existing ships.
- Take up no deck space
- Require minimal retro-fitting,
- Can be taken in out of the weather when not in use.
- Can be taken off the boat for maintenance

The capital cost of the sail system is likely to be much less than a wing sail system and can be recouped in significantly less time and can be very cost effective when retrofitted.

Two companies involved in kite sails are SkySails, in Germany, and KiteShip in the US; relevant websites are included. A typical configuration of a SkySails kite applied to a cargo ship is shown below:

Source: CRS Report to Congress: Navy Ship Propulsion : Options for Reducing Oil Use – Background for Congress, Dec 11 2006 (RL33360)

The kite system, which has been developed over 10 years with help from the German government, uses an automatic pilot, is controlled by computers and runs on a metal track around the ship. This allows the "sail" to move around to collect wind and also prevent tilting.

Relevant Documents:

1. Wind Power to Set Sail Again, Marine Engineers Review, July/August 2008

Websites

2. www.cookeassociates.com/history.html - Cooke Associates Limited, UK
3. www.skysails.com – SkySails Limited, Germany
4. www.kiteship.com – KiteShip Inc., USA
5. www.shadotec.com – Shadotec plc

6.8 Shore-side Power Supplies

While shipping is far more efficient in terms of transporting tonnes/km than air or road transport, international shipping accounts for between 2% and 4% of global CO_2 emissions. (Ref.1). Emissions are emitted both when the ship is travelling and when it is in dock. Port Authorities are increasingly searching for methods of reducing localized pollution and emissions. The use of shore side electrical power supplies for use by the ship when it is in dock is being proposed as an environmental improvement measure. There are currently only a few ports in the world which offer shore-side electricity but this situation is changing rapidly.

When a ship docks, the auxiliary engines are left running, allowing the ship to operate. In some cases with larger vessels the main engines are also utilized during loading and unloading for example when extra power is needed. The diesel fuel burnt emits exhaust gases and generates noise. A potential solution for reducing these pollutant gases and eliminating air emissions such as nitrous oxides, sulphur oxides, diesel fine particulate matter and greenhouse gas emissions is to provide the ship with electrical power from a shore supply. If all vessels were to shut down their engines while in dock and utilize on shore power supplies instead, emissions from shipping could be substantially reduced. If the shore based electricity supply is obtained from distant power stations, the local port emissions can be further reduced and by using renewable energy such as obtained from wind/sea based generators an even further reduction in polluting emissions can be achieved. The provision of shore based electrical services is termed ‘cold ironing’.

The EU has put in place Directives, in order to assist with the above, which:

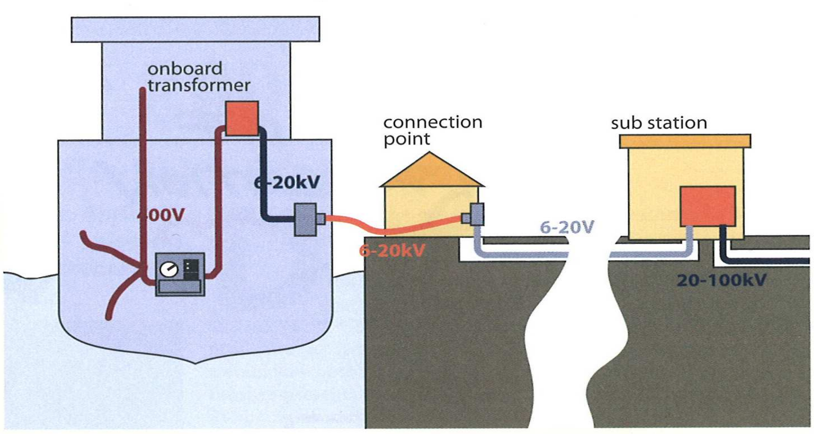
- Limit the amount of sulphur to 0.1%, in all marine fuels used while at berth for more than 2 hours in European ports (Ref. 2 - EU Directive 2005/33/EC)
- Recommends its membership countries to promote shore side electrical facilities (Ref. 3 - EU Directive 2006/339EC)
- Recommends that shore side power supplies be subsidized by a cancellation of electricity tax (Ref.4 - EU Directive 2003/96/EC)

Various studies have been conducted into the effects of ship emissions, their abatement, associated costs and into the likely benefits of using shore based power supplies. Two of these are particularly relevant to European ports (References 5 and 6). However, it should be noted that at present there are no standards or regulations in place which specifically cover shore based power supplies for ships.

Port authorities are increasingly aware of the need to improve port environments and to reduce the effects of pollution on the health of personnel employed at ports and the citizens living in the local urban areas. The World Ports Climate Initiative (WPCI) consists of a membership of 55 of the world's largest ports which have joined forces to reduce the effects of climate change. The Port of Goteborg has been selected as a project port (Amsterdam, Bremen, Hamburg, and Le Havre are other European ports involved) and shore side power supplies are being made available dockside. The first high voltage shore side equipment was installed at the port in the year 2000, the energy being obtained from renewable wind power with the intention of servicing Ferries and RoRo vessels.

In order for a shore based power supply to be used as an alternative to a ship's auxiliary diesel generator, a suitable electrical interface/cable is required to between the ship's electrical system and the shore side power supply. The electrical characteristics of the shore side power supply (e.g. voltage/frequency) must be made compatible with the requirements of the ship's electrical system. About 80% of the world's transatlantic shipping fleet has a 400 volt ac, 60HZ electrical power system whereas most European ports utilize a 50Hz electrical supply – there is therefore the need for a frequency converter.)

Modern shore based power supplies normally provide power to the ship via a high voltage cable (6-20kV) as it is possible to transfer 25 times more power than with a conventional 400V cable of the same dimension. However, there will be a need for a transformer on board ship to transform the high voltage supply down to the standard ship supply of 400V together with a suitable power distribution subsystem. The two most important parameters affecting the cost of the shore based supplies are the on-board frequency requirements and the provision of high voltage supplies dockside. A typical system configuration for a ship/shore installation in Port of Goteborg is shown below:



Source: Asa Wilske, POG, 14/11/2008

Typical onboard cost of a transformer (0.5-2MW) is 40,000 to 70,000 euro and for a retrofit the total installation cost (including transformer) would be between 60,000 and 120,000 euro; on-board distribution/connection costs would be additional. More detailed capital costs and comparisons of operational costs of onboard diesel generators against shore based power supplies are provided in the References below together with estimates of the likely environmental improvements.

The general conclusions of the study reports are that:

- shore side power supplies can effectively reduce air pollutant emissions and noise in ports thus providing environmental and health benefits
- the cost of reducing emissions are significantly lower when ships are connected to shore based power supplies
- the scheme is more cost effective for vessels which spend a long time in ports and therefore have a high annual consumption of electrical power
- the availability of shore-side power supplies is currently limited to a few European ports and types of ships but the intention is to expand these facilities

- there are currently no standards or regulations specified or in place for shore-side power supplies or ship installations; however, these are being considered within the ISO and the IEC

Reference Documents:

1. Brief Summary of the impact of ship emissions on atmospheric composition, climate, and human health, document submitted to the Health and Environment sub-group of the IMO on 6th November 2007 by V. Eyring, J J Corbett, D S Lee and J J Winebrake
2. Directive 2005/33/EC of the European parliament and the council of 6th July 2005 amending Directive 1999/32/EC
3. Directive 2003/96/EC of 8th May 2006, on the promotion of shore-side electricity for use by ships at berth in Community ports
4. EU Council Directive 2003/96/EC of 27th October 2003, restructuring the Community framework for the taxation of energy products and electricity
5. Final Report of Service Contract on Ship Emissions: Assignment, Abatement and Market-based Instruments (Task 2a-Shore-Side Electricity) for the European Commission Directorate General Environment by Entec UK Limited, August 2005
6. Shore-side electricity for ships in ports, *Case studies with estimates of internal and external costs, prepared for the North Sea Commission, Report 2004-07-06 by MariTerm AB*

Projects:

Port of Goteborg - Development of On Shore Power Supplies

Web sites:

1. www.portgot.se
2. www.wpci.nl/
3. www.europa.eu.int/comm/environment/air/pdf/task2_shoreside.pdf
4. www.mariterm.se/nedladdnings/bara_rapporter.htm

Conclusions

Fossil fuels will continue to be the predominant source of power for the majority of the shipping industry until this fuel becomes in short supply which is likely to be 30-50 years. However, the majority of ships used for short sea trades could use Liquid Natural Gas (LNG) in 5-10[12] years time. LNG is much more environmentally friendly than conventional fossil fuels.

Renewable energy sources (such as biofuels) are unlikely to provide sufficient power to operate ships' main engines. Fuel cells (already used in some submarines) may be a possibility for new ships in the very long term, although they are currently too limited in range to offer a viable solution. Nuclear propulsion may be a potential solution in the very long term if all safety and environmental concerns can be sufficiently minimised..

The low-speed diesel engine remains the dominant prime mover for ships, representing about 70% of installed power. Increasing ship size favours the large two-stroke low speed diesels, whereas demand for more flexible and smokeless operation in cruise business favours the 4-stroke engines. During the last decade, diesel engine manufacturers have made steady progress with:

- increasing the performance of the engines (specific fuel consumption)
- ensuring improved levels of safety and reliability for the different types of applications on vessels
- reducing emissions especially NOx

Gas Turbines have some important advantages over conventional diesel engines such as their high power-to-weight ratio and the higher-efficiency gas turbines (compared to the conventional gas turbines currently used in ships) now becoming available have the capability to substantially reduce the fuel consumption of a ship.

Interest in the application of various configurations of hybrid drive propulsion systems (which use a combination of electrical and mechanical drives for propulsion) is increasing due to the need to reduce costs and to minimize exhaust gases. A new EU project HYMAR is aimed at investigating an "optimized and fully integrated" marine hybrid-electric drive.

All Electric Ships are anticipated to provide significant advantages in speed, manoeuverability and in hull space utilization and are expected to deliver significant improvements in efficiency and fuel consumption. Such systems ares becoming standard on cruise ships for these reasons. The main barriers to introduction of these systems across the range of marine vessels are the size and weight limitations of the electric machines and prime movers. Improvements in technologies used are therefore required before general usage is achieved.

Considerable interest has been generated in the potential use of wind power to assist with the propulsion for ships. Methods used include the use of a large sail tied to the ship and large rotors/masts fitted on deck which gather the wind and generate a driving force in the direction of travel of the vessel. The long-haul bulk trades have been identified as the most appropriate application for wind assisted propulsion because these vessels run more or less in a north-south direction in parallel with the globe's principal wind systems. Fuel savings of between 5% and 20 % have been quoted.

Substantially improved environmental performance will be required in the future from ships which could be achieved my improved ways to control the combustion process in diesel engines, alternative fuels, hybrid systems and possibly increased use of wind assisted power.

7. Ship operation systems

7.1 Ship shore communications

A cost effective means of communication between ships and between ships and shore based operational centres is essential for safe and efficient shipping. There are numerous maritime communication system and equipment suppliers; associated service companies often utilise these communication systems to provide communication services to the shipping industry. Maritime communications are regulated by the IMO (SOLAS).

Communication has many uses on-board ship, some examples are listed below:

- voice communication, telex and fax
- mobile phones and blackberries

- transmission of data and management information
- real-time video transmission
- remote condition monitoring
- remote damage assessment
- remote ship management
- shore based technical support
- videoconferencing
- e-learning
- internet access

Communication is also an important part of current major navigation systems and will also be an essential part of e-Navigation systems of the future. Four examples of these major subsystems are listed below:

- AIS (Automatic Identification System)
- LRIT (Long Range Identification System)
- GMDSS (Global Maritime Distress Safety System)
- GNSS (Global Navigation Satellite System

7.1.1 Terrestrial Communications

A large proportion of ship-to-shore and ship-to-ship communications can be carried out effectively using MF (Medium Frequency) and HF (High Frequency) radio transmission links. VHF (Very High Frequency) radio equipment is also usually provided onboard; VHF radios have relatively short range (25 – 30 miles) and are most useful within range of coastal stations and between ships which are within range. The VHF frequency band, however, does provide a higher bandwidth for transmissions and can therefore cope with higher data rates.

There is also the possibility of using line-of-sight microwave links, particularly close to shore provided that the existing environmental conditions are suitable. These links have a higher capacity than MF/HF/VHF communication equipment and are capable of transmitting voice, data, text and video signals due to inherent the much higher bandwidth.

Frequency Bands: MF: 300 – 3000 kHz

HF: 3 – 30 MHz

VHF: 156 – 174 MHz

7.1.2 Satellite Communications

Satellite communication links are not constrained by vessel location, environmental conditions or range from shore base-stations. They operate essentially as a microwave link between ship/satellite and satellite/shore station or satellite/ship. The satellites can either be geostationary with respect to the earth and positioned approximately 22500 miles above the earth or can be in a low earth orbit (at an altitude of approximately 485) around the earth. In each case sufficient satellites must be available to give adequate earth coverage.

Commercial satellite communications systems utilize frequencies in the microwave and millimetric range from approximately 1GHz to around 60GHz. Frequencies at the lower end of the spectrum generally have better propagation properties than those at the higher end of the spectrum which suffer from atmospheric attenuation problems such as rain fade.

The higher the frequency band, the narrower the antenna beamwidth and therefore the need for higher antenna pointing accuracy. This means that an onboard antenna may require stabilization against ship roll, pitch and yaw at the higher frequencies whereas at the lower end of the spectrum with associated wider antenna beamwidth this may not be required

The higher frequency systems are more likely to be found on larger ships such as cruise ships which are relatively far more stable than smaller vessels. An advantage of utilizing the higher frequencies is that they provide much higher bandwidths and hence can cope with much higher levels of information transmission; this being a more likely requirement on a cruise ship.

Examples of two major satellite systems are those provided by companies such as INMARSAT and IRIDIUM.

INMARSAT is a UK based system and service which utilizes geostationary satellites and operates at approximately at L-Band (1.3 – 1.7 GHz.). There are several versions of Inmarsat satellite communication systems. INMARSAT B, for example, provides two-way direct-dial phone, telex, facsimile and data communications at rates up to 9.6kbit/sec. One of the latest systems, INMARSAT Fleet 77, is a newly developed communication service family, Inmarsat Fleet - providing fully integrated satellite communication services incorporating voice and data applications.

Iridium, a US satellite system, provides satellite communication services suitable for the aerospace and maritime industries. It employs a constellation consisting of 66 low-earth orbiting (LEO) at an altitude of 485 miles, cross-linked satellites operating as a fully meshed network and supported by multiple in-orbit spares. It operates at C-Band (4-8GHz) and Ku-Band (12 – 18GHz).

Voice and data calls are relayed from one satellite to another until they reach the satellite above the Iridium handset or terminal and the signal is relayed back to Earth. When an Iridium customer places a call from a handset or terminal, it connects to whatever satellite happens to be overhead, and is relayed among satellites around the globe to whatever satellite is above the appropriate Earth gateway, which downlinks the call and transfers it to the global public voice network or Internet so that it reaches the recipient.

Unlike the terrestrial networks, advancement in maritime broadband networks is severely lagging behind its land counterpart.

The MarCom project, a joint initiative between several national and international Research and Development Institutions, Universities and Colleges, Public Authorities and Industry is aiming at developing a novel digital communication system platform to ensure the proliferation of innovative mobile network applications presently being widely implemented on land-based wireless communication systems. The project started in 2007 and spans for four years.

7.1.3 Broadband applications

The state of the art within broadband communication in relation to user needs in the following areas has been investigated by the MarNIS project:

- Mandatory communication requirements;
- Other required ship reporting and port clearance;
- Extended port and fairway communication;
- Communication with owner and operators and other commercial or operational demands;
- Telemedicine or other forms of critical communication;
- Crew and passenger communication.

It was shown that the availability of broadband communication systems at sea can have a great impact on both crew welfare and safety (e.g., through more efficient use of telemedicine) as well as ship safety through faster update of navigational information and better use of cooperative decision support between ship and land. A key application is support for e-navigation services with the capability of providing common standard resources to the collection, distribution and tracking of all information and data processed and displayed, through networked telematic systems, afloat and ashore.

During all terminal and intermediate phases of the berth-to-berth sailing process, different communication infrastructure can be used, from terrestrial one to satellite. Reasons for broadband terrestrial communications are due to increasing number of port visits. Reason for broadband satellite communication relies on the increasing maritime traffic at high sea along congested routes. This leads to the integration of the two technologies in order to provide continuous-coverage services, seamlessly and transparently operated. Additionally, authorities may want to consider how such services can be made available in a standardised and pan-European format.

The MarNIS broadband service platform emphasises:

1. Multiplex of the information flows, so that a unique common infrastructure can be used for all applications, thus achieving the following advantages:
    a. Standardisation of equipment and services, in favour of technology diffusion, with consequent investment cost reduction, due to scale economy;
    b. Reuse of communication infrastructures, in favour of specific operation cost reduction, which further may thrust the diffusion of services. It is worthwhile to underlying the possibility of sharing the communication resources among the different actors of the maritime services, who encompass port authorities, for their institutional- and safety-related tasks, ship owners, for their commercial-related jobs, all personnel engaged in operations at sea, for their welfare and healthcare, and eventually cruise ship passengers, for their infotainment.
2. Modular system configuration, that allow to size and replicate the system by taking into account local needs for service coverage (A0 and A1 sea zones) in addition to remote service requirements (A2 and A3 sea zones), in favour of a more cost effective deployment of communication and operational resources.

Key technologies identified were:

1. Wireless medium range communication systems, based on IEEE802.16 or ETSI Hiperman (A0 and A1 sea areas);
2. Satellite VSAT long range communication systems, fully and seamlessly interoperable/integrated with wireless medium range communication systems;
3. Adoption of IPv6 protocol for IP networking, in order to facilitate mobility and dynamic extra-LAN connectivity.

Conclusions

Overall, the shipping sector needs significantly faster, higher bandwidth broadband communications. The strong demand for broadband is exemplified by INMARSAT reports (August 09) that FleetBroadband users increased from 2600 vessels to 3200 in a period of two months[12]

Aiming at a bearer independent solution allowing communications over diverse communications media and protocols, we can identify three major challenges[13]:

- Extending the coverage and range at sea for both in-use and novel terrestrial wireless systems/technologies, such as:
  - *Cellular*: GSM/GPRS/EDGE, 3G/UMTS/Turbo-3G (⇨ LTE)
  - *Wireless broadband (WBB)*: WiFi/WLAN, WiMAX, CDMA 450…
  - *Wireless narrowband (WNB)*: Digital VHF (D-VHF), AIS, LRIT.
- Finding appropriate SatCom solutions to complement/supplement the terrestrial ones, mainly beyond their coverage, e.g.:
  - *GEO*: Inmarsat (BGAN), VSAT; DVD-RCS
  - *HEO* (e.g. Molniya) orbits
- Obtaining seamless and continuous handover and roaming within and between the pertinent systems, in addition to implementing satisfactory communication security and integrity.

Future communication systems provided on-board ship should be transparent to the user and seamless in operation. Communication systems providers and service providers should ensure that the most appropriate form of communication will always be selected based on the type of information to be transmitted and the most cost effective way of sending the information. Factors such as the vessel location, the urgency, format and type of information may be used to determine the most efficient and cost effective means of communication.

[12] http://www.inmarsat.com/merchant
[13] Bekkadal, Fritz: "Maritime Communication Technologies", Draft MARINTEK Report, October 2008

Systems should also be capable of graceful degradation in the event of system failure and reconfigurable to ensure the best performance is maintained using the available operational modes. Adequate redundancy should be built-in to ensure that satisfactory performance can be maintained.

The important aspect to consider is that communication technologies aren't exclusive for the maritime sector, and therefore advancements in the other terrestrial and air mobile sectors should be exploited whilst developing standards specific to shipping.

Relevant Documents:

1. MarNIS State of the art on maritime communication technology WP2.2.1RSINTEF20060531version 2.0
2. MarNIS Research report on broadband applications D2.2.C_Part_4
3. **Error! Reference source not found. -Error! Reference source not found.**

Projects

1. MarNIS
2. Flagship
3. MarCom

7.2 Condition monitoring systems

7.2.1 Development trends

In this current economic downturn it is more essential than ever for ship owners to optimise their vessel's operation. Equipment failure and down time can be extremely expensive. Known as predictive maintenance there are numerous methods to monitor and control specific areas of plant and machinery and take pre-emptive measures when the need arises. This can be done either automatically by using sensors linked to analysis computers (condition monitoring systems) or by using a process of periodic inspections. The most common machine condition monitoring methods are analysis of machine vibration, temperature and pressure. Some components are more important to a ship's operation than others such as the main gear boxes, turbo chargers, thrusters and propulsion engines which are critical for a ship's availability, reliability and operating efficiency.

Condition monitoring techniques include vibration measurement and analysis, ultrasonics, infra-red thermography, oil analysis, motor current analysis and engine temperature, pressure and fuel consumption measurements. The lubrication of cylinders is one important area that needs monitoring. On average a container ship can spend 10 million US dollars on cylinder lubrication in its lifetime. Systems exist for monitoring liner wear to allow the optimization of cylinder oil feed rates. Condition monitoring extends to monitoring the condition of the hull in order to optimize the scheduling of repairs. Classification societies have now recognised the potential for reliability and have introduced a condition monitoring notation alongside the traditional planned maintenance requirements.

Condition monitoring involves trend analysis, measuring operational parameters of an engine or other machinery and comparing them with 'design or reference' values to calculate any deviation from expected conditions.

The primary difficulty for condition monitoring is the 'sensors'; intrusive sensors are a no go situation, reliability and calibration are significant problems. This means that condition monitoring should be part of the manufacturer's intention which is increasingly the case and allows remote analysis of data and effective diagnostics.

A second difficulty is establishing the reference values against which actual measurements should be compared. This is because the reference values are affected by many operational variables such as speed or environmental conditions, loading conditions, normal aging related changes, etc.

A third difficulty is in the diagnostics which means that identifying the cause of an observed deviation with a degree of certainty is difficult to achieve and often requires cross checking different expected symptoms for an assumed fault condition or monitoring progressive behaviour and comparing it to known behaviour under fault conditions. Overall the technologies and models for condition monitoring for ship operation which involve simulation, pattern matching and heuristic rules, have been around for over 20 years but their adoption by the industry has been relatively slow possibly due to the outlined difficulties as well as issues arising from cost benefit analysis.

Recent improvements in techniques, sensors and particularly processing software, could change the situation in the foreseeable future.

Condition monitoring is one of the areas being investigated in Flagship project. Developments include a Simulation Tool to Evaluate Fuel and Energy Consumption with the following features:

- Continuous long-term measurement and data storage on board
- No fuel flow meters necessary.
- Use of common available data
- Results under all operational modes and conditions
- No high frequency time resolved fuel consumption measurement necessary
- Calibration by Fuel consumption reports per journey sufficient

The tool is validated for two container vessels with data from approx 2 years (deviation of calculation from fuel used <2%).

A second development stream is concerned with key performance indicators for technical operation with specific reference to the TCI, the Technical Condition Index defined as follows:

- The Technical Condition Index, denoted TCI, is defined as the degree of degradation relative to the design condition.
    - The TCI can apply to equipment, a system, a whole ship or a fleet of ships. It may take values between a minimum and a maximum value, where the
    - maximum value describes the design condition [e.g. sea trial condition], TCI=100, and the minimum value describes the state of total degradation, TCI=0.

The Technical Condition Index provides a holistic view that assesses units:

• Efficiency

• Degradation

• Balance {Balance - comparing units expected to have equal performance}

7.2.2 Conclusions

Condition monitoring technologies for ships has been around for the last two decades, but extensive use has not been achieved. The reasons remain a combination of economic considerations, training requirements, integration issues across fleets, etc.

The environmentally motivated regulations could be the catalyst for broader acceptability of condition monitoring in ship operation

References

1. Katsoulakos, P. et al. *“Monitoring and expert systems in development of fault diagnostics”* International Conference on Computers in Engine Technology. March 1987
2. Gerd Würsig, Malte Freund Simulation Tool to Evaluate Fuel and Energy Consumption Flagship Workshop Athens 13 May 09
3. Brage Mo **Key performance indicators for technical operation** MARINTEK Flagship Workshop Athens 13 May 09

Projects

Flagship

7.3 Integrated Platform Management Systems

7.3.1 Overview

Increasing system integration and information technology aboard vessels brings with it the opportunity to maximise efficiency while providing significantly more information for the crew to enable them to carry out their duties. The current state of the art has lead to the development and fitting of Integrated Platform Management Systems on the latest vessels.

The aim of such a system is to enable the central management of platform subsystems. It combines all vital platform control functions and increases the overall management and automation of most of the time consuming duties associated with all the subsystems and equipment fitted to the platform. In the case of larger ships such as cargo ships, cruise liners and large ferries it will also provide for the management of cargo handling and monitoring, hotel facilities etc. (Refs 1 and 2)

An IPMS consists of an overlaying platform system which is fault tolerant and offers a high level of availability and operational reliability. It provides the following typical management functionality:

- System and ship management
- Propulsion and steering control

- Electrical control
- Auxiliary control
- Stability System control
- Onboard training facility
- Ventilation control
- System and subsystem health and condition monitoring
- Fire Detection System and Damage Control,
- Digital CCTV system control
- Cargo control/monitoring and loading unloading
- Hotel facilities management

The IPMS is a customized ships automation system with inbuilt redundancy and having graceful degradation modes in the event of subsystem/equipment failure so that emergency operation can be effected from several shipboard locations and ensures that failures only impact on a small part of the system. The IPMS can be linked to the Integrated Bridge System on a vessel.

It typically comprises of:

- distributed hardware architecture which has the capability of being interfaced with equipment manufactured by different suppliers
- advanced computer-based technology providing real time data processing
- distributed intelligent processing, interconnected by multiple redundant data highways (often fibre-optic)
- configurable multifunction consoles enabling operation of systems from several locations on the platform

The use of distributed architecture and fibre optic data highways saves a significant amount of cabling and the networking allows for easy expansion in the future and provides for inbuilt redundancy.

7.3.2 Conclusions

Integrated Platform Management Systems have formed part of the overall fit for naval vessels for several years and are becoming standard fit in vessels of the RN (for example, the Type 45 Destroyer), Canadian, French, German, Norwegian, Swedish and US Navies. Such systems are now being fitted to commercial seagoing vessels particularly to high end commercial vessels

IPMSs are suitable for a wide range of applications including cruise liners, FPSO's, research vessels and tanker. These systems bring all shipboard control and monitoring subsystems together into a single system enabling operators on the bridge or at local positions to have a complete overview of the situation.

The fitting of an IPMS with its increased automation and distributed information display facilities can provide an opportunity to minimise the crew members required to operate such vessels.

There are now a number of proprietary systems becoming available on the market from the major marine system/equipment suppliers. These systems, which use distributed architectures, are often scaleable to suit the size and role of a vessel and meet the full range of shipboard control and monitoring requirements from the simplest to the most complex. Such systems allow for easy expansion to increase functionality and to cater for additional subsystems.

References:

1. IPMS Integrated Platform Management System, Logimatic/Rockwell Automation Information Leaflet

2. IPMS Integrated Platform Management System L-3 Communications Leaflet, LDN007a_June 2006, available at http://www.l-3com.com/products-services/docoutput.aspx?id=1026