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REVIEW
NORWEGIAN MARINE TECHNOLOGY RESEARCH INSTITUTE

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Contents:

SINTEF

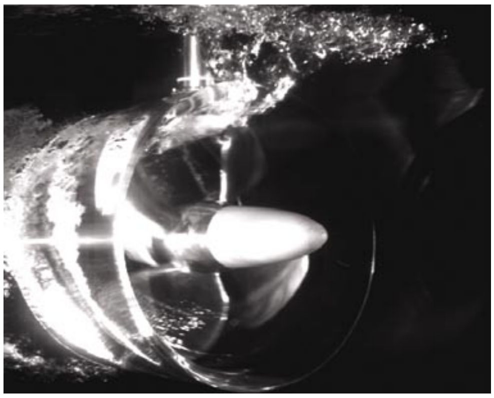
Rolls-Royce, MARINTEK and NTNU open University Technology Centre on "Performance in a Seaway"

On May 9th Rolls-Royce, MARINTEK and NTNU celebrated the official opening of a new University Technology Centre (UTC) on "Performance in a Seaway", in the presence of Norway's Minister for Industry Børge Brende, Head of Research and Technology of Rolls-Royce Mike Howse, the President of Rolls-Royce Commercial Marine Duncan Forbes and several other high-level Rolls-Royce management personnel.

In the course of the past ten years Rolls-Royce has developed a model for co-operation with universities and research institutes that aims to promote research with commercial potential. Some 25 universities and research institutes all over the world have this relationship with Rolls-Royce. The UTC partners are chosen among the top players in relevant fields, and the UTCs are long-term relationships, typically for ten years.

Traditionally, ships and propulsion units have been optimised for operation in calm water. Operation in heavy seas has only been taken into account in terms of crude safety factors.

Opening ceremony of the University Technology Centre. From left: Mike Howse (Head of Research and Technology Rolls Royce plc.), Kjell Holden (Vice President Marketing MARINTEK), Sverre Steen (Professor NTNU), Børge Brende (Minister of Industry), Rune Garen (Director R&T Rolls-Royce Marine). (Photo: NTNU Info/Rune Petter Ness)



Tests with a ventilating ducted propeller in the cavitation tunnel (Overaae). Studies of propeller ventilation will be an important topic in the UTC.

As we all know, ships only occasionally operate in calm water. The use of crude safety factors to accommodate the effects of waves and ship motions usually results in designs that are too heavy, costly and inefficient. What is worse is that in some cases this strategy produces vessels or propulsion units that are insufficiently strong or powerful, leading to costly and sometimes dangerous failures. With the establishment of the "Performance in a Seaway" UTC, Rolls-Royce, MARINTEK and NTNU intend to take design tools for ships and propulsion units to a level at which the effects of waves and ship motions can be taken into account in a sound and scientific manner. *Cont. on page 6*

Propulsion and Control

Safe and efficient ship manoeuvring and positioning require basic knowledge of forces on the hull, propulsor characteristics and interaction effects. These factors can be determined by model tests of actual design concepts, and additional theoretical modelling. We are continuously working on the development of efficient tools for analysis of ship behaviour and propulsors for application in the development of simulators, operational procedures and actual systems onboard.

Propulsor characteristics in calm water

Our AKPA programme system features a boundary element method for calculation of dynamic forces on propulsors/blades operating in the wake field of a ship under various conditions

The examples in figure 1 show comparisons of experimental results and calculations for pod unit tested at MARINTEK at various heading angles and propeller loadings.

Efforts will be made in 2005-6 to improve the AKPA tools by employing model tests and computational fluid dynamics (CFD) calculations.

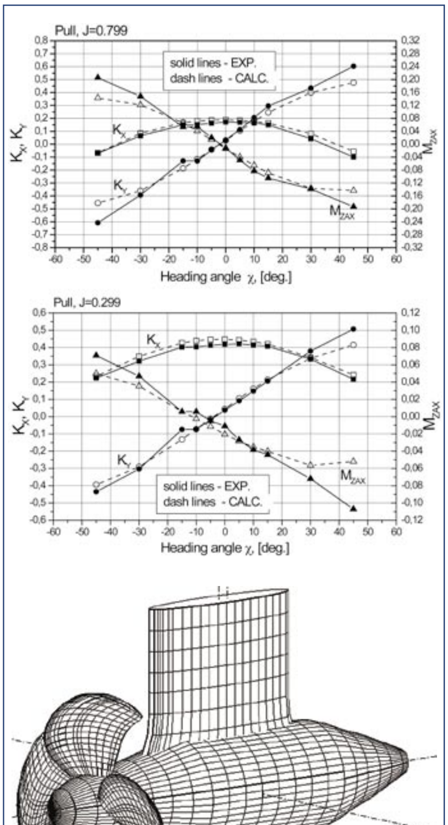


Fig.1. Pulling POD propeller. Comparison of measurements and calculations.

Environmental and interaction effects

A wide range of different interaction and environmental effects are capable of significantly affecting propulsor characteristics. It is of vital importance to include such effects for carrying out a proper design and evaluation of the system.

If two thrusters are installed in tandem configuration (figure 2), for example, at a distance of five propeller diameters, the aft thruster may well lose about half of its thrust. Similarly, a rotatable thruster beneath the hull can lose about one third of its thrust due to interaction with the hull, depending on the curvature of the hull and its distance from the hull.

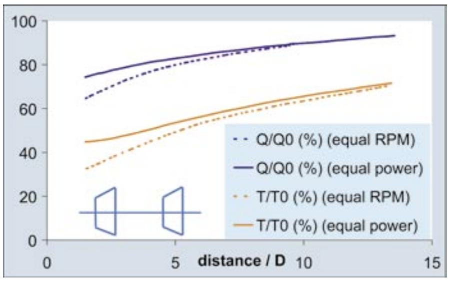


Figure 2. Thrust and torque loss of aft thruster due to the distance between thrusters.

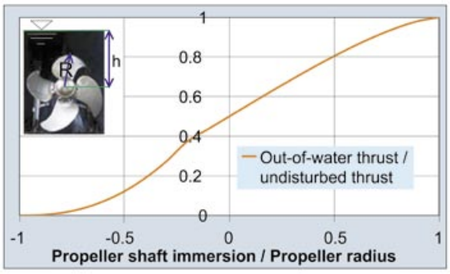


Figure 3. Thrust loss due to out-of-water effect.

Experience has shown that despite the availability of theoretical methods for estimating environmental and interaction effects, there are still many cases for which only model tests can deliver satisfactory predictions.

Forces on the hull can be determined by model tests and CFD calculations. An example is shown in figures 4 and 5, where a double-ended ferry hull is simulated by CFD in a current of 45 degrees. Open-water simulation (figure 4) shows a dominant side force in red along the hull in the lowest of three illustrations in figure 4 (red=high pressure zones).

In figure 5 the same situation is shown, but with a fixed obstacle simulating the terminal wall. It now becomes obvious that the hull will have a smaller side force, but a larger moment is introduced. This is visualised by

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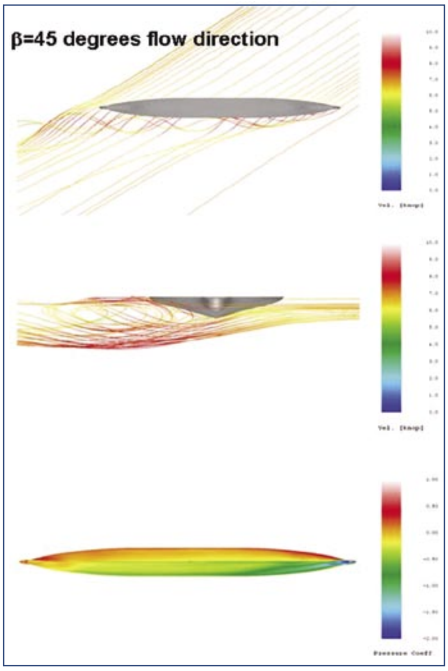

Figure 4. Ferry hull in open water. (CFDnorway)

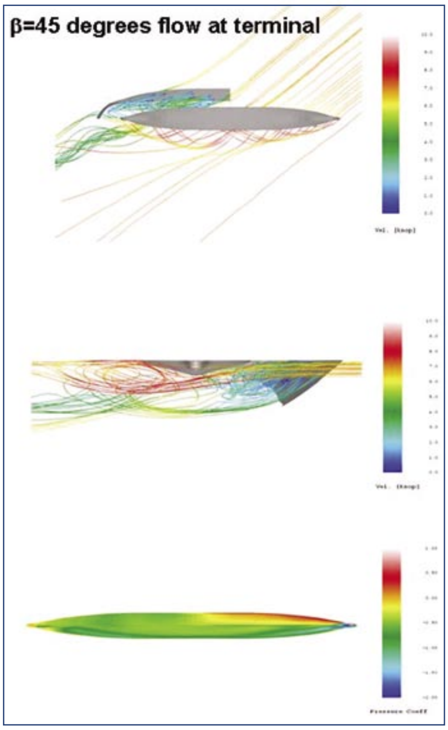

Figure 5. Ferry hull at terminal. (CFDnorway)

MARINTEK Vessel Simulator
- a comprehensive tool for prototyping, simulation and training

The MARINTEK Vessel Simulator has been under development for some years now and is continuously being improved and refined. The purpose of the Vessel Simulator is to provide realistic ship motions in the time domain and to make these motions available to internal and external users in a very open simulator network. Our experience and databases, derived from the development and testing of all types of vessels for many years, both as models and at full scale, are important aspects of these efforts. The Research Council of Norway supports the competence development process via a Strategic Institute Programme called "MS Nautilus", to which the maritime industry also contributes. The work has been carried out in close cooperation with Rolls Royce Marine.

Figure 1. 3D Visualization at OSC.

Common Simulation Interface - an easy to use simulator infrastructure framework

MARINTEK has developed a simulator framework which it calls the Common Simulation Interface (CSI). The CSI makes it possible to connect a number of modules to a simulator network, to produce a complete simulator. CSI handles all communication and synchronization between the modules and is an important easy to use component in the simulator. The CSI enables hydrodynamic and automatic control software to be integrated very flexibly. In the development of the new framework, we emphasized well-defined interfaces, reusable software and interoperability. The CSI framework is platform/independent and is based on XML formatted data structures. CSI is an application-independent standalone product that is used by both industrial partners and the SINTEF Group.

Users:

- Rolls Royce
- ScanWind
- SINTEF Simulation Centre
- Offshore Simulator Centre in Ålesund

MARINTEK Vessel Simulator

MARINTEK has developed a Vessel Simulator capable of integrating hydrodynamic and automatic control software. The main idea behind the simulator is to create a test harness and simulation framework for:

- Development and verification of hydrodynamic software modules for wave, wind, current and interaction effects.
- Development platform for marine control systems

The vessel motion solver uses a numerical six degrees-of-freedom (DOF) ship motion model, in which manoeuvering and seakeeping characteristics are merged and verified against existing MARINTEK software packages, model tests and full-scale tests. All hydrodynamic effects and coefficients can be calculated or configured by existing software packages in MARINTEK's ShipX application and database. A numerical wave model has also been implemented and the corresponding ship motion will be related to the actual wave pattern in real time (Figure 1). The simulator architecture allows several vessels to be simulated concurrently, allowing interaction between the different bodies to be modeled.

Propulsion models, including environmental and interaction effects as described above, have also been implemented in the simulator. Propulsion vendors can interface their own models using the CSI.

Numerical models of motion sensors, including gyrocompass, speed log, wind sensor, MRU and GPS have also been developed.

Examples of projects using the Vessel Simulator are given in the following:

DP Simulator for Rolls-Royce Marine

RRM is integrating the Vessel Simulator into its own control applications and propulsion models. The simulator has seamless integration with hardware control systems and acts as a test bench for control engineers and marine engineers. All expected input signals and responses to the control system are generated by the Vessel Simulator.
The idea is that the control system will not "notice" whether it is running against the simulator or the real vessel.

Benefits:

- Rapid testing of new control strategies.
- Less time needed to tune the control system during sea trials.
- Endurance and FMEA testing can be performed onshore.
- Meeting place for system integration discussions.

Offshore Simulator Centre - Anchor-handling Simulator

A company has been set up by Farstad Shipping ASA, Rolls-Royce Marine AS, Aalesund University College and MARINTEK to build a training centre for anchor handling. OSC will provide full mission training, where crew members on deck, operators of deck cranes, rigs, etc. will take part in the simulation as well as navigation staff. Complete crews can then be trained in a wide variety of incidents and emergency situations.

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SMART Shipping
- an important contribution to the commercial development of shipping companies

SMART Shipping is an effort to strengthen commercial shipping via the development of innovative and competitive logistics solutions. The main element of this programme is the development of methods and tools for more efficient and environmentally friendly operations and for improved market understanding.

The aim of our efforts is to improve the ability of shipping companies to offer extended logistics and transport solutions by strengthening their commercial market-oriented processes. The active use of control information and decision-support systems are central elements of the efforts involved.

Greater potential

Knowledge and information, in addition to good decision-support systems, are among the prerequisites for a secure competitive position in ship management and operation. Shipping companies have to consider decisions on a number of different levels:

- In strategic terms, shipping companies face decisions regarding the type of transport solutions they should be offering the market, which types and sizes of vessel they should invest in, and how large their fleets ought to be. The shipping services of the future will have to be adapted to the needs of customers and industry to a greater extent than they are at present. A more dynamic market means that there is a growing demand for the ability to analyse available market information and to implement changes.
- In tactical terms, shipping companies will have to select the geographical regions in which they intend to offer their services. Should they sign more or fewer long-term contracts, given different market situations? What measures must they take to compete with other players on the market? It is of decisive importance for improved planning that they should be able to strengthen, and ensure the availability of, relevant market information, as well as to systematise and interpret this information in such a way that it offers relevant decision support in the planning process. Systematic, structured handling of such information allows the planning horizon to be extended, enabling market prospects and threats to be predicted.
- In operational terms, ship-owners will continually be faced with making decisions regarding cargo allocation and transport charters. Shipping will be either spot- or contract-based. Wherever possible, shipping companies will have to combine transport contracts in order to ensure optimum employment of their fleets. Closer integration with customers and improved cargo overviews are vital if ship-owners wish to be able to react efficiently with regard to cargo allocation and dealing with unforeseen situations.

Efficient operation means utilising resources (vessels, organisation and systems) as well as possible. Good decision-support systems will help decision-makers in this process, e.g. in their assessments of how well the vessels in their fleets can deal with a set of shipping contracts. The right combination of cargoes reduces ballasting requirements and changeover time between cargo charters.

Being able to accept projects and create new solutions is a matter of being capable of adapting to customer needs and of offering solutions that will enable existing transport solutions to be simplified. In different industries, there are wide variations in the range of services supplied by a typical transport company. The automotive industry has already come a long way in the process of integration in the logistics chain.

Today, the transport company takes responsibility for a vehicle from the moment it leaves the production line until it reaches the car dealer. This service includes a number of "non-transport" services such as warehousing, clearance and quality control. Being able to offer services of this sort requires systems to be in position and the

Figure 1. The vision of SMART Shipping.

possibility of integrating a company's own processes with the needs of its customers.

Important challenges for commercial shipping companies

Traditionally, maritime players based their activities on old routines and the personal knowledge and experience of the individuals in their staff. This makes such companies vulnerable with respect to transfer of knowledge. Typical challenges that commercial shipping companies will have to deal with in developing competitive maritime logistics chains include the following:

- Acquiring knowledge of the industries and branches they serve.
- Performing industrial analyses with the aim of understanding how industry is developing, and its future needs.
- Carrying out competitor and market monitoring activities.
- Understanding the drivers of competition, diversification of products and services, and the ability to react to changes in commercial conditions.
- Enabling efficient information exchange in the transport chain and the re-use of data in commercial analyses and decision-support systems.

- Integrating information and decision-support systems throughout the logistics chain.
- Analysing the experience transfer process and quality-assuring commercial services.

These are all aspects which require relevant information and suitable decision support systems, which are the main aspects of this effort via SMART Shipping.

A concrete example of a decision-support system which integrates information throughout the logistics chain is the TurboRouter system developed by MARINTEK: TurboRouter is the only commercial fleet scheduling system that is tailor-made for maritime logistics. The system offers its users suggestions for operating plans and optimised sailing plans for the fleet, based on agreed cargo obligations in the coming period. TurboRouter provides an indication of future fleet utilisation, positions and status of vessels, etc., i.e. information that is used as a basis for decision-making. The software is very powerful in that it is capable of rapidly analysing a number of different scenarios. On the basis of the results provided by TurboRouter, the user himself modifies his final decisions that were originally based on his own assessments.

Figure 2 outlines the user interface of the scheduler in TurboRouter. The scheduler takes into consideration aspects like e.g. vessel and cargo compatibility, charging/discharging properties, fuel consumption, fixed and variable costs, etc. MARINTEK has been given a great deal of feedback from users that documents significant benefits from utilisation of the TurboRouter system.

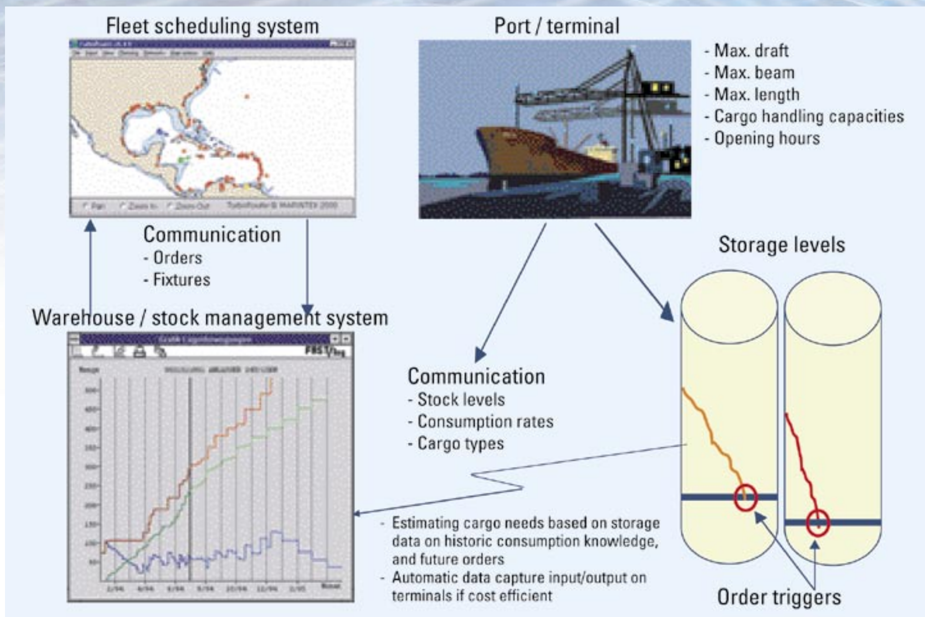

Figure 3. The SMART Shipping planning process.

How can we make basic knowledge available throughout an organisation?

Control information and control systems are important issues for our ability to create cooperative solutions and integration with customers and cargo-owners. Studies of industrial shipping market segments have identified a potential for greater capacity utilisation through improved use of information exchange and the use of control information. SMART Shipping develops structured methods and tools which take care of this issue.

Shipping planning is closely related to warehouse control, as is shown in figure 3. Traditionally, the cargo owner does not provide the shipping company with storage information. A typical form of agreement between the cargo owner and the shipping company is that they sign contracts that will guarantee the shipping of a given amount of cargo in the course of a year at a specified rate. It is also usually up to the cargo owner to specify when his cargo should be carried, once certain criteria regarding the smoothing out of volumes and seasonal variations have been met.

The time from placement of order until date of shipping may also vary. The trigger for when shipping will take place is often unknown. This creates a need for extra slack in the shipping company's sailing plans in order to be able to deal with variations in date of order and shipping date. By integrating information about shipping planning with the cargo owner's warehouse control system, the shipping company itself can obtain an indication of the likelihood of receiving a "call" from the cargo owner in the coming period. This gives the ship-owner a better chance of being able to accept cargoes on the spot market, improving his fleet utilisation factor in the process, thus also the economy on the bottom line.

Figure 2. Allocation of cargoes to actual vessels.

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Small-Scale Supply Chain for LNG - Norway Leads Developments

MARINTEK is involved in RTD along the complete value chain for natural gas. In Norway, end use of natural gas in shipping is in sharp focus, with new coastal ferries on order.

Field ➡	Transport ➡	Terminal ➡	Distribution ➡	End use
• Exploration	• Pipeline	• Processing	• Sea/land	• CHP
• Processing	• Ship		• Ship/pipe/truck	• Industry
				• Transport

The use of natural gas as marine fuel is an innovative concept on the international market. Norway is leading developments in this field. However, the total consumption of natural gas in the shipping industry is still only a minor proportion of total Norwegian domestic consumption of bunker fuel. The main obstacle to the increased utilization of natural gas is access to LNG (Liquefied Natural Gas) and the cost of the technology compared to traditional ship solutions based on standard fuel types.

However, these are barriers to be broken, and current developments in this regard are promising. Norway's maritime industry and scientific expertise have the potential to lead the development of greater utilization of natural gas as fuel. Norwegian shipyards and shipping consultants have the experience and the knowledge to head the development of new vessel concepts, in both traditional and new segments of the fleet. Further additions to the fleet of natural gas operated ships also increase the operational experience of Norwegian shipping companies.

MARINTEK has developed a scenario for the potential development of natural gas as fuel in Norwegian domestic shipping. If growth continues at the same rate as during the past five years, a market for natural gas of some 160 million Sm^3 could become a reality within the next 10-15 years. This represents a 10 per cent market share of the Norwegian bunkers market, and will turn the shipping industry into one of the largest end-user markets for natural gas in Norway.

If suitable conditions are encouraged to develop with the support of industry, natural gas could make a substantial contribution to reducing emissions from Norwegian domestic shipping.

MARINTEK is involved in the entire supply chain, including end use of gas, and our activities include:

- Development of a strategy for conversion to natural gas
- Complete logistic chain analysis utilizing in-house analysis tools

The "Kystgass" concept.

- Assessment of feasibility of new short-sea supply chains
- Development of tools for estimating supply chain regularity
- Design basis for small-scale reception facilities for LNG
- Development of new gas engine concepts for CHP (Combined Heat and Power) production and for use in new vessel applications.

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Rolls-Royce, MARINTEK and NTNU open University Technology Centre …

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The subject of the UTC will be ship performance in a seaway, but most emphasis will be put on the propeller and the dynamics of propellers in a seaway. The following topics will be covered:

- Dynamic forces on propellers in a seaway due to effects of ventilation, cavitation and ship motions
- Interaction effects between hull and propulsors
- Added resistance and speed loss in waves for modern hull forms
- Use of intelligent control methods to enhance performance; such as roll damping by use of tunnel and azimuth thrusters, and use of active control to reduce dynamic forces on propellers and azimuth thrusters
- Optimum design of azimuth thrusters
- Development of an advanced ship simulator for simulation of ships in a seaway. The simulator will be utilised as a platform for implementation of the results of basic studies in other parts of the UTC.

The Centre is headed by Professor Sverre Steen. NTNU does the most basic research, while MARINTEK performs more applied projects, and implements methods in the simulator and other computer-based tools, such as the ShipX Hydrodynamic Workbench.

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TOCC – Technical Operations Competence Centre

Recent developments in legislation and reporting requirement represent new challenges in ship operation. Requirements cover both certification of equipment, operation procedures and various recordings and documentation.

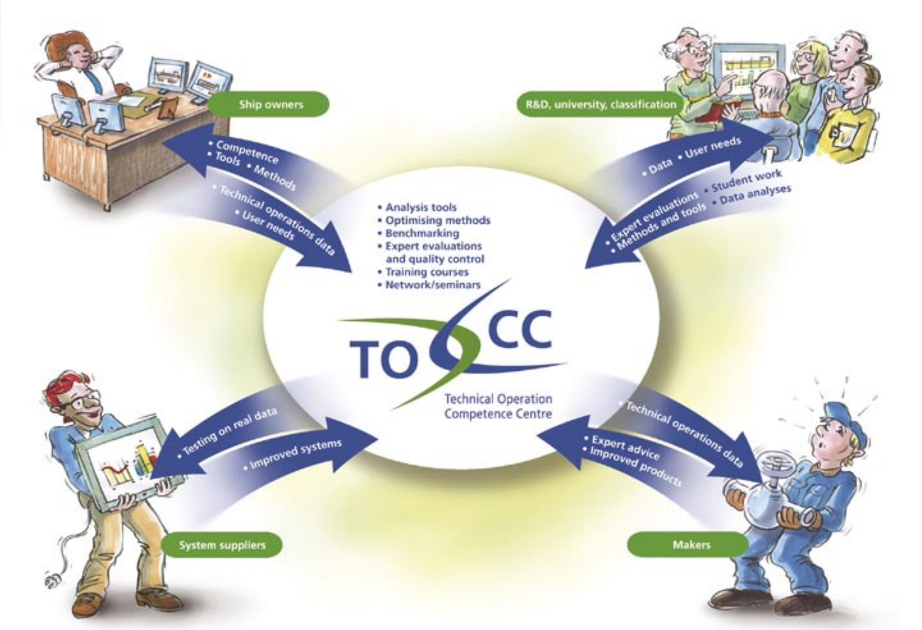

Figure 1. The TOCC concept.

Ships are being equipped with extensive systems for sensing, monitoring, diagnostics and decision support, and new communication infrastructures are being explored to provide a closer integration of ship and shore-based resources. However, due to the increasing complexity of onboard systems, the development of next generation shipping operations must be supported by relevant developments of technology, procedures and regulations.

Modern ship systems are capable of providing a prodigious amount of data. Therefore, it is essential that relevant information is presented to the ship operator in the best possible way, and that rational tools are available that give the ship crew and onshore support teams intelligent guidance.

In January 2005, MARINTEK launched the Technical Operations Competence Centre (TOCC) together with DNV, NTNU and Høegh Fleet Services, Torvald Klaveness Group and Jebsens Ship Management shipping companies. The joint industry project was expanded into a user-led project cofunded by the Research Council of Norway when we were awarded a three-year project funding from the MAROFF programme.

The concept of the TOCC is that the shipping company supplies the TOCC with operational data, while MARINTEK and NTNU provide data analyses and expert evaluations (figure 1).

In the first year of operation of the TOCC, the following case studies will be given priority:

- Technical condition index for main engine: TeCoMan/performance data
- Speed/consumption analysis

Technical Condition Index for Main Engine

In 2004, before the TOCC was established, a draft model for the development of technical condition assessments of ship main engines was drawn up. This model is based on a shipowner's general assessments of his vessel's main engines. Main engine measurements translated into index values representing the main engine and its subcomponents in a tree structure. The index values are dimensionless and represented as TCIs (Technical Condition Indexes).

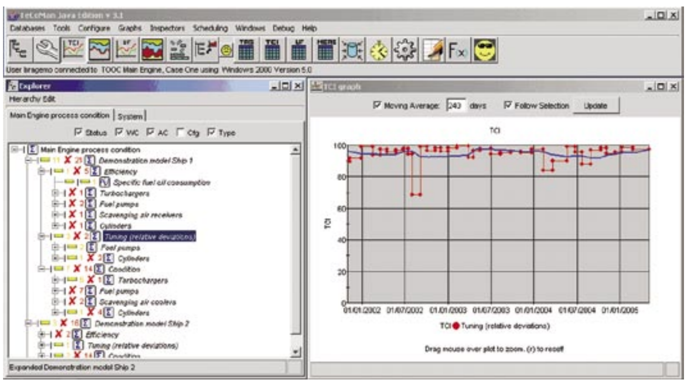

Figure 2. Technical Condition Index.

TeCoMan was used to build the model and calculate main engine performance on the basis of three years of historical measurements. The models developed in 2004 will be further developed and tested in 2005 on data from participating shipowners (figure 2).

Performance monitoring speed/-consumption

Shipping companies can improve vessel maintenance and operation by using condition monitoring and operational analysis in combination:

- Improve voyage planning by utilising historical operational data.
- Improve hull, propeller and machinery maintenance by extended condition monitoring and trend analysis.

In this project activity, the SOPRAN tool will be used (figure 3).

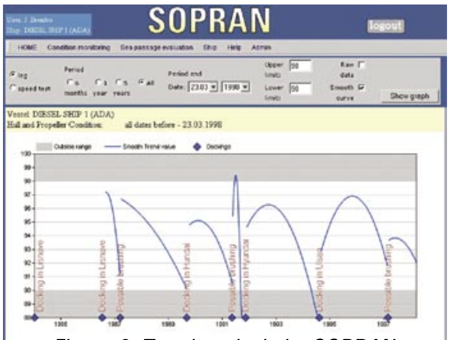

Figure 3. Trend analysis by SOPRAN.

This autumn, shipowners will be invited to participate in an expanded TOCC project in 2006 and 2007.

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Propulsion and Control …

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the red colour on the forward half of the hull side. Such information about forces on the hull in different manoeuvring and berthing situations is of vital importance when simulation tools for manoeuvring are being designed.

Although CFD tools are available for making such analyses, model tests are still essential for validation purposes.

Interaction effects between propulsor and hull in different situations are vital information when simulation tools for manoeuvring and dynamic positioning are being designed.

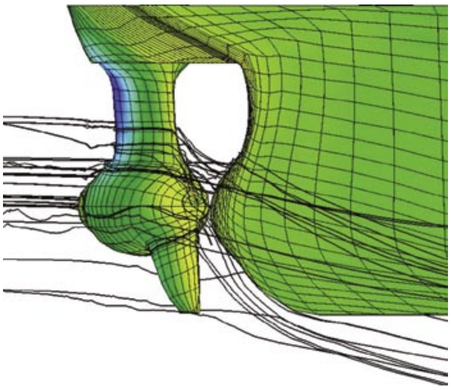

Figure 6. CFD calculations, thruster-hull (CFDnorway).

CFD calculations of hull, pod unit and propeller modelled as an actuator disc, can be performed in order to provide information about interaction effects. An example is shown in figure 6, where a CFD study of interaction effects has been carried out for a podded car ferry.

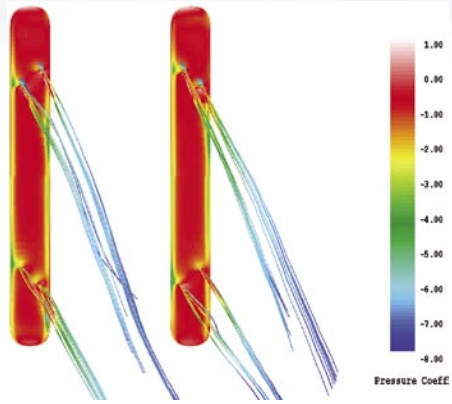

Figure 7. Bottom view showing Cp distribution with superimposed streamlines indicating the propeller slipstream for a current of 1.75 m/s at 30 deg.

Figure 8. Cp distribution and streamlines in the propeller stream for a current of 2.2 m/s and 0º flow angle. Warm colours denote high velocities.

Another example which has been the subject of CDF studies is a real drift-off situation for an offshore platform in the North Sea. In that case a simulation study was performed for the platform in wind and current, at different heading angles, and with eight azimuthing thrusters in operation. It was shown that such a study can provide vital information about the operational window and optimum thruster settings as regards interaction effects and the resulting manoeuvring forces on the platform. Visualisations from such a study are shown in figures 7 and 8, where each thruster is represented by an actuator disc, including the slipstream swirl.

Figure 8 shows that even if the slipstreams are directed downwards away from the bottom of the hull, they still “cling” to the hull, causing sub-optimal working conditions for thrusters located in the slipstream, and generating serious thrust losses.

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MARINTEK Vessel Simulator …

Cont. from page 3

MARINTEK’s contributions to OSC include modules for vessel motions, environmental forces from wind, current and waves, sensor modules, rig motions, anchor forces, line dynamics, CSI and integration support. The simulator has been created by integrating modules from different suppliers who usually provide systems for real vessels. Each supplier is responsible for the description physics and logics of their own modules. Rolls-Royce Marine has delivered a fully operative bridge, propulsion units and winch-control station. Farstad Shipping ASA has provided human resources with anchor handling knowledge and experience to develop a training course. OSC has provided 3D visualization for the bridge and the training station where deck personnel wear 3D glasses and control a virtual seaman by joystick. OSC was officially opened by HRH Crown Prince Haakon on April 6, 2005.

Figure 2. Royal Opening of OSC.

Prototyping of a joystick control system for FerryCat

In another project with Rolls-Royce Marine, MARINTEK has developed a joystick control system for the FerryCat™ 120. The FerryCat™ 120 is a high-speed aluminium catamaran built by Fjellstrand AS and is an innovative commuter ferry concept. The ferry will have a capacity of 112 cars and 400 passengers, and will be capable of making 22 knots using a newly developed propulsion system known as Azipull (Azimuthing Pulling Propeller) from Rolls-Royce Marine AS. The propulsion system consists of four propeller units, one at each “corner” of the vessel. The ferry will be steered from a wheelhouse that can be rotated 180 degrees, depending on the direction of travel of the ferry.

This project employs the Vessel Simulator to create a common arena for the design, development and understanding marine control systems, covering software-in-the-loop, hardware-in-the-loop and full-scale testing and verification.

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