The Royal Institution of Naval Architects

Energy Efficient Ships

International Conference

Energy Efficient Ships

4th November 2015, Rotterdam, The Netherlands

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10.00-10.30 **COFFEE & REGISTRATION**

10.30-10.55 **HYDRODYNAMICS FOR ENERGY-EFFICIENT SHIPS**
Markus Aarnio, Foreship, Finland

The role of hydrodynamic modelling in optimising ship efficiency is often overlooked, but sometimes overstated. Drawing on an unparalleled industry database covering the real life hydrodynamic performance of vessels, Foreship will present its experience in some of the highest profile ship construction and conversion projects in shipping, offering insight into how its scope of work provides the basis for generalised recommendations of value for naval architects. In doing so, Foreship's presentation will also explore the use of 'in waves' technology in simulation, assess the real impact on vessel efficiency of a range of new technologies, and highlight how even minor vessel conversion work can have a major impact on hydrodynamic performance.

10.55-11.20 **ENERGY EFFICIENT SHIP DESIGN AND OPERATION**
Jan O. de Kat, Director of Energy Efficiency and Vessel Performance, ABS, USA

Cost reduction and control, optimizing efficiency, improving environmental performance and safety are among the key issues for ship owners and operators. The combination of theoretical insight, operational experience and technology allow us to take a more holistic approach to manage the performance of vessels from an energy efficiency perspective while complying with prevailing regulations. A lifecycle approach to performance optimization is taken from a combined design and daily operations perspective. In this paper we will discuss an approach aimed at achieving an energy efficient hull, propulsion and machinery system, efficient operational performance combined with cost-effective environmental compliance with air emission regulations (NOx, SOx and CO2). Technical and economic issues will be addressed. The best package of measures to improve efficiency depends on ship type, cargo, trade route and other factors. It is important to assess the effectiveness of each different design or operational measure, while the application of one measure may influence the benefit of another measure. The financial perspective is based on a total cost of ownership assessment, requiring the quantification of all relevant phases of the lifecycle related to design, purchasing, operating, maintaining and sale or disposing. Some cases will be provided in relation to vessel performance monitoring and fuel consumption analysis, as well as a class perspective on MRV (monitoring, reporting and verification).

11.20-11.45 **HOLISTIC SHIP ENERGY SYSTEMS MODELING FOR EFFICIENT SHIP DESIGN AND OPERATION**
Fabian Tillig, Jonas W. Ringsberg, Wengang Mao, Bengt Ramne, Chalmers University of Technology, SWEDEN

With today's striving to increase the energy efficiency of ships, ship owners, naval architects and ship operators claim that their ships' hull forms, routes and systems are "optimized". However, most ships are designed for artificial points of operation – one or multiple speeds in calm water – with empirical corrections in order to cope with worst case operational conditions. This procedure does not ensure that the "optimized" ship really is close to the best solution for its mission or trade. Generic models are of great use in the early design phase of ships when decisions need to be taken without detailed knowledge of the later ship. In retrofitting and operational improvement studies a holistic model provides insight into interactions between ship components and enables the naval architect to gather an understanding of possible changes and their effect on the whole system. Additionally, a dynamic and holistic model opens the opportunity of full journey simulations offering advanced route planning as well as the improvement of operational conditions throughout the journey. The paper presents an introduction to and an overview of the state-of-the-art of energy systems models of ships. An example of a generic, holistic and dynamic energy systems model is presented and its components and their interactions are discussed. Examples from different stages of a ship's lifecycle, from main dimension variation and engine selection through retrofitting studies to speed profile improvements, are shown. Employing the results from these examples, it is discussed how this type of model can help solving the challenge of finding suitable design targets with respect to energy-efficient ship design and operation.

11.45-12.15 **COFFEE**

12.15-12.40 **PRACTICAL ASPECTS OF ENERGY SAVING DEVICES**
Craddock C., Ponkratov D., Caldas A., Zegos C., Hurford A., Fetherstonhaugh C., Vroegrijk E., Ship Performance Group, Technical Investigation Department, Lloyd's Register Global Technology Centre, Southampton, UK.

Following the recent implementation of the Energy Efficiency Design Index (EEDI) and Energy Efficiency Operational Indicator (EEOI), Lloyd's Register Ship Performance Group (LR SPG) have been heavily involved in a significant number of projects ranging from design advisory to sea trials attendance and in-service monitoring. This involvement has positioned LR SPG to be a leading independent verification consultancy for Energy Saving Device (ESD) performance. ESD performance is measured not only by hydrodynamic efficiency but also by the propensity to cavitate. Extensive cavitation on the ESDs themselves or downstream on propeller or rudder can potentially lead to vibration and erosion problems. In the proposed paper, these aspects for Pre-Swirl Stator (PSS), Wake Equalising Duct (WED) and Propeller Boss Cap Fin (PBCF) will be addressed.

12.40-13.05 **DEVELOPING A ROUTE MAP TO NOVEL GREEN TECHNOLOGY INTEGRATION AND ACCEPTANCE**
Sam Hill, Programme Manager IMCS, QinetiQ, UK

Designers aiming to utilise novel green shipping technologies such as windpower must contend with the conservative nature of the maritime industry, coupled with owners who need to be convinced of the benefits to their bottom lines from such technologies. This paper seeks to set out a potential roadmap to a full scale technology demonstration, considering the stakeholders who need to be convinced of the projects application, and the evidence required to invest. The paper will then consider having conducted a full scale demonstration, at what point does the technology 'tip over' into the mainstream and become accepted as a viable option for refit or newbuilds.

13.05-13.30 **INTEGRATED DESIGN OF AN ASYMMETRIC AFTBODY AND A PROPELLER TO MAXIMIZE THE ENERGY EFFICIENCY**
Ir. L. Rueda and Dr. Ir. J. Dan, Marin, Netherlands

With the implementation of the EEDI, energy saving and emission reduction of ships, especially for merchant ships, become more and more important. To achieve high efficiency and low emission, Energy Saving Devices (ESDs) have been re-studied recently and installed to many ships in full scale. Various ESDs, including also new concepts, have been tested and big improvements on powering performance of ships have been confirmed in model scale. Due to the fact that most ESDs are fitted in the wake field of a ship, the performance of the ESDs, however, suffer typically the scale effects. In addition, fouling and structure integration of the ESDs with the hull remain the issues for operators to make decisions on applying ESDs to their ships. Distinguished from the ESDs where additional appendages have to be added to the hull in front of or/and behind the propellers, asymmetric aftbodies can change the inflow towards the propeller without add-ons. The wake with pre-swirl generated by an asymmetric aftbody is in general more uniform than that generated by an ESD (such as a pre-swirl stator with finite number of blades), with limited or no penalty on the resistance. By integrating an operating propeller, asymmetric aftbodies can be designed so that the ship-propulsor interaction is optimized for the total propulsive efficiency. Therefore the required shaft power is minimized. This paper presents the optimization procedure by using CFD towards a totally-integrated hull form and propulsor design for a great energy efficiency of a single screw ship. Comparative CFD calculations and model tests have been carried out to enlarge the insights into the working principle of asymmetric ships. More than 6% of energy efficiency gain has been found by a moderate asymmetric aftbody, without detriment to the manoeuvring performance of the ship, especially the course stability.

13.30-13.55 **BULBOUS BOWS FOR ENERGY EFFICIENT SHIPS: A NOVEL APPROACH**
Andrea Grech La Rosa, Prof Giles Thomas, Ema Muk-Pavic, UCL, UK, Tom Dinham-Peren, BMT DSL, UK

Improving the energy efficiency of a vessel by means of optimising its hydrodynamic characteristics is sometimes limited by the fact that a vessel's design condition may at times not coincide with its actual operating conditions. Bulbous bows are widely used to improve the hydrodynamic characteristics by means of primarily influencing a ship's wave system. Despite this, they are optimised for a discrete band of operating and loading conditions, making them susceptible to actually hindering performance once the vessel operates outside this performance band. If new technology and materials can be applied to create a mechanism that allows the geometry of the bulb to change, an optimisable bulbous bow would be generated that adapts its shape according to the vessel requirements at that instant. Examples of the vessel's requirements may include its resistance, seakeeping or hull efficiency characteristics. This paper discusses the different parameters that affect bulbous bow performance in order to create a new perspective to their design. By having the opportunity to alter the bulb's shape once constructed, different longitudinal and transverse profiles are expected to be identified that better cater for the real time requirements of the ship. Preliminary work showing the hydrodynamic benefit of installing a new system such as a morphological or adaptable bulbous bow will be reported. This, together with a review of bulbous bows, their influences and how they may be affected when in service, will act as a guide for a high level bulbous bow assessment.

13.55-14.55 **LUNCH**

14.55-14.20 **DESIGN OPTIMIZATION FOR OPERATIONAL PROFILE – WHAT CAN BE ACHIEVED FOR BULKY HULLS?**
Juryk Henrichs, Justus Heimann, Karsten Hochkirch, Volker Bertram, DNV GL, Germany, Uwe Kowalewski, Intership Navigation, Cyprus

Hull optimization is one of the most powerful levers to reduce fuel consumption. For large containerships, efficiency gains of 4-6% are typical. For full-bodied ships, such as bulkers and tankers, ship designers expect intuitively lower saving potentials. This is not necessarily so, as we show for an industry project for a bulk carrier. The optimization is based on parametric hull modelling, CFD and formal optimization, using extensive parallel computation. The optimization process employed several stages, combining high-performance computing with the naval architects' intelligence: In a first phase, the effect of various parameters on hydrodynamic performance (at various speeds and drafts) was investigated. The insight gained in this phase helped identifying parameter ranges for the actual optimisation search. Employing a low-fidelity hydrodynamic model (less accurate, but very fast) a formal optimization yielded designs of low resistance. Employing a high-fidelity hydrodynamic model (accurate, but requiring extensive computer resources), the near-optimum designs selected from the previous step were now formally optimized. Some 37000 hull variants investigated resulted ultimately in reduction of yearly fuel consumption by 26% for calm-water conditions, confirmed in model tests. So, very high gains may be achieved for full-bodied ships if high-performance design approaches are used and realistic operational profiles are considered. High-fidelity CFD and suitable parametric models are keys to unlock this dormant saving potential.

14.20-14.45 **POTENTIAL FOR IMPROVEMENT OF SHIP LIFECYCLE COSTS THROUGH DEVIATION FROM STANDARD SHIP DESIGNS AND PRACTICES**

Hans Richard Hansen, Ph.D, Low Carbon Shipping AS, Norway, Thomas Dinham-Peren, B.Sc, BMT Defence Services Ltd, UK

A majority of ship newbuildings are standard designs developed primarily by shipyards in order to serve a multitude of customers and services. This of course leads to designs which are relatively cheap to build because of repetition, standardization of dimensions and a uniform build process. Shipyards have, however, to attempt to cover the commercial and operational requirements of as many owners as possible. This does not lead to optimal ship propulsion performance. For an owner it is often difficult to evaluate the opportunities available in deviating from such designs. An analysis of the potential has traditionally required a lengthy process of design development and verification by model testing or at least relatively time consuming CFD calculations. Both are traditionally performed by the yard after a contract has been signed. A procedure developed by BMT for Teekay Shipping since 2007 has significantly reduced the time and cost of evaluating the propulsion improvement potential for alternative ship deadweight and main dimension combinations. This was used to develop innovative Aframax and Suezmax tanker designs with revised dimensions. The paper will show an example of the improvement of fuel economy provided by such a design. To what extent this exceeds any extra shipyard cost will also be discussed, taking into account the possible variability of fuel prices and of newbuilding costs, the later of course subject to market conditions and shipyard negotiations.

14.45-15.10 **A RESEARCH ON DECREASING WIND RESISTANCE OF LARGE CONTAINER VESSEL**

Dr. Kazuyuki Ouchi, Ouchi Ocean Consultant, Inc., Japan, Dr. Tingyao Zhu, ClassNK, Japan, Yoshikazu Tanaka, Akira Taniguchi, MOL Technotrade, Japan

Recently, in case of large container ship, more than half numbers of total containers are stowed on deck and the project area above the ship's water line is more than three times of that below the water line, so that the air drag on the ship is not so small enough especially in rough sea. The wind tunnel tests and CFD calculations were carried out in the various cases of the windshield and container stowage plan on a 6,700TEU container ship. From the experiments, the significant effect of air drag reduction is observed in case of putting the front windshield on the forecastle deck, the side windshield blocking the spaces between the every container bay, and the wing tail shape stowage in bays on the deck of ship's Stern. By adopting these various ways of air drag reduction, more than 5% (average in a year) of the total fuel consumption will be saved in the real sea of North Pacific Ocean.

15.10-15.35 **MEASURING NOW IS IMPROVING THE FUTURE: USING VESSEL DATA TO OPTIMIZE SPEED, TRIM AND MORE**

Fenneke Sterlini and Leon Adegeest, ABB Competence Center Dalfsen, the Netherlands

Vessels are equipped with various sensors, measuring e.g. speed, location, position, wind speed etc. All this measured data can be stored and used to further improve the specific vessel performance. Having an insight in the vessels performance and to have the actual information at the right time is crucial for making the right decisions for safe and efficient vessel operations. The OCTOPUS Onboard advisory system, continuously measures and stores key vessel features. All measured performance statistics are sent daily to the onshore performance database. Using the performance database, essential information for efficient navigation is analysed, reported and (in some cases) sent to the vessel as an RPM-advice. In this presentation we present some of our results based on several years of measured data obtained on different vessels. Results show that this data can lead to e.g. a lower and more constant RPM or power for a forecasted journey, an advice on the ideal trim. Further use could be to forecast when hull cleaning actions need to be performed or to create a better insight in the effect of stabilizing fins on performance. The result is that without changing anything on the vessel, the key factors that affect the performance can be distinguished and fuel use of an existing vessel can be significantly improved.

15.35-16.05 **COFFEE**

16.05-16.30 **A METHODOLOGY FOR SYSTEMATIC FLEET PERFORMANCE EVALUATION**

Stefanos Glaros, Eastern Mediterranean Maritime (EMM) Ltd. Greece, Antonios Tzamaloukas, Eastern Mediterranean Maritime (EMM) Ltd., Greece

The shipping industry is operating at an environment of multivariable operational parameters, increasingly stringent regulatory framework and commercial demands. Targeted environmental impact of the industry, resulting in stricter air emissions' regulations, in combination with continuous fluctuation of bunker types and costs, constitute fuel efficiency a challenge greatly pursued. Eastern Mediterranean Maritime (EMM) Ltd., operating a fleet of sixty vessels (tankers, bulk carriers and containerships), emphasizes on environmental protection as well as on fuel efficiency, in line with its environmental policy and necessary economic welfare. Therefore, several strategies are adopted on EMM fleet, such as: - Installations of retrofit solutions addressing fuel efficiency, i.e. propeller ducts, slow steaming kits etc. - Hull maintenance, dry dock and underwater, i.e. hull treatment, advanced anti-fouling paints, propeller polishing and hull cleaning as required - Detailed monitoring, trending and evaluation of day to day vessels' performance using traditional Noon Reports in conjunction with EMM performance evaluation methodology. EMM performance evaluation methodology consisting of four stages, namely data pre-processing, data filtering, corrections and evaluation, is developed and implemented in-house. Applying the methodology, reported main engine loading/ fuel oil consumption, cylinder oil consumption and diesel generators fuel oil consumption are comprehensively assessed. Vessel updated performance curves are utilized for performance assessment, benchmarking and evaluation of retrofits/enhancements. The methodology has been evolved, applied and tested for a considerable period. The difficulties faced, the solutions given and representative results are presented in this paper. Moreover, economotechnical considerations and technical annotations, on the early evaluation of some recent energy saving retrofits at EMM fleet, are included.

16.30-16.55 **AIR LUBRICATION: FROM CONCEPT, TO SEA TRIALS, TO COMMERCIALISATION**

TBC, Silverstream Technologies, UK

How delivering rigorous and robust sea trials is the key to building market confidence and trust in viable clean technologies. Despite the commercial and environmental opportunities of utilising clean technologies within the shipping industry, uptake has been slow. A key reason for this is the lack of direct proof of the savings figures that many manufacturers claim, and questions on the validity of correlated trial results. In 2014, Silverstream Technologies, after more than ten years of development, looked to correct this imbalance by conducting meticulous sea trials of its air lubrication technology, the Silverstream® System. The trial was funded by Shell, with the proviso that, to ensure credibility, it needed to espouse transparency and independence with all elements of the process carefully defined, monitored and analysed. The technology was installed within 14 days at the Fayard shipyard in Denmark on an MR1 40,000 DWT products tanker, MT Amalienborg, owned by leading Danish shipping company Dannebrog Rederi. Shell independently contracted Lloyd's Register's Ship Performance Group to specify the trial procedure, and to verify and report on the results. Other partners included classification society RINA and hydrodynamic research experts, HSVA. The BMT SMART performance monitoring system was used to record raw data from the trial. Following 52 single runs under ballast conditions and subsequent laden trials conducted six months later, the results were conclusive; the air lubrication system provided verifiable gains in both conditions. Based on these results, and ongoing monitoring, Silverstream Technologies and Shell are confident that the fully optimised system will produce net efficiency gain in excess of 5%. This paper will go into the detail of these landmark sea trials, the challenges involved, how they were overcome and how they have positioned Silverstream Technologies as a company with a viable clean technology; one that is already proving its worth with its first commercial installation, and with more in the pipeline with a range of ship owners and operators.

16.55-17.20 **SUPPORTING THE ENERGY EFFICIENT SHIP DESIGN PROCESS WITH ENERGY FLOW SIMULATIONS: CASE EFFICIENT COOLING WATER SYSTEM**

Mia Elg, Deltamarin Ltd. and VTT Ltd., Finland

The main auxiliary machinery for cooling the engines is recognized as one potential saving target in a cargo ship. The key components in this system are the low temperature (LT) water circulating pumps, the central cooler heat exchanger and the sea water cooling pumps. The energy saving possibilities in this system emerge from the possibility to control the flow with variable-speed pumps in both LT- and sea water circuits, and the general saving potential can be demonstrated with simple energy balance calculations. Practically, however, evaluating the true energy saving potential in this system is difficult, as the LT-water cooling system affects strongly in many of the key components in the ship machinery. The ship energy flow simulator, developed originally by Deltamarin, ABB and VTT, was utilized for evaluating the potential in the cargo ship fresh cooling water system, once considering the individual requirements from the various components in the cooling system. With the tool, the main topology for an efficient cooling water system could be demonstrated. The system consists of a balanced ring network with an optimal set-up of pumps and heat exchangers that were dimensioned for both minimizing the building cost and for performing best at the average operational conditions, instead of the extreme design conditions. The cooling system is controlled by varying both flow rate to components and return temperature to central cooler according to the operation profile. This new design method can efficiently support the ship design work already at the crucial concept development phase, where the main decisions regarding ship energy efficiency are made.

17.20-17.45 **THE BENEFITS OF SHIP WASTE HEAT RECOVERY USING A SUPERCRITICAL ORGANIC RANKINE CYCLE**

Sean McCracken, Granite Power Limited, UK, John Buckingham, BMT Defence Services Limited, UK

The energy contained within the exhaust gases of ship engines offers a good potential source for useful energy using waste heat recovery. Organic Rankine Cycles (ORC) are a relatively new but proven technology, but remain little used on ships (beyond some limited trials) as it appears ship owners have not yet been convinced on their benefits. A recently developed supercritical version of the ORC called ScORC GRANEX®, has many desirable features for marine application. Compared to a steam Rankine cycle it requires less heat exchanger surface area and has greater thermodynamic efficiency delivering more useful power. This leads to a more compact system that can be more easily retrofitted with a reduced payback term. This paper presents the performance features of the GRANEX® technology and examines the conceptual installation on a merchant and military vessel, showing the size and weight of equipment and how it can be installed. Based upon the engine exhaust data at specific loadings, the recovered electrical energy is identified to determine the fuel saved, the emissions reduced and the increased range of a transit. Equipment and installation costs are estimated and the calculation of predicted fuel savings on typical ship operations determines the likely return of investment. A careful consideration of the maintenance of the technology is included, which highlights the state-of-the-art equipment developed towards minimal maintenance.

17.45-18.00 **GENERAL DISCUSSION & CLOSE**

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