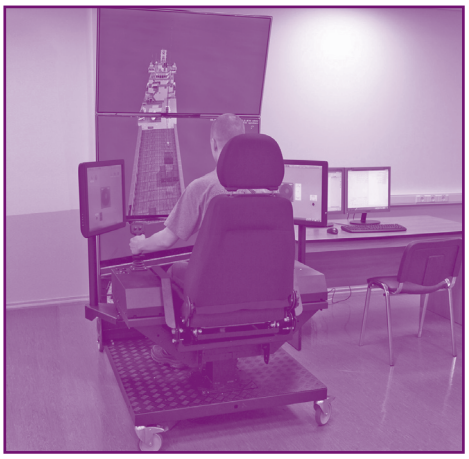
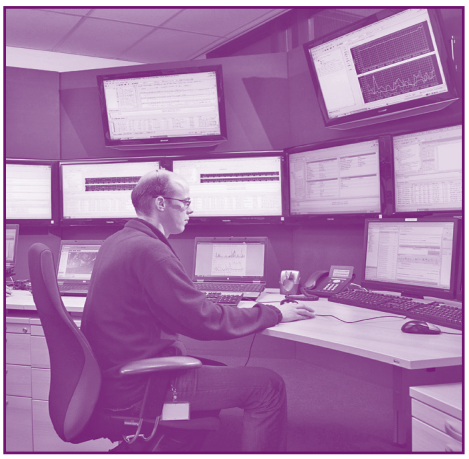
The Royal Institution of Naval Architects

# Smart Ship Technology



## International Conference on Smart Ship Technology

## 24-25 January 2017, London, UK

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**08.30-08.55** **COFFEE AND REGISTRATION**

**09.00-09.35** **TOWARDS SHIPPING 4.0,** *Ørnulf Jan Rødseth, MARINTEK, Norway.* In parallel with land industry, shipping has experienced three technical revolutions: steam engines (~1800), diesel engines (~1910) and digital control systems (~1970). Still in parallel with industry, it is facing its fourth revolution based on the so-called "Industry 4.0" revolution, integrating Internet of Things, Cyber Physical Systems, Big Data and other technologies. As with previous revolutions, we expect that "Shipping 4.0" will have a profound effect on shipping operations and on how the business will be put together. The society's focus on energy efficiency and reduced emissions is expected to speed up the uptake of the new technology. Shipping 4.0 is mainly characterised by a huge increase in available digital information, but also by new service and operation concepts made available with better connectivity between ship and shore. Examples are already emerging in e-navigation, third party analytics and shore services. Supporting evidence is, e.g. in the amendment to the IMO FAL convention which will require electronic port clearance of ships from 2019 and the strong interest in cyber security in IMO and elsewhere. The interest in, and eventual deployment of autonomous ships is the culmination of Shipping 4.0. This paper will examine the different components of Shipping 4.0 and how they can change the business. The paper will also point out some key elements in the new technology that will need attention by the community, particularly in the area of international standards. Finally, it will indicate some ongoing projects that are expected to influence the developments.

**09.35-10.10** **WILL A SMART SHIP BE LIABLE?: AN ANALYSIS OF THE APPLICATION OF LIABILITY TO THE SHIP ITSELF,** *Hannah Stones, University of Southampton, UK.* Maritime law is preparing for a technological overhaul of shipping, as engineers develop smarter ships: unmanned ships, and autonomous operating systems. Without a master and crew on-board, or even operating the ship from shore, it is asked 'who shall be held responsible?' Humans are easy to consider responsible and the owner can be held vicariously liable. Research into autonomous systems has considered holding the owner, the manufacturer or programmer responsible by considering the autonomous system as their instrument. Another suggestion is to make the ship liable. The problem is that the idea of the system itself being held liable has not been considered in relation to shipping. It is concluded that it would not be possible to hold the ship liable in international maritime law. Previous research found that it is problematic to impose remedial measures on a system; additionally in maritime law the system is based on the owner being liable and minimal change is needed to ease the introduction of unmanned ships. Despite concluding that the ship itself would not be a liable party, this paper found that there are ways of facilitating the imposition of remedial measures. The findings in this paper provide an initial exploration of liability in international maritime law to unmanned ships and autonomous systems. Although this paper suggests that minimal changes are needed to ensure the future of the technology, other aspects of the law that practically rely on the physical presence of humans will require more changes.

**10.10-10.45** **EMBRACING A SMARTER FUTURE – HOW NAVIES COULD GAIN ADVANTAGE FROM SMARTER AND MORE AUTONOMOUS SHIPS SYSTEMS, Justin Paul, QinetiQ, UK.** This paper will introduce an Offshore Patrol Vessel concept that makes use of smart and autonomous systems to amplify and enhance the ships capabilities. It will look at four main areas of interest: · Open Architecture Combat System, · Smart equipment management, · Highly mechanised handling systems, · Modular mission packages utilising autonomous off board systems. It will explain how the combination of these technologies will increase a ships situational awareness, the ability to make timely tactical and operational decisions and deliver military effect; while also reducing operator loading. Through the use of automation and autonomy a ship can use it's sensors and equipment to gain the information edge and deliver effect in a more efficient manner. The second half of the paper will look at the impact of these developments on design, procurement and the competency & training requirements of the future crews. It will identify key areas in which a modern navy can adapt to take best advantage of the technology: · Exploiting flexibility through modular designs making more use of COTS equipment that is cheaper and easier to upgrade through life and allows "plug and play" options to suit specific missions. · Achieve responsiveness and agility through a split between procurement of the platform and the capability. Breaking dependency between platform build and equipment procurement. · Identify skills and training needed to deliver this new capability?· Is a paradigm shift in the way these vessels are operated required?

**10.45-11.15** **COFFEE**

**11.15-11.50** **CAD TOOLS FOR DESIGNING SMART SHIPS IN THE WORLD OF THE INTERNET OF THINGS (IOT),** *Jesús A. Muñoz, Rodrigo Perez, SENER Ingeniería y Sistemas, S.A. Madrid, Spain.* The Internet of Things (IoT) is a concept and a paradigm that considers pervasive presence in the environment of a variety of things/objects that through wireless and wired connections and unique addressing schemes are able to interact with each other and cooperate with other things/objects to create new applications/services and reach common goals. There are a great variety of areas of application. The smart cities, smart Factory and smart manufacturing are one of them. The ship vessels and offshore structures are like small cities or industries or even both. These kinds of artifacts can integrate the developments on IoT to deliver smart vessels that improve operation, usability and profitability for ship owners, users and workers. IoT is one of the most important challenges in the current society. All the areas in which men and woman live will face this advance, and the ship vessels are one of them. The different possibilities of introducing IoT in vessels need to start from the initial concept and the initial design. CAD systems need to be prepared and adapted in order to provide the characteristics that the ship and o_-shore designs need to take advance of all the developments related with the world of IoT. In this paper, several of the features of CAD systems related with the paradigm of IoT are presented focused in the shipbuilding concept.

**11.50-12.25** **INFLUENCE OF LOSS OF SYNCHRONIZATION BETWEEN SIGNALS FROM VARIOUS MARINE SYSTEMS ON ROBUSTNESS OF PREDICTIVE MODELS ALGORITHMS,** *Anna Swider, Rolls-Royce Marine AS, Norway.* Ship industry nowadays enter the challenging phase of smarter shipping by operational cost saving and optimization of installation. The crucial role play on board measurements from sensors of various installations, which availability expands the functionality of marine products. Machine learning algorithms and statistical modelling become widely used tools in ship monitoring and advisory systems, however they are sensitive for quality and correlations between data. Various data acquisition systems (DAS) introduce disturbances what can influence the output of used algorithms. The importance and effect of the data collection is often omitted in the process of data analysis and researchers assume that DAS does not introduce distortions. However, in the reality, processing of data from several marine systems creates many challenges. One of them is lack of data synchronisation, which can be introduced by specific systems setups and different time intervals. In the analysis of tremendous amount of data – Big Data, ignoring the fact of e.g. introduced additional time delay to the signal during data collection can have serious consequences of improper output response. In case of for example on board monitoring systems, the delay effects their reliability. Additionally correlations between specific signals can be corrupted and influence expected results. This article will focus on real examples from marine systems, which visualise loss of synchronization between various signals and their impact on predictive models algorithms used in marine applications, demonstrating the importance of data synchronization.

**12.25-13.30** **LUNCH**

**13.30-14.05** **REQUIRED FLOODING SENSOR ARRANGEMENT FOR RELIABLE AUTOMATIC DAMAGE DETECTION,** *Esa Takkinen, Pekka Ruponen, Petri Pennanen, Napa Ltd, Finland.* Modern passenger ships are filled with smart technology that can be used for improving the safety and survivability of passengers in an emergency situation. For example, IMO regulations require passenger ships, constructed after July 2010 to be equipped with flooding detection system. Decision support systems (DSS) can use these sensors to automatically detect breaches and to perform progressive flooding analyses in time-domain. However, the current minimum requirement for sensor arrangement does not necessarily provide enough information for automatic breach detection. One of these DSS that does automatic breach assessment is NAPA Emergency Computer. For this system to be able to reliably perform automatic damage detection, the number of sensors needs to be sufficient. Accurate damage detection is crucial for reliable progressive flooding calculation. Three different sensor arrangement are studied: the current SOLAS requirement, FLOODSTAND recommendation and one with very large number of sensors. The effects of the sensor arrangement on the automatic breach detection are studied with several realistic damage scenarios, and the results for the predicted breach sizes and predicted development of progressive flooding calculation are compared. Finally, conclusions on the required flooding sensor arrangement are drawn based on the presented case studies.

**14.05-14.40** **THE UNGOVERNED SPACE OF FIRE SAFETY ENGINEERING,** *C. S. P. Hunter, tbc, COLTRACO Ultrasonics, UK.* This paper explores the trending topic of harnessing data from improved and continuous monitoring on smart ships in order to, primarily, increase safety and secondly, to make economical savings, with regard to the "Ungoverned Space" of fire safety. Going above and beyond regulation compliance to secure additional benefits are vital to increasingly high value and safety critical vessels in terms of fire safety. Traditionally, the industry cares little about this ungoverned space, with too few qualified engineers considered subject matter experts. Owners focus on systems delivered at the most competitive rates rather than seeing fire protection as an investment. Moreover, many are not even aware of the relevant regulations. However, with the impact of fire being more widely recognised, new research and development explores ultrasonic technology to monitor the extinguishing systems through inspection and integrated, continuous monitoring with alarm relay and remote diagnostics. The latter gives eyes to shore-based operators at a time of fewer crew and hopes for autonomous shipping. New smart ship technology counters the environment in which a "safety first" culture remains un-pursued and unrewarded. With multiple ships sailing with partially-filled, over-filled or empty cylinders, and many unpublished instances of accidental discharges or slow seepages, there is a real cause for concern – now there is an impetus to change. Ultrasound - largely used in shipping as a tool to gauge thickness, yet with more varied uses across military, medical and industrial fields - is now being put to more advanced, innovative uses in shipping for fire safety solutions too.

**14.40-15.10** **COFFEE**

**15.10-15.45** **RESPONSE TIME ANALYSIS CHALLENGES ON A SMART SHIP - AN INITIAL CASE STUDY,** *Demetres Armanes, American Bureau of Shipping, Greece.* Integrated Automation Systems (IAS), generally considered as the stepping stone for Total Ship Automation and Autonomous Vessels, provide today the platform for further cost reduction and advanced functionality onboard modern vessels. Although, there are many best practices to be followed during testing, commissioning and maintenance time, during analysis and design time there is an increasing response time complexity with any new integrated process. Consequently, sound methods and tools are increasingly important for their precise and reliable verification. This paper explores the fundamental notions in response time analysis by using a well know IAS, sufficiently generalized, as an example. The process identifies initial engineering data for the analysis and proposes simplistic behavioral and architectural models, annotated with these data for faster response time verification.

**15.45-16.20** **HANDLING BIG DATA IN SHIP PERFORMANCE & NAVIGATION MONITORING,** *Lokukaluge Prasad Perera, Norwegian Marine Technology Research Institute (MARINTEK), Norway.* Ship navigation strategies are often based on ship performance and navigation data collected by various onboard sensors and data acquisition systems. However, there are many industrial challenges encountered in such full scale data handling situations in various vessels. These large scale data handling approaches are often categorized as "Big Data" challenges in shipping; therefore various solutions to overcome such situations should be identified. The proposed approach consists of a marine engine centered data flow path with various handling layers to overcome those challenges. That consists of identifying the operating regions in the respective engine-propeller combinator diagram as the basis for the data handling process. Data classification step along the combinator diagram is executed, where the respective data driven models for ship performance and navigation monitoring are introduced. These data driven models consist of identifying various data clusters within the data set and the structure of each data cluster. Then, the classified data sets are transferred through the proposed data flow path that consists of pre and post processing sections with the respective data driven models. Data pre-processing consists of sensor faults detection and data compression steps supported by data driven models. The compressed data set is communicated to shore based data centers for data post-processing and that consists of data expansion and data regression steps supported by the same. A comparison between the actual and estimated data sets is conducted to evaluate the success in the data regression steps. Finally, the respective data are analyzed at shore based centers for various decision support applications. Hence, these results can be used to develop data analytics thought the proposed data flow path that relate to energy efficiency and system reliability applications of shipping.

**16.20-** **GENERAL DISCUSSION & EVENING DRINKS RECEPTION**

**08.30-09.00** **COFFEE AND REGISTRATION**

**09.00-09.35** **THE EVOLUTION OF CONDITION MONITORING,** *Larry Rumbol, Condition Monitoring Market Development Manager (Marine), Parker Kittiwake.* The container shipping fleet has now passed 20 million TEU, but it's difficult to find anyone celebrating. Persistent overcapacity in this sector as well as most others alongside stubbornly low freight rates and tough market conditions mean that consistent profitability remains an elusive dream for many. In the battle to remain competitive, the protection of vital equipment and maximisation of a vessel's operational efficiency become even more acute priorities. Yet despite this, maintenance practices are still heavily reliant on an inconsistent combination of recommendations from manufacturers, legislation, company standards and personal experience. Marine operators have a long history of relying on experience and gut feel, but this is having a knock-on effect that is impacting predictability and excellence of performance. What is more, increasingly stringent and widespread environmental regulation provide an additional challenge, as new operating methods for fuels, lubricants and equipment can lead to unintended consequences. Yet despite universal acknowledgement that time not spent at sea is revenue lost to unachieved output, contractual penalties or brand reputation, common sense improvements are being missed. As the first line of defence for identifying issues with critical machinery and equipment, the installation of condition monitoring tools and techniques has never been more valuable in helping operators manage and mitigate potentially costly issues. Easy access to information that gives an accurate picture of the state of the system in real time, and not just when an engineer can get to a machine for routine testing and sampling, ensures operators are forewarned when issues arise. By effectively harnessing the readily available data provided by condition monitoring solutions, it quickly becomes clear that the savings it delivers far outweigh the initial capital investment required setting up these useful tools. With reference to real life case studies including work with Doosan (LinerSCAN), Gram Car Carriers (Alternator Bearing Monitor) and Norbulk Shipping (Cat Fines Test Kit), this presentation will explore how condition monitoring tools can provide operators with the information they need to proactively schedule maintenance, avoid catastrophic engine damage and prevent unexpected downtime.

**09.35-10.10** **SHIP MACHINERY CONDITION MONITORING USING PERFORMANCE DATA THROUGH SUPERVISED LEARNING,** *Christos Gkerekos, University of Strathclyde, Glasgow, UK, Iraklis Lazakis, University of Strathclyde, Glasgow, UK, Gerasimos Theotokatos, University of Strathclyde, Glasgow, UK.* This paper aims to present a methodology for intelligent monitoring of marine machinery using performance data. Monitoring of machinery condition is a crucial aspect of maintenance optimisation that is required for the vessel operation to remain sustainable and profitable. The proposed methodology will train models using pre-classified (healthy/faulty) data and then classify new data points using the models developed. For this, performance measurements are acquired, pre-processed and stored. Measurements are then suitably analysed and processed in order to retain most of the information (variance) of the original dataset while minimising number of required dimensions. These data are then used to train supervised models pertinent to specific machinery components. Finally, new data are compared against the models developed in order to evaluate their condition. The above will provide a flexible but robust framework for the early detection of emerging machinery faults. This will lead to minimisation of ship downtime and increase of the ship's operability and income through operational enhancement.

**10.10-10.45** **FAULT TREE ANALYSIS AND ARTIFICIAL NEURAL NETWORK MODELLING FOR ESTABLISHING A PREDICTIVE SHIP MACHINERY MAINTENANCE METHODOLOGY,** *Yiannis Raptodimos & Iraklis Lazakis, University of Strathclyde, Glasgow, UK.* In the day-to-day ship operations, machinery failures may lead to major accidents, endangering crew and passengers lives onboard, posing a threat to the environment, damaging the ship itself and having a great impact in terms of business losses by reducing ship availability and increasing downtime. Efforts have being made to transform corrective/preventive maintenance techniques into predictive ones. Condition monitoring is considered as a major part of predictive maintenance. Condition monitoring is defined as the collection and interpretation of the relevant equipment parameters for the purpose of the identification of the state of equipment changes from normal conditions and trends of the health of the equipment. The equipment condition and the fault developing trend are often highly nonlinear and time-series based. This paper proposes initially the utilization of a fault tree in order to obtain the most critical ship machinery items. An autoregressive dynamic time series ANN is developed in order to monitor and predict future values of selected physical parameters of the most critical ship machinery equipment obtained from the fault tree analysis. Overall the combination of the fault tree and neural network provide the platform for developing a predictive maintenance methodology for ship machinery equipment.

**10.45-11.15** **COFFEE**

**11.15-11.50** **SHIPBOARD POWER SYSTEMS RECONFIGURATION: A COMPARED ANALYSIS OF STATE-OF-THE-ART APPROACHES,** *Luca Agnello, Massimo Cossentino, Giada De Simone, Luca Sabatucci, National Research Council of Italy - ICAR Institute, Italy.* The Shipboard Power System (SPS) supplies power to navigation, communication, operation and weapon systems. The capability of facing single or multiple faults caused by heterogeneous reasons is a mandatory issue for any vessel. This paper reports a systematic survey on SPS reconfiguration methods; most recent state-of-the-art contributions to the field have been classified according to a taxonomy of criteria. Main categories include: reconfiguration strategies, techniques, quality of reconfiguration, and validation. Reconfiguration strategies define priorities among loads and operations. Examples of them are priority load reconfiguration, load shedding, and achievement of an optimal trade-off between switch operations minimization and reconfiguration schemes. Reconfiguration techniques strongly depend on the physical and control layers and the fault diagnosis methodology; literature approaches deal with mathematical methods, knowledge-based approaches or multi-agent systems. Such techniques may sometime provide multiple configurations and decision criteria have to be applied to them. Quality attributes of techniques include distribution of the reconfiguration system control layer, and approaches response time. Of course, it is desired the reconfiguration procedure be timely in restoring power in vital areas of the ship also to avoid subsequent cascade failures. The literature results encompass several case studies, both software and hardware. They are validated by analysis of employed methods, hardware test-beds, repeatability of the simulations, execution times, etc. Finally, some limits in the current state of the art have been identified.

**11.50-12.25** **SHIP'S CENTRAL COOLING SYSTEM LIVE PERFORMANCE OPTIMISATION AND MODELLING,** *Alessandro Boveri, Federico Silvestro and Alessandro Panzera, DITEN University of Genoa, Italy, Irene Crociccia and Romano Lodde, ABB Marine & Ports - Process Automation Division, Italy.* Central cooling systems play an essential role in ship operations, since guarantee the correct operating mode of vital users such as the main engine and generators. These systems are normally sized according to the design point so that they can deliver the cooling demand even in extreme conditions, while these conditions are very rare events in the ship's life. In order to improve the overall cooling efficiency, a variable frequency drive can be adopted [1-3]. In this work, a physical model of a real Ro/Con central cooling system is presented with an integrated process control scheme. An experimental campaign has been carried out for six months to collect the overall cooling demand (e.g. sea water and fresh water temperatures, flows and valve position) before and after the introduction of variable speed drive on the sea water pump. An algorithm for the control of the cooling water system is proposed and implemented in the model in order to improve the performances and guarantee the basic features of each component. The estimated annual saving coming from the recoded data and the model are around the 40 and 60 percent with a reduction between 10 and 27 percent for the pump speed. The methodology and model are planned and developed in order to better exploit the data available after by the on-board measurement system.

**12.25-13.30** **LUNCH**

**13.30-14.05** **UNLOCKING THE HIDDEN VALUE OF DYNAMIC POSITIONING SYSTEMS,** *Mark Carter, Sonardyne, Guidance, Veripos, UK.* Over the last decades dynamic positioning systems have grown in popularity and applications, by proving highly effective and efficient in keeping vessels safe in a multitude of applications and operations and providing invaluable support to vessel crews and reducing the burden from increasing operational demands and complexities. The key technology components which every DP system relies upon are the environmental, motion and position reference sensors which provide the crucial measurements for the vessel automation system to function in the first place – whether these are below surface (acoustic), on surface (laser and microwave) or above surface (GNSS) position reference systems. This paper outlines an open system architecture for industry wide discussion aiming at providing significant and quantifiable additional value from position reference systems to allow efficiencies and effectiveness beyond DP for a wide range of relevant stakeholders. To avoid the temptation of vendor specific closed DP architectures this approach explores the possibilities available outside or alongside any existing or future architecture in order to get best value from the actual sensor systems that provide the original measurements in the first instance. The white paper clearly identifies all relevant stakeholder groups, then focusses on categories of data available from a range of position technologies and attempts to quantify potential value for access to this information in aggregate form. Last, the paper outlines potential solutions, their advantages and disadvantages compared to existing or alternative approaches and the suitability for future operations such as remote control or autonomous vessels.

**14.05-14.40** **ENERGY SAVINGS FOR A SHIP IN IRREGULAR WAVES BY USING REAL-TIME OPTIMAL CONTROL OF PROPELLER PITCH AND ELECTRIC PROPULSION,** *Hidenori Makino, Yuichiro Hirano, Naoya Umeda, Osaka University, Japan, Toshiyuki Ohtsuka, Kyoto University, Japan, Katsuji Tanizawa, Hidenori Sekiguchi, National Maritime Institute, Japan, Junichi Suzuki, Masaki Fukazawa, Kamome Propeller Co. Ltd., Japan, Hironori Suzaki, Furuno Electric Co. Ltd., Japan.* Normally a ship engine is controlled by its governor for keeping its constant engine speed and the propeller pitch does not change in time. However, a ship at sea runs under oscillatory external environment so that its optimal control for realizing minimum energy consumption could be different from the constant revolution and pitch control. Based on this viewpoint, we propose to develop an optimal control system of propulsion power plant and propeller pitch for minimizing energy consumption of a ship in irregular seaways. In this system, coming irregular wave data are estimated by a wave radar and the Fourier transformation, quick responses are realised with the use of AC induction motor and purpose-designed controllable-pitch propeller and their optimal control signals are calculated in real time by an efficient algorithm of receding horizon receding control. For the state equations, the ship surge motion with the wave exciting force and the added resistance due to waves, the rotational motion of the motor and the propeller, the electric circuit of the motor and the response of the CPP controller are modelled. The performance index for the control is the required energy for the specified horizon and the constraints of actuators are properly taken into account. The numerical results indicate for a short-crested irregular seaway having the significant wave height of 3 m and the mean wave period of 12 seconds that the energy required to propel the 217 m long- bulk carrier with 14.7 knots is reduced by about 2% in head waves, and about 7% in following waves with the optimal-control system proposed herein.

**14.40-15.10** **COFFEE**

**15.10-15.45** **SIMULTANEOUS OPTIMIZATION METHOD OF THE DIRECTION AND SPEED FOR SHIP ROUTE PLANNING,** *Ki-Su Kim, Myung-Il Roh, Sung-Min Lee, Hoeryong Jung, JongJin Park, Dongyeon Lee, Booki Kim, Seoul National University, Seoul, Republic of Korea.* The aggravation of financial condition of shipping companies in recent years and the emphasis on reducing greenhouse gas emissions have resulted in renewed interest in further optimizing ship performance through the development of green-ship or smart-ship technologies. A recent IMO study has indicated that ship route planning can achieve reductions in fuel consumption and the associated greenhouse gas emissions through technical and operational measures such as speed management and route planning. Related to these issues, a simultaneous optimization method of the direction and speed for ship route planning is proposed in this study. For this, an optimization problem for finding an optimal ship route is mathematically formulated considering fuel consumption and weather condition. The direction and speed of the ship are selected as design variables. The requirement on the estimated arrival of time and the avoidance of land are selected as constraints. And the minimization of fuel consumption is selected as one of objective functions. To solve this problem, the genetic algorithm is used as an optimization algorithm. To check the applicability of the proposed method, it is applied to various problems for ship route planning and compared with the results from existing methods and the commercial program. The results show that the proposed method is better than them in terms of fuel consumption.

**15.45-16.20** **IMPLEMENTATION OF STATISTICAL METHODS ON SHIP DATA FOR VESSEL SPEED MODELLING TO IDENTIFY THE ECONOMICAL RUNNING SPEED,** *Ibna Zaman, Kayvan Pazouki, Rose Norman, Shervin Younessi, Shirley Coleman, Newcastle University, UK.* Shipping is already a cost-effective mode of transportation for global trade but increasing the ship efficiency and reducing operational costs will bring further competitive advantage to ship operators. Smart sensor technology has been implemented in vessels for performance monitoring and optimisation. However, it is analysis of the resulting data and its synchronisation that are the key activities to monitoring performance. Due to the increase in fuel price and environmental legislation, the fleet operators are thinking about how to save fuel by managing speed. Just-in-time arrival into port is an important and common strategy to increase efficiency. The vessel speed must be properly tuned as part of this strategy otherwise, the financial benefit will be at risk. To get the maximum fuel efficiency, the operators need to maintain constant performance by implementing appropriate speed adjustments. An economical running speed algorithm (ECO Speed) has been developed by using statistical analysis of the ship data; adjustments to the speed are made based on a combination of historical and real-time reading of the ship data in different conditions. The ECO Speed system also gives information on the estimated fuel consumption, duration and CO2 emissions for an upcoming journey. This paper demonstrates how the statistical methods have been used to identify the economical speed and predict the fuel consumption for travel over a desired distance.

**16.20-** **GENERAL DISCUSSION**

International Conference

# Smart Ship Technology

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