A three-dimensional RANS method to numerically solve ship’s wave-making resistance compared with the Rankine source method

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According to the forming reason and classification of the hull resistance, this paper puts forward a three dimensional RANS method to solve the wave-making resistance. The obtained numerical results are compared with the results obtained from numerical program based on Rankine source boundary element method and the results obtained from Experimental fluid dynamics (EFD) method. The conclusion is drawn that the three dimensional RANS method matches well with EFD method, and its accuracy is higher than Rankine source method. From the results of the used methods it appears that the value of shape factor \((1 + k)\) for three dimensional RANS method is slightly increased with the increase of Froude number, the free surface wave system of three dimensional RANS conforms to the characteristics of the Kelvin wave system, the height of wave crest for three dimensional RANS method is bigger than Rankine source method, while the wave trough is lower, and the variation tendency of wave profile based on three dimensional RANS method is almost the same with Rankine Source method. The proposed method is proved to be appropriate for engineering application.

Keywords: Three dimensional RANS method, Rankine source method, EFD method, wave resistance, shape factor, wave pattern

1. Introduction

Resistance performance is of great importance among a vessel’s various performances (e.g. stability, sea keeping, maneuverability etc.). The prediction of hull resistance is always being the main research subject in ship engineering and academia for a long time. Especially, the description and simulation of free surface wave has been paid much attention.

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On the damping coefficient of laminated glass for yacht industry

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After a long period in which the most attractive characteristic of a motor yacht was represented by her maximum speed, nowadays the target has moved towards comfort on board which became the fundamental parameter to deal with in the yacht design process.

Noise and vibration, together with seakeeping behaviour, became the fundamental subjects on which the research effort of shipyards and technical offices turned on. Since many years the Department of Electrical, Electronic, Telecommunication Engineering and Naval Architecture (DITEN) is involved in a research on the dynamic behaviour prediction of large motor yachts in cooperation with one of the most important Italian shipyards. In this perspective the assessment of the dynamic properties of materials used for the vessel construction, such as the damping coefficient, is an important step to perform preliminary analyses for vibration and noise levels.

This paper is focused on the definition of the damping coefficient of laminated glass, which is a complex material commonly used for windows in the current yacht market. As a matter of fact the actual trend of using larger and larger windows for owner’s cabins and saloons could represent a critical point in terms of noise and vibrations and makes the laminated glass dynamic characterization a fundamental issue to be investigated.

Different experimental modal methods to obtain the damping coefficient at natural frequencies are applied to laminated glass specimens, while the Reverberation Time test is proposed to assess the coefficient in the whole frequency range of interest. In the final part of the paper, a comparison between the results of different methods is presented.

Keywords: Damping coefficient, laminated glass, dynamic structural analysis, yacht structures
Ship stability analysis during launching from longitudinal sloping slipway by pneumatic airbags

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The changing forces acting on a ship during launching from a longitudinally sloping slipway can be divided into four stages: the 1st stage — from beginning of ship movement until the launching runners or the ship’s aft end contacts the water; 2nd stage — from the end of 1st stage until the ship begins to float off the ways; 3rd stage — from the end of 2nd stage until the ship passes the slipway threshold and is fully afloat; 4th stage — from the end of 3rd stage until comes to a full stop. The biggest danger for a ship during the launch is the end of stage 2 and the beginning of stage 3, when tipping is possible as the ship rotates around the slipway threshold; also as the ship pivots on the slipway’s threshold there are large concentrated forces imparted on the forward section of the ship due to pivoting pressures (the difference between the mass of the ship and launching devices and the rising buoyancy). This paper presents, for the first time, a new analysis method of taking into account the possibility of a tanker tipping during launching on pneumatic airbags. Launching calculations and diagrams for both the traditional and pneumatic airbags launching are presented along with a comparative analysis of the two launching methods. The analysis showed that during launching using pneumatic airbags, float off begins earlier than during a traditional launch. This earlier float off does not increase the risk of tipping but does increase the pivoting pressure due to the increased buoyancy from the airbags.

Nomenclature

\( S \) the way passed by ship at the beginning of stage 2
\( W_c \) launching weight of the ship and launching device
\( V \) the volume of submerged hull part
\( \gamma \) specific gravity of the water
\( X_G, Z_G \) center of gravity coordinates
\( L_1 \) the length of forward runners part (from plane \( y'O'z' \) to aft perpendicular)
\( L_2 \) the length of back runners part (from plane \( y'O'z' \) to fore perpendicular)

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Prediction of ship power and speed performance based on RANS method

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This paper adopts virtual tank experimental technology to study ship rapidity performance. Based on RANS method, a new method is put forward to predict the speed and power performance of full scale ship. The open water performance of propeller model, the resistance performance of ship model and the self-propulsion performance of ship model are numerically calculated. Through the analysis of rapidity numerical results of fishing ship and the change law of wake flow field, some conclusions can be drawn. The numerical prediction accuracy of propeller open water efficiency has a direct influence on total thrust efficiency. The interference between hull, propeller and rudder leads to the formation of a lower pressure zone on stern hull surface and rudder surface. The axial velocity and radial velocity are affected by the interference between the flow of hull stern and propeller; the absolute value of axial velocity on blade leaf is smaller than that on blade back, and the radial velocity induces vortices on the blade tip of the propeller. The increase of propeller rotation speed nearly has no effect on the free surface wave pattern. The prediction results deviations of full scale ship speed and propeller rotation speed between RANS method and EFD method are 0.04 kn and 0.4 r/min, and therefore they are negligible. The proposed method can provide reference for engineering application.

Keywords: RANS method, EFD method, power performance, self-propulsion factor, speed prediction

1. Introduction

In the field of ship hydrodynamics, rapidity is a vital performance index. The prediction of power and speed performance of full scale ship is always an important study subject in the field of naval architecture and academia. The traditional prediction method of the power and speed performance of full scale ship is based on model test, including ship model resistance test, propeller model open water test and ship model self-propulsion test [15]. The primary advantages of traditional method
A numerical technique for sloshing in an independent type C LNG tank with experimental investigation and validation

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The sloshing induced by partial loading is violent when a resonance condition occurs. Given strong nonlinearity, rapid and accurate prediction of sloshing loads under resonance conditions is the key factor in the design of LNG (liquefied natural gas) cargo tanks. Therefore, a numerical technique based on CFD (computational fluid dynamics) technique was developed for sloshing simulations. Next, a series of physical tests were designed to validate its accuracy. Sloshing characteristics under resonance conditions is discussed experimentally by profiling the free surface and sloshing loads. The resonant test conditions were selected for simulations. Both the shape of the free surface and the sloshing pressure were compared with the test results. The computational model and parameters were also verified. It can be proven that based on reductions in the large computational expense, the numerical simulation has good accuracy for sloshing simulations.

Keywords: Sloshing, resonance, independent type C LNG tank, numerical simulation, experimental investigation

1. Introduction

In partially filled containers, under external excitation the presence of an unrestrained free surface may result in sloshing. This phenomenon is a source of concern in a number of engineering applications, such as naval architecture, aerospace, and civil and nuclear engineering, etc. The early research into sloshing started in aerospace. Given the consumption of fuel, the unrestrained free surface will affect the motion of the aircraft [1].

Because the sloshing phenomenon encompasses strong nonlinearity and randomness, an effective approach for research on sloshing is a model experiment, as it can
Introduction

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Green retrofitting through optimisation of hull-propulsion interaction

Energy saving has been a top priority for ship owners and operators for many years now. Despite fluctuating fuel prices, reducing the energy consumption of a ship remains financially attractive and has a positive impact on the environment and exhaust gas emissions. New design methods can be used for new built vessels to optimise the hull shape and the propeller, including optimisation of the hull – propeller interaction. For existing vessels changes in the hull shape are too costly, and Energy Saving Device (ESD) can be installed to optimise the hull – propeller interaction providing a potential fuel saving of several percent.

Over the past decades many ESDs have been developed with varying success. A limiting factor in the success of ESDs is the lack of validation data. In several applications model tests promised positive results while results of the full scale application were disappointing. Model testing a device operating in the boundary layer of the ship is subject to scale effects due to the difference in boundary layer between model and full scale.

With CFD calculation tools developing and computer capacity increasing, CFD evaluation of ESDs becomes a viable option. One of the mayor benefits of CFD is the possibility to study the local flow around ESDs accurately helping in the understanding of why certain ESDs work and others don’t. CFD furthermore supports the model tests as the calculations can be done for both model and full scale, giving insight into the scale effects on ESDs.

In order to study the working principles of ESDs, a consortium consisting of BV, CMT, Fincantieri, HSV, VICUS, Wartsila, Acciona, Imawis, Uljanik, CETENA and Arttic lead by MARIN, started the project GRIP supported by the European Commission under the 7th Framework Program. GRIP extensively studied the working principles of pre-swirl stators, pre-ducts, rudder bulbs and propeller boss cap fins. CFD analysis has been applied to these devices to study the working principles in details.

An Early Assessment Tool (EAT) was developed in GRIP by Wartsila and MARIN in which a first estimate of the fuel saving potential for different ESDs can be evaluated. Based on main ship dimensions and ESD type, a first principles calculation is
On the working principle of pre-swirl stators and on their application benefit and design targets

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BACKGROUND: In an early design stage of ship and propeller or in a propeller retrofit case one may consider a pre-swirl stator (PSS) to recover rotational energy.

OBJECTIVES: A model for the working principle of a PSS was to be developed and then to be applied for power saving estimates. This model should also support the PSS design procedure.

METHODS: The PSS 'working principle model' is based on a very fundamental quantity related to a propellers characteristic, namely the circulation distribution. An extended model addresses hub vortex contraction losses. In specific cases a BEM (Boundary Element Method) based propeller analysis is performed. To confirm actual PSS designs, a RANS/BEM coupling method is invoked.

RESULTS: Global parameters as $K_T$ and $C_{TH}$ rule the rotational losses of a propeller and determine the energy recovery potential of a PSS accordingly. The potential of a PSS is considerably enlarged, if it works properly against the hub vortex. Estimates for realistic power savings due to a PSS installation are 4-5% when the hub vortex suppression is included.

CONCLUSIONS: The simple PSS 'working principle model' delivers very reasonable predictions. RANS results and available full scale trial measurements can be reproduced using this approach.

Keywords: Energy saving device, propulsion, retrofit, propeller hub vortex, propeller rotational losses

Nomenclature

- $A$: Propeller disk area ($\pi R^2$)
- $C_{TH}$: Thrust Load Coefficient, $C_{TH} = T/(1/2\rho A R t^2)$
- $D$: Propeller diameter
- $R$: Propeller radius
- $T$: Propeller thrust
- $\Delta T$: Added thrust requirement of propeller in combination with an ideal pre-swirl stator

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Hydrodynamic design for mitigation of bubble sweep down in sonar mounted research vessels

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Oceanographic research vessels are fitted with acoustic sonar transducers at the bottom keel region. For a ship underway, atmospheric air gets mixed naturally with the surface water in the presence of wind and waves. Bubbles get entrapped in the region within the draft of the vessel and flow in the stream past the vessel. Literature records show that the bubbles are formed in the upper regions (made worse by the pitching motion) below the surface. When they flow immediately below and in the region of the sonar transducer resulting in bubble sweep-down phenomenon, they directly interfere with the acoustic transmission and deteriorate the functioning of the sonar transducer. Degradation of performance of the acoustic transducer seriously limits the mission capability of the vessel. This is a major concern and there is no complete remedy as of date, for the avoidance of the bubble formation in the flow stream. This paper describes a hydrodynamic re-design approach for the hull geometry in the forward region and the creation of an effective bubble diverter bow. A new modified bow form is investigated to help in deflecting the streamlines away from the location of the sonar transducer. The strategy in the approach here is to design the bow region to control hydrodynamic flow such that the bubbles-entrapped water of the upper surface layers is strategically diverted to flow side-ways of the hull or at the bottom side-ways well away from the location of the sonar transducer. Numerical flow simulations for the developed hull form using CFD tools demonstrate that the streamlines can be effectively thus diverted without degradation of the performance of the sonar transducer. The strategy for the hull form design is evolved by parametric variation of the side-shape using computer aided surface generation tools. The parameters influencing drag as well as diversion of the streamlines are the length parameter of the bubble diverter bow at side, the cross-sectional area parameter at a pre-defined section at the forward and the wetted surface parameter of the bubble diverter bow. The beneficial effect of the bubble diverter bow is to be weighed against increased hull resistance. The validation studies include simulation of the flow and drag assessment and comparison from towing tank tests as well. Three hull forms are created and the streamlines traces are studied in these cases respectively. The results demonstrate that a minor re-design of the forward sides of the hull form can drastically minimize the bubble streamline interference at the sonar transducer without penalty on the resistance. A major breakthrough is offered in the mitigation of bubble sweep down by the new design.

Keywords: Bubble sweep-down, oceanographic research vessel, bubble diverter bow, acoustic transducer, streamline trace
Efficient retrofitting of vessels by using simulation tools and reverse engineering technologies

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The technological advancement in the equipment used in ships and emission restrictions from the classification societies forces the ship owners to periodically perform retrofitting on their ships. Therefore, ship owners today plan to utilise the docking downtime of a ship at a shipyard to its maximum potential. During this docking period in the shipyard, they would plan to perform all the retrofitting activities as well as any maintenance activities required for the ship equipment. In order to execute all the activities within the minimum downtime, a thorough and careful planning of the activities is required. With the ship under continuous operation before its docking at the shipyard, it could be possible that all the required documents for planning activities are not available for the shipyards. In order to tackle this problem, in the European Commission (EC) funded project GRIP – Green Retrofitting through Improved Propulsion, the use of Simulation Tools and Reverse Engineering was executed and tested, and so to perform the retrofitting activities more effectively and efficiently. Of the different Green technologies accessed by the GRIP Consortium, the retrofitting of Pre-Swirl Stator Fins was selected as the prototype study for testing and validating the Simulation Tools and Reverse Engineering Technologies proposed in GRIP. Tools developed in the Simulation Toolkit for Shipbuilders (STS) and newly developed planning tool anteSIM were used by CMT to perform simulation of retrofitting activities and thereby provide planning recommendations to the shipyard. IMAWIS used Laser Scanning as the Reverse Engineering technologies studied in the project to perform measurements and dimensional accuracy comparison after the assembly process of the Pre-Swirl Stator Fins. The methodologies and results from the execution of the Simulation Tools and Reverse Engineering Technology are satisfactory in order to provide beneficial recommendations for efficient planning of retrofitting activities in the shipyards.

Keywords: Retrofit, laser scanning, production simulation
ESD design and analysis for a validation bulk carrier

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In this paper the hydrodynamic design procedure for Energy Saving Devices (ESDs) developed in the FP7 EU project GRIP is applied to full scale validation vessel - a newly built handymax Bulk carrier by Uljanik shipyard in Croatia. Three ESDs such as a Pre-Swirl Stator, a Pre Duct and a Rudder Bulb have been designed for this ship by three partners - HSVA, MARIN and VICUS respectively. From the three ESD designs that were submitted, the most promising alternative was selected via a thoroughly performed cross check by all participating partners. For the ESD selection, the hydrodynamic performance of the ESD is the most but not the only important factor; other aspects, such as cavitation risk, structural, manufacture and installation aspects have also been considered, but will not be covered in this paper. The finally selected ESD was HSVA’s Pre-Swirl Stator, which has been developed further and successfully tested during the trials of the full scale ship. In this paper only the conceptual design of PSS during the ESD hydrodynamic design phase and the results of the cross check which has been performed for the selection of ESDs will be presented.

Keywords: Energy saving device, ESD, pre-swirl stator, PSS, CFD, RANS-BEM coupling, full scale, hub vortex, cavitation reduction, parametric model, retrofit, hydrodynamic design

1. Introduction

The European 7th framework project GRIP (Green Retrofitting through Improved Propulsion) addresses the urgent need from industry for installing ESD solutions for existing ships. The high demand for retrofitting is driven largely by four factors: the reduction of CO2 emissions, the fluctuating high fuel prices, effective regulations and the lifetime extension of existing ships. However, it remains highly uncertain whether these devices actually improve the performance of the complete hull-propeller system, and if so why. Some devices showed great promise in model tests, but failed in full-scale validations. For other devices, manufacturers claim proof of large improvements on real-size ships, but these claims cannot be verified by independent

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Evaluation of an energy saving device via validation speed/power trials and full scale CFD investigation

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Energy saving devices (ESD)s designed to improve the propulsive efficiency of a ship are often designed and validated using CFD tools and model tests. Evaluation at full scale is however still required to understand extrapolation methods and scale effects. This paper describes the evaluation of an ESD by means of dedicated speed/power trials just prior and directly after the installation of the device in dry dock. The energy saving device is in the form of three stator fins located at the port side just ahead of the propeller creating a pre-swirl in the flow into the propeller which reduces rotational losses of the propulsion. The stator was build and retrofitted by Uljanik shipyard in Croatia on a new build 52,000 DWT bulk carrier. Trials were done prior and after retrofitting of the ESD in almost ideal weather conditions. Comparison of the trial results revealed a fuel saving effect of 6.8% in power. Cavitation observations of the stator and propeller showed a removal of the cavitating hub vortex of the propeller after the installation of the fins. This can be detected and confirmed in the CFD computations as well. Full scale CFD investigation employing the RANS-BEM coupling method to simulate the propeller effect gives a power saving of more than 5%, which is in good agreement with the trial results. The geometry used in the CFD simulation is based on the 3D in-situ geometry measured via laser scan technique after the retrofitting of the fins.

Keywords: Pre-swirl stator, PSS, energy saving device, ESD, trial analysis, trial uncertainty, sensitivity analysis, CFD validation, full scale, RANS-BEM coupling method, hub vortex, cavitation reduction

Nomenclature

BEM Boundary Element Method
BF Beaufort wind scale
CFD Computational Fluid Dynamics
DGPS Differential Global Positioning System
ESD Energy Saving Device

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Influence of ESD on neighbouring hull outfitting

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BACKGROUND: Within GRIP, ESD (Energy Saving Device(s)) are installed on existing vessels. Installation of an ESD can influence the neighbouring hull outfitting elements.

OBJECTIVES: The influence of ESD installation on the hull outfitting elements have been investigated.

METHODS: The classification rules have been studied to identify all parameters and subjects that could be influenced by installation of an ESD. A selection of subjects is further investigated to provide an estimation of the magnitude of the impact. Five example ESD's have been investigated. The influence on the neighbouring hull outfitting elements has been determined by comparison of results of hydrodynamic calculations without and with an ESD.

RESULTS: The possible effects of an ESD on the requirements according class rules (overview table). For selected subjects, the magnitude of influence is defined in relation to the change of a directly influenced parameter. For the example cases, the influence on the neighbouring hull outfitting elements and on propeller cavitation behaviour has been reported.

CONCLUSIONS: Installation of an ESD affects indeed the neighbouring hull outfitting elements and their compliance with class rules in certain cases. The possible effects of an ESD on the compliance to class rules requirements are summarized in Table 1. Most significant impact can be expected for up-stream installed ESD and ESD directly mounted on the propeller. The addition of an ESD to a propeller has a linear influence on torsional frequency and stress as well as whirling frequency, bearing load and misalignment. Adding 10% MOI (of total propeller MOI) results in 3% decrease of torsional frequency, 10% increase of torsional stress, decrease of 2.5% of natural critical whirling speed. Addition of 10% mass results in a decrease of 1.7% of critical whirling speed. The influence of an ESD on alignment are shown in Table 3.

Keywords: Efficiency, influence, classification rules, energy, ESD, PBCF, whirling, TVC, alignment

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ESD design for a validation bulk carrier

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The FP7 project GRIP deals with Energy Saving Devices (ESDs). These are devices placed in front, or aft of the propeller with the aim to reduce the fuel consumption of the vessel. VICUS has worked on a hydrodynamic design procedure and had the opportunity to apply it to a validation vessel: a new-build handymax Bulk carrier by Uljanik shipyard in Croatia. VICUS has selected a downstream device, named Rudder Bulb, for this application case: it is positioned aft of the propeller and allows for a reduction of the rotational energy of the outflow. Two other partners within GRIP have also been developing their own methodology for the hydrodynamic design of an ESD. MARIN have worked on a Pre-Duct and HSVA on a Pre-Swirl Stator. Each partner has designed its ESD according to its own procedure for the Uljanik bulk carrier. From these three ESD, a cross check was carried out in order to select the device that will be manufactured on the full scale vessel. HSVA’s Pre-Swirl Stator was chosen and was been installed on the UlJ vessel. Full scale trials were carried out on the vessel, giving satisfactory results (see (Xing-Kaeding ISP (2015)) and (Hasselaar and Xing-Kaeding, ISP (2015))). In this paper, only the procedures employed by VICUS for the Rudder Bulb design as well as the results of the cross check are presented.

Keywords: Energy saving device, ESD, pre-swirl stator, PSS, pre-duct, rudder bulb, CFD, RANS-BEM coupling, frozen rotor, sliding interface, full scale, model scale, hub vortex, cavitation reduction, parametric model

1. Introduction

Naval architects and designers are always looking for ship improvements in order to reduce fuel consumption of a vessel and its impact on the environment. The FP7 project GRIP (Green Retrofitting through Improved Propulsion) focused on the propulsion of the vessel, with the aim to investigate devices, Energy Saving Devices (ESDs), which can be retrofitted to the stern of the vessel in order to improve the propeller efficiency and by this, reduce the required propulsion power. ESDs have been analysed and classified in different categories such as downstream devices (aft of the propeller) and upstream devices (in front of the propeller). A methodology for
Early assessment of ESD benefit

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One of the first stages during the evaluation of the viability of an Energy Saving Devices (ESDs) for existing ships is a global scan of the field of application, performance and the required investment. Based on this preliminary data the Return on Investment (RoI) for an ESD retrofit can be estimated, which is a key figure in decision making processes. To this end an Early Assessment Tool (EAT) is developed, containing a database of reliable performance data, a patent database, a benefit tool, cost model and an economical tool.

The EAT is compatible with container vessels, bulk carriers, tankers, ferries/RoPax vessels and short sea shipping cargo vessels. Integrated ESDs are the pre duct, pre swirl stator, PBCF, rudder fin, rudder bulb-hub cap system, ducts surrounding the propeller, hull fin and the combination of a pre duct and pre swirl stator.

The benefit tool calculates the power reduction at a given sailing mode by application of a specific ESD type. The cost tool determines approximate ESD costs, broken down into design, material and installation costs. The economical tool combines output from the benefit and cost tools and calculates the RoI.

A web-based EAT for public use and an extensive EAT for project members have been created.

Keywords: Early Assessment Tool, EAT, iEAT, Energy Saving Device, ESD, Literature, Cost Tool, Benefit Tool, Return on Investment, RoI, Quaestor

List of Symbols

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{EEGI}$</td>
<td>Specific CO₂ emission per nautical mile</td>
</tr>
<tr>
<td>$\text{FCF}$</td>
<td>Fuel conversion factor ($&lt;3.11$ for HFO)</td>
</tr>
<tr>
<td>$k$</td>
<td>Constant depending on the ship type</td>
</tr>
<tr>
<td>$\text{NCR}$</td>
<td>Main engine's Nominal Continuous Rating</td>
</tr>
<tr>
<td>$P$</td>
<td>Power requirement of the vessel</td>
</tr>
<tr>
<td>$\text{SFOC}$</td>
<td>Main engine’s Specific Fuel Oil Consumption</td>
</tr>
<tr>
<td>$V$</td>
<td>Vessel speed</td>
</tr>
<tr>
<td>$V_{\text{NCR}}$</td>
<td>Vessel speed at NCR power</td>
</tr>
<tr>
<td>$\Delta$</td>
<td>Displacement of the ship</td>
</tr>
</tbody>
</table>

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Hydrodynamic working principles of Energy Saving Devices in ship propulsion systems

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Throughout the years, many types of Energy Saving Devices (ESDs) have been introduced to the naval industry, each claiming to achieve several percent of power reduction. Although their commercial success is undeniable, there has always been much controversy regarding the assumed working principles of ESDs. Therefore, the basis of this paper is a comprehensive explanation of the hydrodynamic working mechanism of an Energy Saving Device known as the Blade efficiency improving Stator Duct (BSD). Using knowledge of this working principle, an alternative way of analysing propulsion efficiency dedicated to pre-swirl devices has been developed. The working mechanism of the BSD and the assessment of its performance is subsequently demonstrated at model scale by means of RANS simulations.

Another topic of discussion regarding ESDs are the scaling procedures used in model testing to predict the full scale performance, which possibly lead to exaggerated claims. The scale effect on the performance of the BSD is therefore addressed in the final part of this paper, also based on numerical simulations.

Keywords: Energy saving, propulsion improvement, working principle, propulsion efficiency, scale effects

1. Introduction

1.1. Background

For more than 35 years, Energy Saving Devices (ESDs) have been designed, tested and built to improve the fuel efficiency of ships. Especially during the second oil crisis, new ESDs were rapidly introduced to the market. After the eighties, as the world economy recovered and the oil prices dropped, interest in ESDs slowly diminished, partially due the absence of clear evidence regarding their working principles and performance. However, reducing fuel consumption in the current challenging world economy, the restrictions regarding engine power with the upcoming EEDI regulat-
ESD structural issue – UPstream device

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BACKGROUND: In order to design an Energy Saving Device (ESD), shipyards need to know the forces applied on the structure.
OBJECTIVES: The objective is to develop a methodology able to evaluate the forces applied on an ESD in navigation conditions.
METHODS: From existing hydrodynamic potential codes, such as HydroStar, and tools developed by Bureau Veritas, the forces applied on an ESD have been evaluated and the methodology has been tested on a Pre-Swirl Stator structure.
RESULTS: The design process for an ESD has been described and tested including static analysis, dynamic analysis and fatigue analysis.
CONCLUSIONS: The forces applied on an ESD can be estimated following a design process and a methodology developed in GRIP.
Keywords: Energy saving device, Pre-Swirl Stator, angle of attack, fins, force, lift, drag, ship motions

1. Introduction

Nowadays, the Energy Saving Device (ESD) structure is not reviewed by classification societies. Only its attachment to the hull is considered. From a safety point of view, it is important to demonstrate that the ESD does not represent any hazard for the structural element on which it is mounted and for other neighboring hull outfitting.

The main challenge is to evaluate the loads applied on the ESD structure in sailing conditions, because the regulations give no guidance to validate its design. In order to estimate these dynamic loads, Bureau Veritas has developed a methodology to define the maximum forces expected to be applied on an ESD for given wave conditions and return period.

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