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Energy Saving in Ship Operation

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ABSTRACT

It Around 90% of world trade is carried by the international shipping industry. Without shipping the import and export of goods on the scale necessary for the modern world would not be possible. Seaborne trade continues to expand, bringing benefits for consumers across the world through competitive freight costs. Thanks to the growing efficiency of shipping as a mode of transport and increased economic liberalization, the prospects for the industry's further growth continue to be strong. There are over 50,000 merchant ships trading internationally, transporting every kind of cargo. The world fleet is registered in over 150 nations, and manned by over a million seafarers of virtually every nationality. Today shipping faces strategic challenges: escalating energy costs and impact on climate change. The common challenges are the industry's reliance on fossil fuels. The fuel cost represents the most significant cost item when operating a vessel (46% of the operating cost - standard Panamax containership) hence it is necessary to find alternate and Clean source of energy to power ship and operate.
Keywords: Ship Operation, Energy Management, Biodiesel, DME, Biogas, LNG, Methanol, Fluo-Dynamics

I. INTRODUCTION

The research of better efficiency measures will concern all areas of energy loss. Breakthrough solutions are needed in hull, propulsion and auxiliary domains whilst not forgetting the important areas of overall ship operation and energy management.

Two important aspects should need to be taken into consideration: Efficiency measures differ according to the type and the operational profile of the vessel; Measures for increasing efficiency are generally not cumulative.

This highlights the important role of a ship designer who has to choose and integrates different possible technological solutions for the best overall performance of a ship.

Promising areas of the research that can assist to meet the strategic goals could address:

Hull: Developments of Computer Fluo-Dynamics tools for eco-efficient design in order to innovate and optimise hull forms for multi-mission operational profiles; new molecules for hull treatment reducing resistance and combining anti-fouling properties; viscous resistance reduction identifying new laminar hulls concepts; wave-ship motion optimization; advanced hull designs for inland / shallow water navigation; and next generation propulsions. This section addresses issues related to the basic hull form design including selecting proper proportions, reducing resistance by optimizing the hull form and appendage design, and assessing the impact on resistance of waves and wind.

Materials: Breakthroughs are expected regarding the use of lightweight / higher strength composite materials (e.g. metal foamed sandwich) and the relevant joining techniques.

Engine: Combustion optimization of marine engines (injection timing, compression ratio, fuel spray geometry, etc.); alternative fuels (LNG, methanol, ethanol, DME, biodiesel and biogas); renewable energy propulsion (wind, sea and solar power); fuel cells running on hydrogen as auxiliary propulsion power; and in a longer term vision a diverse fuel mix adoption, with LNG, biogas, batteries and hydrogen produced from renewable sources. This section looks at the efficiency gains that are possible in the design and operation of the ship's machinery and systems. It covers main and auxiliary diesel engines, waste heat recovery and other auxiliary equipment.

Fuel Efficiency of Ships in Service The final section addresses operational measures that can reduce fuel consumption. These include voyage performance management, hull and propeller condition management, optimum ship systems operation and overall energy efficiency management. Overall ship operation and energy management: innovative solutions are expected for the monitoring, control and automation suitable to optimise the energy use on board permitting cost efficient operations in different vessel conditions.

Introduction : Methods for using a ship's propeller as a power absorption dynamometer employ the propeller as a measuring instrument to estimate either water speed or shaft power. The resulting propeller model can be used to detect hull fouling while comparing ship performance against a standard "clean-hull" baseline.

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Introduction Ship operators realize that hull fouling causes drag-related speed loss and increases fuel consumption when additional power is required to maintain service speeds. The wasted energy due fouling-related losses can be substantial but have historically been difficult to quantify, sinc changing ship and environmental conditions cause high variability in performance data. This is a method of separating out these effects and using a ship's propeller as a tool for early detection of hull fouling (as explained by Bose, N. and S. Molloy in "Reliability and Accuracy of Ship Powering Performance Extrapolation", Power Required to Overcome Resistance is defined as

$$P=c\ Rt\ v$$

Where P = Power
C = constant
Rt = Total Resistance
V = Speed through water

The following components are commonly considered to comprise total calm-water resistance, RT:
1) frictional resistance 2) wave-making resistance
3) eddy resistance 4) air resistance

Additional resistance will come into play when a ship experiences heavy weather and considerable research has been performed to quantify these effects. Carlton (2008) references some of these techniques, but in general, most practical methods for estimating weather-related resistance rely on model testing, either for deriving regression equations or empirical correction factors. Recent Resistance Modeling One of the most recently published works describing the practice of ship performance monitoring can be found in Aas-Hansen (2011). Although newly published, the book describes the decades-old, traditional approach of attempting to quantify the effects of hull and propeller fouling by first removing or correcting for all other factors that affect ship resistance, including those previously mentioned (i.e. wind, waves, etc.). The book describes detailed mathematical models founded on known principals of naval architecture and previous experimental work by several researchers, but lacks information regarding the expected accuracy of ship performance predictions based on these techniques. In a recent study of the economic impact of hull fouling for the US Navy Schultz, Bendick, Holm, and Hertel (2011), resistance models were used for predictions of full-scale ship resistance based on scale-model tank test measurements and similarity law analysis Schultz (2007). 2.4 Inconsistencies with Resistance Approaches Because not all researchers include the same components of resistance in their work, the power prediction results are inconsistent. Typically, a separate model is developed for each included resistance component, but component interaction effects are largely ignored. Resistance models developed by many researchers remain unvalidated against actual ships. The correlation allowance is essentially a correction factor applied to align power factors that affect propeller slip include:

• Draft • Trim • Propeller pitch (for ships with controllable pitch propellers (CPP) • Current • Weather-induced ship motions • Rudder-induced ship motions • Operating transients (rapid power and speed changes) • Hull and propeller fouling.

Table 1. Various performance measuring areas

Ship Performance Data		
Description	Source	Unit
Ship Speed	GPS	KTS
Ship Heading	GPS	Degree
Wind Speed	Anemometer	(K/M/N)
Wind Angle	Anemometer	Degrees
Shaft Torque	Torque Meter	FT-LBS
Shaft Rpm	Sensor	RPM
Pitch Propeller	Ship Sensor	Degrees
Engine Bhp	Engine Sensor	BHP
Engine Fuel Consumption	Engine Sensor	Gal /HR
Forward Draft	Ship Data	Metres
Aft Draft	Ship Data	Metres
Sea State	Weather condition	Beaufort number
Sea Direction	Weather condition	Degrees

II. METHODOLOGY

Ship performance monitoring traditionally has been a complex subject, requiring knowledge of naval architecture, marine engineering, mathematics, statistics, and more recently, computer science. In the past, a major constraint impacting analysis accuracy has been data quality, typically based on manually and infrequently recorded data. This has restricted the use of well-proven statistical methods dependent on large sample sizes. With the modern automation systems installed on today's vessels, these constraints have become less restrictive. High speed data acquisition, low-cost computers, and advanced database technology are now at the practitioner's disposal to eliminate past barriers to accurately measuring hull and propeller performance.

Methods for using a ship's propeller as a speed or power measuring device were established at least eighty years ago, but were not highly publicized. The unique characteristics of these methods are their simplicity, high accuracy, and their use of actual ship performance data, instead of scale models. The propeller model can be used to track speed loss and power /fuel increase over time using metrics that are easily understood by both ship crews and their management counterparts. Beyond this, propeller power absorption techniques can also be employed for optimizing other aspects of ship operational efficiency, such as quantifying draft, trim, and weather effects on fuel economy. In conclusion, rising fuel costs, hull maintenance expenses, and mounting environmental regulations make hull condition monitoring a cost-effective tool for prudent ship operators to eliminate energy waste due to hull fouling, reduce carbon emissions, eliminate the carriage of invasive species between ports, and impartially assess hull coating effectiveness.([15] Ship Design and Performance for master and mates –Dr C.B Barrass) Summary & Conclusions Hull fouling can impact ship schedule, fuel expense, and, in severe cases, overload propulsion engines and increase their maintenance cost. A growing number of international environmental regulations have come into effect relating to greenhouse gas emissions and the carriage of aquatic invasive species on fouled ship hulls. More regulations are likely to come in the future.

All ship owners are aware of these factors. However; ship performance losses due to hull and propeller fouling are difficult to quantify as inputs to techno-economic models of optimal ship operations. Changing ship and environmental conditions cause performance variations that make the separation of hull and propeller effects a difficult task. From a business standpoint, prevention of marine growth through the use of an effective anti-fouling paint is an obvious choice, but selecting the best paint for a given ship's operating profile is not so obvious. Almost all paint companies promote similar fuel savings with their products. An industry trend has developed whereby paint companies offer performance guarantees under the stipulation that their approved ship performance system is used to quantify savings. In some cases, the ship performance analysis methods employed are not transparent and rely on undefined and unproven "correction" factors. An easily-understood and accurate hull monitoring capability can guarantee an impartial assessment of the effectiveness of competing hull coatings, while detecting hull fouling at the earliest stage to save fuel. Ship performance monitoring traditionally has been a complex subject, requiring knowledge of naval architecture, marine engineering, mathematics, statistics, and more recently, computer science. In the past, a major constraint impacting analysis accuracy has been data quality, typically based on manually and infrequently recorded data. This has restricted the use of well-proven statistical methods dependent on large sample sizes. With themodern automation systems installed on today's vessels, these constraints have become less restrictive. High speed data acquisition, low-cost computers, and advanced database technology are now at the practitioner's disposal to eliminate past barriers to accurately measuring hull and propeller performance. Methods for using a ship's propeller as a speed or power measuring device were established at least eighty years ago, but were not highly publicized. (Newswave)

The unique characteristics of these methods are their simplicity, high accuracy, and their use of actual ship performance data, instead of scale models. The propeller model can be used to track speed loss and power /fuel increase over time using metrics that are easily understood by both ship crews and their management counterparts. Beyond this, propeller power absorption techniques can also be employed for optimizing other aspects of ship operational efficiency, such as quantifying draft, trim, and weather effects on fuel economy. In conclusion, rising fuel costs, hull maintenance expenses, and mounting environmental regulations make hull condition monitoring a cost-effective tool for prudent ship operators to eliminate energy waste due to hull fouling, reduce carbon emissions, eliminate the carriage of invasive species between ports, and impartially assess hull coating effectiveness.(Hydrex Group, "Clean Ship Hulls and Ports - Without Compromise)

Energy Saving can be done in many ways, some important areas where Energy Saving can be done is illustrated in below figure.

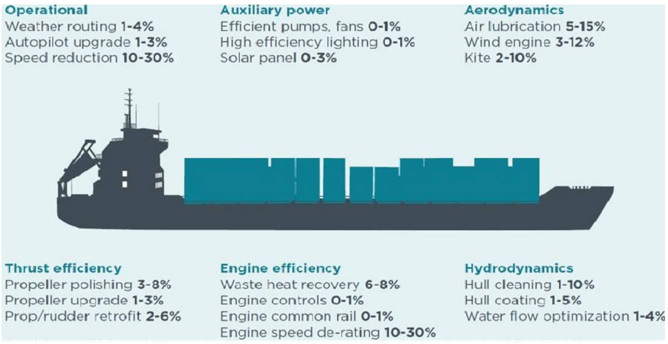

Figure 1. Potential Fuel use and CO2 reduction from various energy Efficiency Approaches for Ship - International Council on clean transport July 2013.

Types of Resistances

Wave-Making Resistance: belongs to the category of normal dynamic pressures. Due to these dynamic pressures waves are generated on the surface of water and spread away from a ship. Waves possess energy. Thus a ship making waves means a loss of its energy. Wave-making resistance is important to surface ships, especially those of high speeds, but may be negligible to submarines.

Frictional Resistance: arising due to the viscosity of water, i.e. tangential stresses. Because of viscosity & velocity gradient in the direction normal to the ship hull, there is a mass of fluid being dragged along with a ship. Energy necessary to drag the mass of fluid is the work done by the ship against the frictional resistance.

Eddy-making Resistance: contributed from normal pressure applied on a hull. Due to the viscosity of the fluid, the flow separates from the surface of a hull and eddies (vortices) are formed. These eddies induce the changes in the velocity field and thus change the normal pressures on a hull. The changes in the pressure field around a ship result in the eddy-making resistance.
Air resistance (mainly resulting from wind resistance).
Appendage resistances: are caused by the appendages of a ship, such as propellers, rudders and bilge keels.

Frictional Resistance

Laminar and Turbulent Flow.

Laminar flow: the fluid appears to move by the sliding of laminations of the infinitesimal thickness relative to adjacent layers. Turbulent flow: is characterized by fluctuations in velocity at all points of the flow field and these fluctuations with no definite frequency. Whether a flow is laminar or turbulent flow depends mainly on its Reynolds #. For a plate flow. ([17])

Influence of Roughness of a plate on CF

The formulas for computing CF are applied to the flat plates with smooth surface. The rough surface (of a ship) will result in the increase of CF. Roughness (on the surface of a hull) may be Classified into 3 types.

1) Structural roughness: caused by welded joints, warviness of shell plating on the hull. A newly-built ship will have (for Schoenherr formula).
2) Corrosion
3) Fouling: caused by the attachment of marine organisms such as seaweeds, shells and barnacles.
4) Corrosion & fouling occur for ships having sailed for a certain period of time. They will decrease the velocity of the ship. Ship owner will decide when the ship should go to the dock for cleaning.

What are Hull Fouling /Bio – FOULING?

The Accumulation of Marine Growth on underside and sides of ships. Their types depends upon temperature and water quality .these are of types Shell, weed, Slime. Shell Species such as barnacles and Mussels .weed such as seaweed and Brown weed. Slime caused by Accumulation of Algae.

DATA ANALYSIS

Using the high precision data collected from the sensors and onboard systems, processes the collected data and applies state-of-the art modelling techniques that enable to identify all the energy consuming elements that make up the total propulsion energy consumption on board a vessel. Only by identifying and isolating the amount of energy consumed by different factors (trim, sea state, wind speed and direction, water depth and possible squat, the rudder angle, hull and propeller fouling) collectively known as Dynamic Sea Margin, are we able to identify the amount of energy lost on these factors due to suboptimal operations.

Fouling is one of the most difficult factors to quantify accurately because the energy changes due to the build-up of frictional resistance are slow, as there is a large number of highly variable measurements, as well as a range of affecting factors to consider.

Figure 2. Ship Automation System Data Collection for Analysis

FOULING For the purposes of this study hull fouling includes biofouling as well as the ageing and degradation of the hull and coating. Biofouling is the settlement and accumulation of micro-organisms, plants, algae and even animals on an underwater surface. The organisms usually attach and form in areas of the hull where sunlight can reach, which is why significant growth is rarely found on the flat bottom of a ship. Fouling can be further divided into to two basic forms, micro (slime and weed) and macro fouling - larger organisms (Lewthwaite, J.C.; Molland, A.F.; Thomas, K.W. An Investigation into the Variation of Ship Skin Frictional Resistance with Fouling)

The rate of accumulation of fouling depends on factors such as geographical location, temperature of the water, nutrients in the water and seawater salinity and water depth. In addition, the quality and type of underwater coating as well as operation of the vessel has an influence on fouling. The wide range of factors that influence fouling condition of the hull are summarized in Figure below (Ship Knowledge –K Vondokkum)

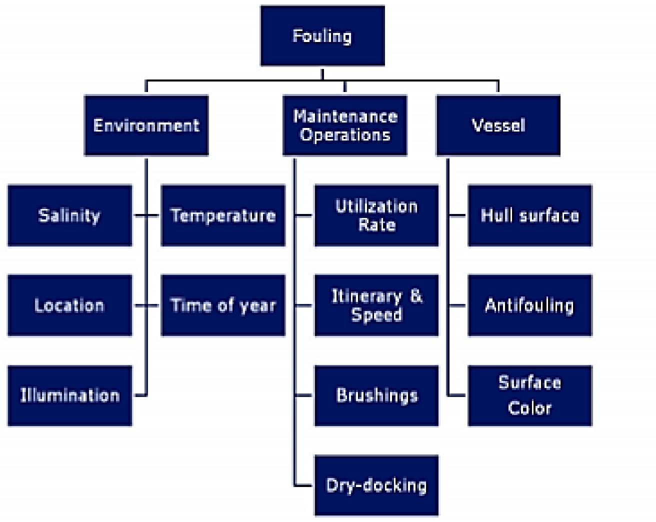

Figure 3. Various Factor affecting Fouling

III. REVIEW RESEARCH WORK:

Reduction of fuel cost, which increased incredibly in the recent past, and with an expectation of further increases Compliance with ongoing and future regulations Protection of the environment Preparedness to comply with possible future IMO initiatives i.e. Market Based Instruments (Styhre, L. and Winnes, H. (2013), Energy efficient shipping)

Excellent ship design, optimal trim and speed, use of alternative fuels such as gas (LNG and CNG), focus on energy efficiency, fuel consumption monitoring and analysis will help our customers to improve their ships' performance.

Ships characterized by a good energy saving and efficiency performance are attractive to stakeholders too, thanks to the decrease of harmful and greenhouse gas emissions [23] (Johnson, H. and L. Styhre (2013), Increased energy efficiency in short sea shipping through increased port efficiency, in manuscript.)

A fouled hull leads to increased frictional resistance which results in loss of speed or increased fuel consumption (in order to maintain speed and schedules). Fouling may cause the coating system to deteriorate; leading to premature corrosion of the hull. This, together with an increased frictional drag has both an economic and environmental impact on the ship's operations. According to MEPC Assessment, even a small amount of fouling can lead to an increase of fuel consumption of up to 40%, due to the increased resistance to movement. A clean ship can sail faster and with less energy.

High bunker costs and increased environmental regulations are forcing operators of all vessel types to search for ways to monitor fouling conditions and cost-effectively counteract its effect [24] (Woods Hole Oceanografic Institute. Marine Fouling and Its Prevention)This topic is gaining increasing amounts of attention throughout the industry. A recent report from the Clean Shipping Coalition (CSC), which was submitted for consideration to the MEPC 63/4/8 in 2011, estimated that over a typical 4 to 5 year sailing interval, inadequate hull and propeller performance could be reducing the efficiency of the entire world's fleet by 15-20%. For ships travelling at normal speeds, this equates to a directly proportionate increase in bunker consumption and GHG emissions.

Typically, the deterioration that occurs in hull and propeller performance between dry-dockings is mainly the result of biological fouling and mechanical damage. Regular hull cleaning and propeller polishing can assist in negating these effects between dry dockings depending on hull coating. In the past, many of the coatings that were used were themselves harmful to the marine environment. The IMO's International Convention on the Control of Harmful Anti-fouling Systems on ships, came into force in 2008; and prohibits the use of harmful elements in anti-fouling paints.

The IMO and Governments also recognize that some areas need additional protection, the Baltic Sea, Alaska and certain coastal areas for example. These are known as Emission Control Areas (ECAs) or Particularly Sensitive Sea Areas (PSSAs) which are deemed to require a higher degree of protection because of their particular significance for ecological or scientific reasons, and because they may be vulnerable to damage by international maritime activities (ENIRAM Hull Fouling Study)

Benefits of energy management
Fuel savings
Reduced emissions
A complete operational overview
Decision support
Reliable and clear reports
Operational history
Voyage tracking
Reduction of fuel consumption
Monitoring of cylinder load
Reduction of CO_2, NO_X and SO_X
Reduction of maintenance costs and improved planning of maintenance Reduced risk for engine damage ((CMA-CGM Press)) [27]

Moving towards a culture of energy efficiency

International shipping is a complex industry and multi-stakeholder action is required to realize the optimum energy-efficiency gains that are achievable, in order to move towards a sustainable and more energy efficient operation of maritime transport.

IV. RESULT ANALYSIS

Fuel Saving per Day after Hull Cleaning is different for different ship and depends on type and size of ship for average handymax Tanker ship around 1.88 Ton per Day. Ship Fuel Cost which is known as Bunker is Calculated in Base Currency of USD and Various Prices Based on Port and Market. At Major Port Cost is Around 300 USD Per Ton of Bunker Port Includes (Rotterdam, Fujairah, Singapore) Thus Cost Saving Per Day is Around 600 Usd for Fuel Saving and Hull Cleaning Operation which also Depends on Port and Based Currency for Operation is in usd cost will be around 8000 usd . Thus Cost of operation will be recovered in first 15 days of fuel saving.

Hull cleaning intervals

The optimum interval between the periodic cleanings and inspections that comprise a preventive maintenance program will vary with the type of vessel, the location of the vessel, and its service profile (speed of operation, idle time, etc.). The type and condition of bottom coatings will also have an effect on the cleaning interval. Large vessels typically have several layers of coatings, up to 6 millimeters thick, and generally operate 4 to 6 months between hull cleanings. The location of the vessel also has a substantial influence on the rate of fouling since marine organisms flourish in warm tropical waters. The U.S. Navy has established geographic fouling zones, indicating the frequency with which the hull and unpainted surfaces (propellers, rudders, and sonar domes) should be cleaned for vessels operating within each geographic zone. Propeller cleaning is recommended up to six times a year and hull cleaning is recommended up to three times a year.

V. CONCLUSION

Emission of greenhouse gases (GHG) such as carbon dioxide (CO2) and nitrous oxides (NOx) as well as pollutants such as sulfur oxides (Sox) into the earth's atmosphere by the burning of fossil fuels to drive ships. While other aspects of ships and shipping play their own part in this environmental concern, a key factor is the underwater ship hull. This is subject to biofouling, as micro-organisms and vegetable and animal matter naturally attach to a ship's hull. If not dealt with effectively, this can lead to three main sources of damage to the environment:

Excellent ship design, optimal trim and speed, use of alternative fuels such as gas (LNG and CNG), focus on energy efficiency, fuel consumption monitoring and analysis will help our customers to improve their ships' performance.

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