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HISMAR - UNDERWATER HULL INSPECTION AND CLEANING SYSTEM AS A TOOL FOR SHIP PROPULSION SYSTEM PERFORMANCE INCREASE

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Abstract

The cost of ship operation is dominated by the cost of fuel. The efficiency of ship propulsion depends on number of parameters. After selection of the most important we can further analyze them for taking relevant action to increase the ship propulsion efficiency. Biofouling of underwater part of ship's hull has direct influence on vessel resistance and engines power required to maintain the speed or keep optimal fuel consumption. HISMAR is a name of the project directed on development of robotic system that can be used to introduce new approach to keep ship hull clean and almost free of bio-fouling. Frequent cleaning using HISMAR robotic system could be a new tool to increase ship performance as well as conduct specific types of ship hull surveys underwater. New approach for inspection and cleaning needs field research to validate the financial and technical benefits.
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Keywords : *underwater cleaning, robotic system, underwater inspection, ship propulsion, efficiency*

1. Introduction

We observe continuous growth both the global and EU shipping fleet. When speaking about the measures that can be taken to improve the shipping efficiency one of major issues is hull performance increase by the reduction of the wave and frictional resistance and increase of propulsion system efficiency. Whilst shipping is one of the cleanest forms of transportation, the fouling of ships reduces efficiency, increases fuel consumption and in extreme cases - corrosion. To minimize wave drag, special attention is given the smooth ship hull design and construction quality. The numerous efforts focus on frictional drag reduction using not only computational techniques. Modern anti-fouling paints and special low friction coatings are another large area of investment into research and achieved spectacular performance. When speaking about the increasing efficiency of the propulsor system there is a number of another opportunities like new highly efficient diesel engines, advanced propeller designs as well as promoted by some companies propeller coating techniques that prevent biofouling. Some guidelines and draft data regardding potential savings due to lowering of fuel consumption can be found in technical literature. An example taken from data collected by Wartsila is presented in Table 1. The important comment to that table is that, there is very limited amount of data available that could be referenced as being confirmed by measurements at real sea conditions. Bearing that in mind, when using such data for calculation of potential savings we have to treat that figures as guidance. More detailed data can be collected during research on ship performance using real object data gathered during ship operation. This is quite complex task and will need certain financial resources and positive approach from ship operators to collect and validate the data with assistance of ship crew.

Table 1. Estimated savings due to selected measures applied to various types of ships

Ship Type	Tanker	Container	Ro-Ro	Ferry
Efficiency measures				
Hull clearing	< 3%	< 2%	< 2%	< 2%
Propeller clearing and polishing	<10%	<10%	<10%	<10%
Modern hull coatings	< 9%	< 9%	< 5%	< 3%
Propeller efficiency measurement	< 2%	< 2%	< 2%	< 2%
Constant versus variable speed operation	< 5%	< 5%	< 5%	< 5%

Source: Wartsila [1]

It is obvious, that machinery that operates for longer time and at higher power and loading is more susceptible to failures. Lower engine loading in general means lower wearing of certain components of ship drive system that could lead to longer operational life of the ship propulsion. Furthermore, it results in better reliability of the main propulsion and resulting ship safety improvement - particularly important for tankers, bulkcarriers, ro-ro and passenger ships. Monitoring of the ship hull condition for estimation of fouling or coating roughness measurements when coupled with means for cost effective ship hull cleaning (an example could be HISMAR system), could be valuable operational tool that could be used for ships in operation. Such procedure could be a part of more complex propulsion efficiency audits being a part of modern ship hull survey procedures.

2. Environmental and legal aspects

There is ongoing discussion at International Marine Organisation (IMO) with regard to Marpol Annex V (Regulations for the Prevention of Pollution by Garbage from Ships). IMO has already defined the residue from hull scrubbing as ships waste and it is therefore covered by the convention. As a consequence of this, it is likely that restrictions will be introduced as to where and how ship hulls may be scrubbed. The scrubbing of hulls by divers is forbidden within many European harbours. Fouling on a hull increases a ship’s drag through the water, thus increasing the amount of power required to maintain the same speed or reducing the speed of the vessel for a given power. Fundamental data on that subject can be found in reference [2]. It is estimated that serious fouling can increase the drag on a ship by up to 40%, reducing the speed by up to 2 knots and increasing the fuel consumption by 10÷20% [3]. For the shipping industry, this means increased costs and time delays. The extra fuel consumption also increases greenhouse gas emissions, being composed of NOx, SOx and CO_2 from ships by up to 20 million tonnes per annum. Although shipping produces the least amount of greenhouse gases annually when compared to other modes of transportation, under the Kyoto agreement the EU is committed to a 5% reduction in emissions by 2012.

3. Underwater ship hull cleaning -- advantages and tools

For over 130 years people have thought about machines or robots for cleaning ship hulls. Various devices and technology has been developed and tested. Only few developments have found wider application, an example could be hydraulic brush system operated by diver (BrushCart). In recent years, we are observing growing interest in robotic system that are developed to cope with the bigger ships and eliminate diver's presence underwater. Important issue is stress on marine ecology requirements. Robots are able to cope with that case using suitable tools. However, the investment in robotic system may be substantially high, such system will be able to work continuously underwater and possibly above the water where divers do not have access. Plug in sensor modules could allow to conduct detailed inspection of the almost whole hull during the same mission.

3.1 Brush technology

Brushes are used in cleaning carts, handheld polishers and some robotic systems and are able to cope with almost all types of fouling. Most systems consist of one or more rotating brushes pneumatically, or hydraulically driven. This requires the minimum of equipment beyond the cleaning device itself thus reducing the cost of the system. Before the ban on tributyltin (TBT) came in, brush technology was preferred to underwater jetting systems, as it was easier and more economical to use. However, the increase in use of environmentally friendly low friction coatings can cause a problem, as these coatings are less durable and more easily damaged by the abrasive action of the brushes. Research has shown that bristle density, angle and gauge have a greater effect on shear and normal forces produced by brushes, while the brush speed and stand-off distance has little or no effect. The main point demonstrated by the research was the selection of the brush cleaning system and forces involved is dependant on a number of factors and their relationship is very complex. The major problems in cleaning using heavy duty brushes could have place when dealing with calcerous forms of fouling.

3.2 Water jetting technology

The use of high pressure water jets has become an accepted alternative to brush cleaning systems. Unlike the brush-based systems, water jets can be easily controlled by reducing or increasing the pressure from the pump. A water jet's effectiveness is dependant on the surface, pressure of water, jetting angle and distance from the cleaning surface. Jet nozzles, such as CaviJet or SwirlJet have been developed to enable effective cleaning of the hull underwater.
Tests using cavitating water jet nozzles showed that the cleaning process can remove various types of fouling from hull coatings, while at the same time, minimizing the damage to the coating. Although jet washing provides increased control of the cleaning process, the perceived increase in the cost of the equipment is still thought to be prohibitive. In hase of the HISMAR system low pressure jetting will be sufficient to remove effectively and safely the layer of slime from the hull surface.

4. Cleaning problems

Diver(s) presence enhances the risk of diving accidents at work. Some data revealed by HSE show that probability of diver accidents during professional diving operation is higher than in farming or civil engineering. The number of accidents in offshore and inshore diving is in a range 20-40 for 100000 dives while fatal accidents occur in number of 6-7 for 100000 dives. Additionally to the risky job, diver has limited time to be able to work underwater so a team of divers is required to perform cleaning task. An open issue is the cost of diver safety measures and environment protection requirements that must be taken into consideration discussing the cost benefits. Remotely controlled machines are not able to clean the whole wetted ship surface due to some hull features that restrict the robot operation. Ship bow and stern, due to hull shape are very difficult for automatic cleaning and that area will probably be cleaned by divers. Generally it is assumed that cleaning of 80% of the ship underwater area from slimes could provide suitable effect of drag reduction.

5. HISMAR idea

The abbreviation HISMAR stands for **H**ull **I**dentification **S**ystem for **M**aritime **A**utonomous **R**obotics. HISMAR is intended to be a multifunctional robotic platform which will be able to perform specific inspection or maintenance tasks such as structural integrity monitoring of the ship's hull or cleaning operations. Apart from Project leader - Newcastle University, the other partners in the project were Graal Tech of Genoa; the UK's Shipbuilders and Shiprepairers Association; TecnoVeritas of Portugal; Polski Rejestr Statków; Robosoft of France; Carnival; Moscow State Technological University; Royal Thai Navy and TEPAC Technology & Patent-Consulting of Germany.

Robotic platform is to be deployed for the board of the ship, harbour service craft or from the pier using simple care or special launching and retrieval device. The control over the vehicle is provided via the special umbilical with power, control lines and hoses used for removal of cleaning wastes to the surface. Intervention with the use of HISMAR robot needs some preparation before the vehicle is placed on the surface of the ship hull. The desired situation is the case when digital data of the ship hull construction are provided to the robot control computer. On the other hand, at start of the job a map of the hull is automatically charted, recording the location of every weld, thickness change, rivet and indentation on the ship's surface. Adjustable jets of pressurised sea water blast the marine growth off the surface of the ship which is then sucked up into the main chamber. Here, ca 150 litres of water a minute is filtered and the bio-fouling removed and rendered harmless to the local environment. In this way, the ship's robotic 'vacuum' can continuously roam the ship's hull, preventing the build up the layer of slime.

Hull surveying is an important part of any vessel's life span and a number of periodic inspections of the hull are required during the vessel's life. Currently, the minimum requirement is for a visual inspection of the hull and with some thickness measurements being taken in specific areas of the hull, or where a probable defect might have occurred. These are usually performed using an ultrasonic sensory system that is placed on the plate's surface. Due to the size of the detection head and the skill required to operate the equipment, only a small proportion of a vessel's hull can be accurately measured. A full hull inspection is required to be performed in dry dock every five years, but up to 20% of the hull may not be inspected due to the vessel's dock supports. Between these class renewal inspections, intermediate hull inspections are required. These are general visual underwater inspections performed by divers. However, in recent years a number of robots have been developed to improve the accuracy, coverage and reliability, while reducing the time and cost of the inspection. The current robotic systems available are limited to visual inspection and ultrasonic plate thickness measurements.

6. The critical components of the HISMAR Robotic Platform

The HISMAR robot design is presented in Fig 1 and 2. The key systems of the robot include:

Drive Systems & Central Robotic Platform

Key to the HISMAR robotic platform is the versatile central drive module. This incorporates the robot's drive systems, navigational sensor systems and control electronics. Robot is linked with the surface by a mean of specialised umbilical that contain power and data conductors and possibly hydraulic hoses for removal of cleaning debris.

Cleaning & Debris Extraction Systems

The cleaning system will utilize a water jetting to clean the hull. The jet spray system is intended to provide the customer with sufficient control for their cleaning needs while preventing damage to the hull coatings. A complete extraction and waste handling system is to be developed to comply with current and future marine environmental legislation.

Mapping & Navigation Systems

HISMAR's unique mapping and navigation system will allow for full autonomy of the robot after the initial process of mapping the hull. This will allow for complete or partial cleaning of a ship's hull, the latter being complete at the crew's convenience with no loss of operating time. The map will be a permanent record of the condition of the ship's hull, being updated by the navigational system whenever a cleaning operation is performed.

7. HISMAR robotic system advantages

Marine growth on ships is a huge environmental and financial problem for the marine industry and HISMAR offers a unique solution to both of these — and more. Created is a system that works totally independently — in or out of the water — and not only keeps the ship clean but also feeds back vital information about the hull's condition. Because the map it follows is so detailed, if there is a change to its path caused by corrosion or a crack in the steel then it feeds this information back. This means it can be used as an additional check the condition of ship's hull and provide important reference data for classification society surveyors. All other developed cleaning or inspection systems currently available are remotely controlled during their operation, requiring highly skilled and experienced operators to effectively clean the hull, while the ship is out of operation and usually in dry dock. The advantage of the HISMAR robot is that it is an autonomous system so it can continue cleaning with the ship remaining in service.

The platform can be launched whenever the vessel is in port or at anchor. The device will be able to complete its tasks partially whilst in one port and be re-launched at successive points to complete the task. The generic platform will offer the option of using targeted plug-in modules to perform specific inspection or maintenance tasks such as structural integrity monitoring of the ships hull or carrying out cleaning and waste recovery operations. This project offers a means to effectively and efficiently undertake hull inspection and maintenance thereby extending the safe working life of the vessel. Cleaning of the hull ensures the vessel maintains the lowest possible hydrodynamic resistance and consequently reduces amount of fuel oil consumed. Therefore ensuring a clean and smooth vessel underwater hull surface reduces vessel emissions and reduces operating costs.

8. Validation of fuel consumption data and effectiveness of cleaning

There is noticeable amount of published data providing general information about cleaning benefits but only few data available that provide reliable figures of possible savings due to periodical cleaning of the ship hulls. A very optimistic diagram that presents possible advantages from cleaning ship hull is given in Fig. 3. Some companies are offering advisory optimization services of vessel performance and in some cases also hull cleaning underwater using hydraulic tools. Up to our knowledge, only one company is using specialized ROV system and no reliable commercial or scientific data regarding its performance are available.

Taking decision about cleaning requires certain data to be analyzed. US Navy underwater husbandry practice requires the decision to be taken after underwater inspection and precise estimation of the area covered by fouling after comparison with reference data. Other commercial practice requires analysis of periodically collected voyage data as well as basic data about the prime mover operation like – rpm, specific heating value of fuel oil, fuel oil consumption, power measured by special device or torsiometer, turbocharger revolutions, exhaust gas temperature – just as example. In that case, the collected data are subject of evaluation using dedicated software by commercial company on a subscription basis. In case of some ships and sea routs potential savings are big enough to pay for kind of ship services..

9. Conclusions

The use of remotely controlled technology for underwater cleaning is subject of numerous R&D activities. Commercially available devices are not cheap and the cleaning in dry dock is much more popular and usually coupled with class surveys. Prime target for robotic tool is to achieve performance and cost of operation at the competitive level. Hull cleaning by cost-effective robotic devices that are able to cope with slime will limit fouling and lower the fuel consumption. The use of intelligent crawling underwater robots will expand as there will be more comparable data available describing ship propulsion performance increase as a result of more frequent robotic cleaning. Collection of reliable data about the financial and technical benefits of the robotic cleaning technology will be important for independent assessment of ship propulsion system performance. Plate thickness measurements and other data describing ship hull condition that will be collected by robot during cleaning missions could be further used by classification societies for class renewal surveys. The hull surveying using innovative robotic technology is in development phase and needs additional founds to be recognized as mature technique recommended for wider use.

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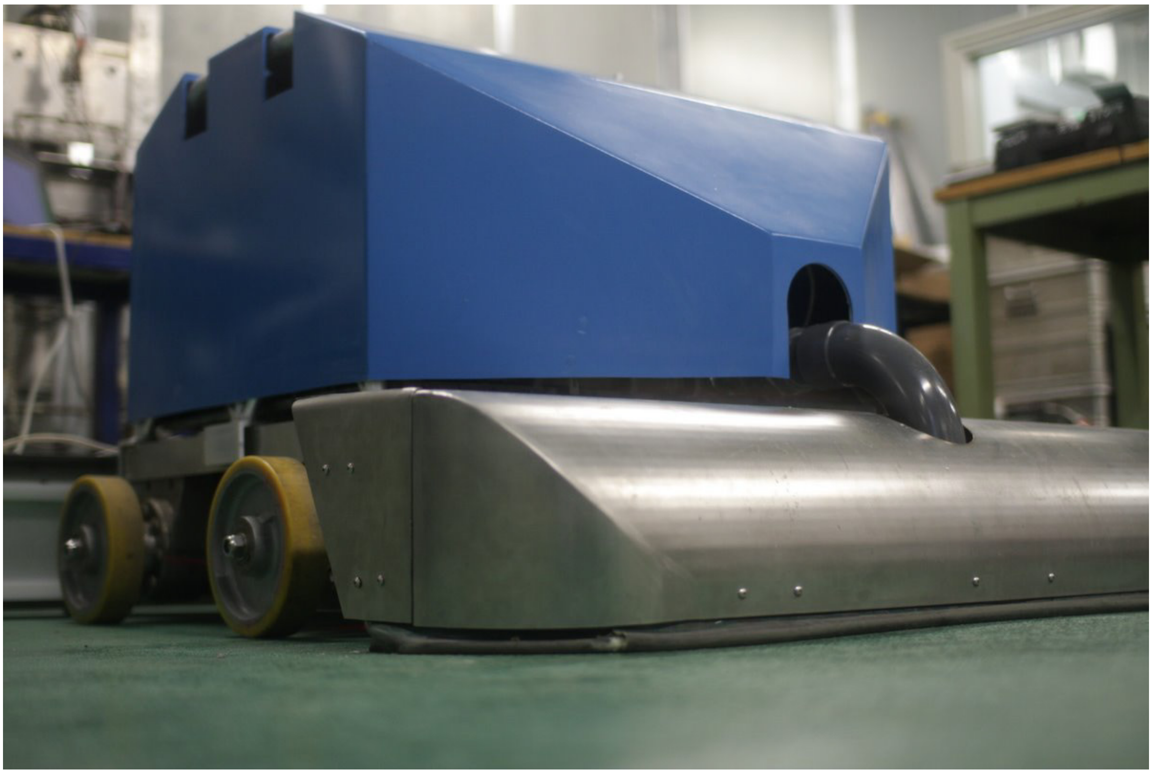
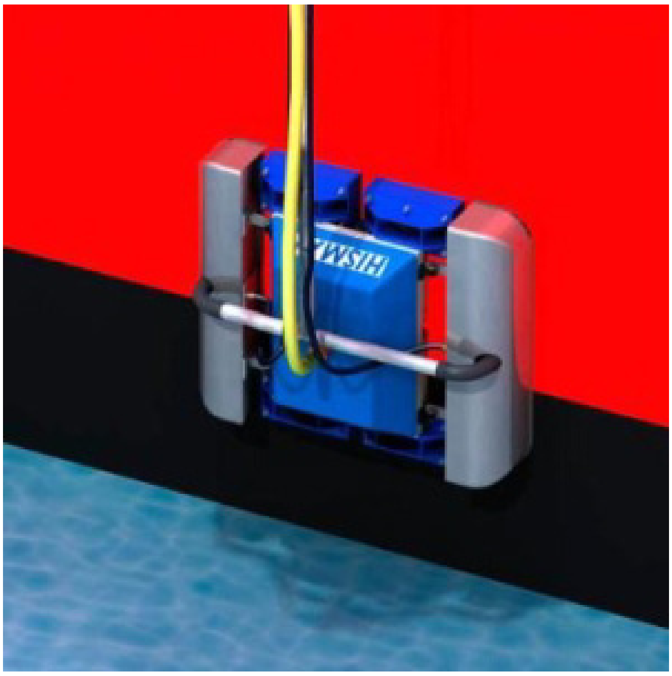


Fig, 1 General view of HISMAR robot prototype



Fig, 2 General view of HISMAR robotic platform

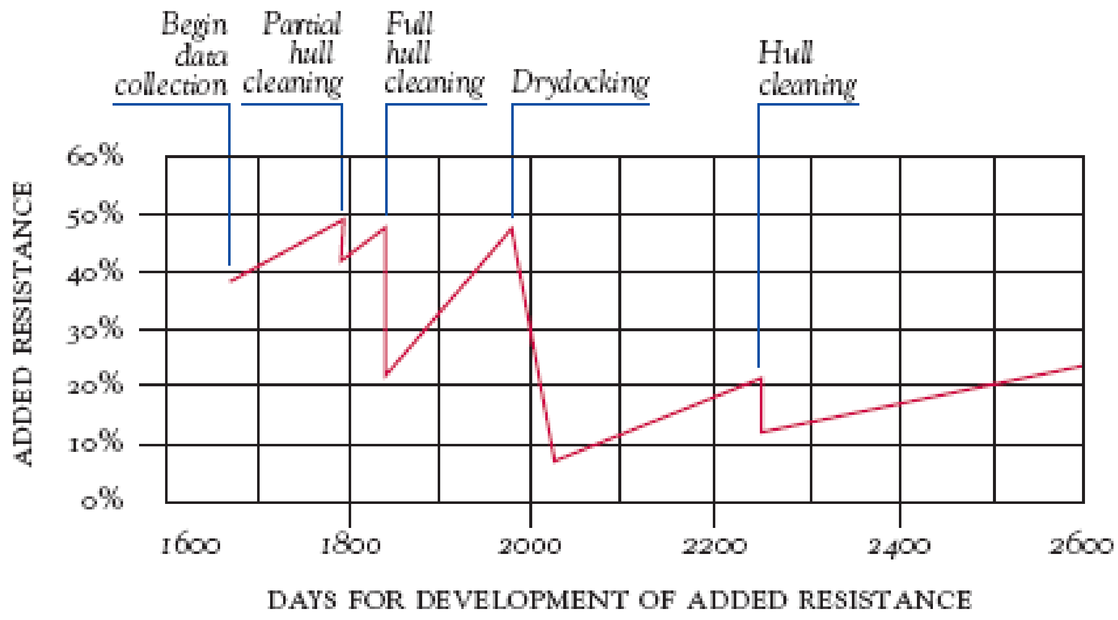


Fig. 3 Long term development of hull and propeller resistance [2]

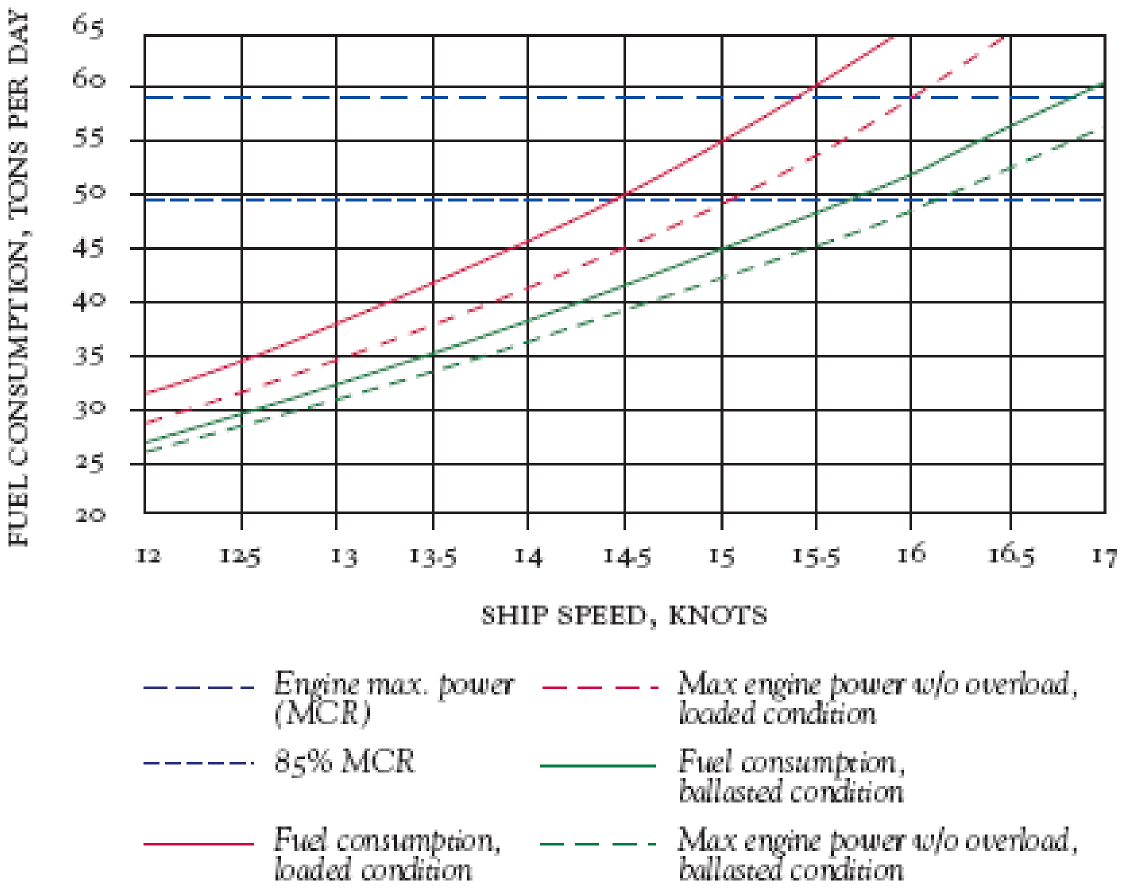


Fig. 4. Vessel performance in comparison to sea trials [2]