INCREASING OPERATIONAL EFFICIENCY OF HIGH SPEED RO-RO VESSELS VIA NEW HULL COATING TECHNOLOGIES

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Abstract

The purpose of this study is to review results of new hull coating technologies for high speed RO-RO vessels and analyze the potentials to decrease fuel consumption as well as speed loss. In maritime economics, the fuel consumption of ships accounts for the important part of operational expenses and it is straight forward that every ship owner would aim to run their fleet as optimum as possible in terms of fuel efficiency. IMO has developed the Energy Efficiency Operational Indicator (EEOI) that provides information concerning the efficiency of the ships in operation where fuel consumption is the main criteria for the calculation. The reduction of fuel consumption through decreased frictional resistance of hull is one of the most well-known method in maritime industry to increase operational efficiency of ships. Ship operators are generally making their decisions according to real-life experiences. It is clear that literature needs further studies regarding hull performances with the real-life data even if there will be higher uncertainties compared to laboratory test results. In this study, actual field data of 8 high speed RO-RO vessels has been studied according to the new standard ISO 19030 - Ships and marine technology, Measurement of the changes in hull and propeller performance. Results indicate the importance of full blasting for hull performance and a significant fuel savings through decreased speed loss via new technology foul release silicone coatings.

Keywords – Fuel consumption, Antifouling coating technologies, speed loss, high speed Ro-Ro vessels

1. Introduction

The reduction of fuel consumption and fuel costs through keeping ship's hull as smooth as possible is one of the most known method in maritime industry to increase operational efficiency of ships. Increased hull roughness leads to increased frictional resistance, causing higher fuel consumption and GHG emissions. The best method to reduce frictional resistance is to apply a treatment to a ship's hull, to minimize its physical and biological roughness.

Antifouling coatings are the most effective solutions to avoid fouling and help to keep hull performance as better as possible. Demirel et al. (2013) state that antifouling coatings are the primary protective measure to mitigate marine bio fouling and surface roughness on ship’s hulls. $60 billion of fuel saving, 384 million tones reduction in carbon dioxide and 3,6 million tones reduction in Sulphur dioxide emissions are estimated to be provided by the use of antifouling coatings.

There are technologies and solutions on the market undertaking to protect the hull and maintain good performance over the full duration of the docking interval. So, even there are available products and plenty of methods in the market, why is then hull and propeller performance still so poor? Which coating is best for which ship types or under which working conditions? Or is there any coating performs well under all conditions? These questions are still valid and still there isn’t any clear reply even plenty of research carried out by producers and academicians.

On the other side, what is the problem and approach for the final user, i.e. ship operator? Also, problem for them to make decision to select correct antifouling technology for their fleet is going on and repeats again on every dry-docking cycle when new application will be applied.

According to Soyland and Oftedahl (2016) the problem has been a lack of measurability. You can't manage what you can't measure is an old management adage that is still accurate today. Now a multitude of measurement methods is being introduced in the market; but there has not been a specific standard of hull and propeller performance measurement method until ISO 19030 released. Previous studies have been carried out to determine the impact of antifouling coatings by laboratory tests of coated cylindrical or flat panels, CFD computer modelling tests, coated rotor tests, chemical comparisons or adhesions tests.

It was not easy for analyzers to reach real life data from ships due to most of the ships did not have required measurement tools like torque meters and sensors, any data logging system to keep records, any useful and systematic recorded data to analyze in respect of hull and propeller performance. Also, uncertainty was well high for the data received from ships in respect to human error or equipment errors. To the best of our knowledge, only Corbett (2010) and his friends worked on real data from ships with a subject of "Energy and GHG Emissions Savings Analysis of Fluoropolymer Foul Release Hull Coating". They compared results of Self Polishing Copolymer coating and Fluoropolymer Foul Release coating which were applied to 7 new built vessels, one tanker, one bulker and 5 sister container vessels.

It is clear that the related literature needs more studies regarding antifouling coating performances or hull and propeller performances with the real field data even there will be higher uncertainties when compared with laboratory test results. In order to fill the gap here, we studied a high-speed Ro-Ro fleet which has 11 sister vessels all built in the same shipyard in Germany with the same technical properties, working under the same operational conditions between the same ports in Mediterranean Sea since 2000.

In respect to the importance of hull performance on fuel costs, the Ro-Ro Company wanted to create efficiency via using new hull coating technologies and to define the best antifouling coating technology for high speed Ro-Ro vessels. Thus, the company decided to apply different type of new hull coating technologies to each sister vessel and measure the results of reference and evaluation periods of different applications.

All vessels have been coated with 1st type of self-polishing coatings at the beginning then tested with different type of new technology antifouling (self-polishing or foul release) coatings. Then results of reference and evaluation periods are compared in respect to speed loss and fuel efficiency according to the methodology described in ISO 19030 part 3. It is not possible fully comply with the ISO 19030 due collected data and collection period is different, but is tried to carry out analysis according ISO 19030 as practicable as possible.

2. IS0 19030 Ships and Maritime Technology, Measurement of Changes in Hull and Propeller Performance

The aim of this International Standard is to prescribe practical methods for measuring changes in ship specific hull and propeller performance and to define a set of relevant performance indicators for hull and propeller maintenance, repair, retrofit activities.

Measurements of ship specific changes in hull and propeller performance can be used in a number of relevant performance indicators to determine the effectiveness of hull and propeller maintenance, repair and retrofit activities. There are 4 performance indicators defined in ISO 19030. These are Dry-docking Performance, In-service Performance, Maintenance trigger and Maintenance effect. The performance value, PV, is defined as the percentage speed loss compared to a reference speed-power relation.

3. Data and Methodology

Application and test of new technology hull coatings to specified Ro-Ro Fleet started in 2013, 10 vessels docked until July 2014, 8 of them completed their first docking cycle with test application and docked again in 2015 and 2016, which we achieved performance of complete docking cycle on these vessel's results.

Reason of selecting these 8 high-speed sister Ro-Ro vessels listed below:

- All vessels built in the same shipyard with same technical properties, only there were some changes with the generations regarding the built date
- All vessels had the same technology SPC antifouling coating at the beginning
- All vessels have used the same fuel oil from same supplier during test period
- All vessels have been loaded with the same type of cargo (trucks and trailers)
- All vessels have been operated by the same technical management with same planned maintenance system
- All vessels have been maintained with only genuine spare parts during their engine overhauls and routine maintenance activities.
- All test vessels traded between the same ports in Mediterranean Sea.

Table 1. Dry-docking History of Test vessels

		DDn-1	DDn	DDn+1
VESSEL 1	Date of Drydock	4.05.2011	11.11.2013	13.08.2016
	Shipyard	BESIKTAS	BESIKTAS	SEFINE
	Blasting	SPOT	FULL	%10 sweep blasting
	Hull Coating	Self Polishing Coating 1	Foul Release Coating 1	Foul Release Coating 1
	Engine Overhaul	NO	NO	Both Engine 90.000 Hours overhaul Completed
VESSEL 2	Date of Drydock	17.08.2011	10.06.2014	17.01.2017
	Shipyard	BESIKTAS	BESIKTAS	SEFINE
	Blasting	SPOT	FULL	%10 sweep blasting
	Hull Coating	Self Polishing Coating 1	Foul Release Coating 1	Foul Release Coating 1
	Engine Overhaul	NO	NO	Both Engine 90.000 Hours overhaul Completed
VESSEL 3	Date of Drydock	8.04.2010	22.01.2013	29.03.2015
	Shipyard	BESIKTAS	GEMAK	GEMAK
	Blasting	SPOT	SPOT	FULL
	Hull Coating	Self Polishing Coating 1	Self Polishing Coating 1	Foul Release Coating 2
	Engine Overhaul	NO	NO	NO
VESSEL 4	Date of Drydock	29.06.2010	5.05.2013	16.05.2015
	Shipyard	BESIKTAS	GEMAK	BESIKTAS
	Blasting	SPOT	FULL	FULL
	Hull Coating	Self Polishing Coating 1	Self Polishing Coating 2	Foul Release Coating 1
	Engine Overhaul	NO	NO	NO
VESSEL 5	Date of Drydock	30.08.2010	27.07.2013	2.06.2015
	Shipyard	BESIKTAS	BESIKTAS	BESIKTAS
	Blasting	SPOT	FLAT BOTTOM FULL, VERTICAL SIDES SPOT	FULL
	Hull Coating	Self Polishing Coating 1	Self Polishing Coating 3	Foul Release Coating 2
	Engine Overhaul	NO	NO	NO
VESSEL 6	Date of Drydock	22.04.2010	8.03.2013	9.10.2015
	Shipyard	BESIKTAS	GEMAK	BESIKTAS
	Blasting	SPOT	SPOT	FULL
	Hull Coating	Self Polishing Coating 1	Self Polishing Coating 1	Foul Release Coating 1
	Engine Overhaul	NO	NO	NO
	Other			KAPPEL PROPELLER MODIFICATION
VESSEL 7	Date of Drydock	4.02.2012	31.05.2013	28.04.2016
	Shipyard	BESIKTAS	BESIKTAS	SEFINE
	Blasting	SPOT	SPOT	SPOT
	Hull Coating	Self Polishing Coating 1	Self Polishing Coating 1	Self Polishing Coating 4
	Engine Overhaul	NO	NO	NO
VESSEL 8	Date of Drydock	17.08.2011	28.08.2013	31.03.2016
	Shipyard	GEMAK	BESIKTAS	BESIKTAS
	Blasting	SPOT	SPOT	FULL
	Hull Coating	Self Polishing Coating 1	Self Polishing Coating 5	Foul Release Coating 1
	Engine Overhaul	NO	NO	Both Engine 45.000 hours overhaul completed.
	Other			CLT PROPELLER MODIFICATION

The following procedure is applied to understand if there is any significant improvement of speed loss and fuel consumption reduction by using new technology hull coatings:

1- Detailed tables are created as raw data for all test vessels from the company's official arrival, departure, and noon and Energy Efficiency Operational Index reports. Only data of the voyages completed in normal conditions included in the analysis. Any voyage which had any engine failure or any unexpected delay on schedule, were not included.

2- Raw data is filtered with +- 5% for displacement of model test or working displacement according actual data of test vessel, if the model test displacement does not fit with it. Any data for any voyage which is in not limit, not included.

3- The SFOC reference curve based on actual shop tests of the specific engine in question, was already corrected in shop test report for environmental factors as per ISO 3046-1:2002. Then it is also corrected for normal fuel of 42700 kJ/kg and the new SFOC curve is issued.

4- Delivered power of one engine is approximated for each data point based on calculations of brake power, P_B from an engine specific SFOC reference curve defined in Annex D of Part 2 of the standard.

5- Delivered power is multiplied by 2 to find total power of both engines

6- Model test predictions are available for 18557.6 tons Displacement. For all vessels, a correction factor is applied to Speed-Power curve according to ITTC displacement correction methodology.

7- Expected speed is calculated for each data point from a speed-power reference curve at the corrected delivered power of both engines.

8- Percentage speed loss which is defined as Performance Value in the ISO19030 is calculated for every data point in the corrected data set.

9- The average percentage speed loss over the Reference period(s) is calculated.

10- The average percentage speed loss over the Evaluation period is calculated.

11- Differences between the average percentage speed loss of the Reference period and the Evaluation period are calculated. The change in the average speed loss in the Reference period(s) and the average speed loss in the evaluation period is defined as performance indicator.

12- In order to evaluate changes on fuel consumption, average fuel consumption per hour value of Reference and Evaluation periods is calculated from the data set.

13- Due to Fuel consumption being effected by speed, fuel consumption of evaluation period is normalized based on average speed of reference period.

14 – Student t-test is used to check if the calculated differences were significant.

The limitations and assumptions related with the research are as follows:

- Methodology explained in the International Standard ISO 19030-Measurements of changes in hull and propeller performance, Part 3 is taken as a reference and tried to be used in this study as practicable as possible.
- Sample fleet is not fitted with Torque meter, therefore delivered power is calculated from fuel consumption. The model test result of the ship and engine acceptance test result are explained as in Part 3 of the International Standard.
- As all vessels are sisters with the same technical properties and working under the same operational conditions and due to data of high number of voyages has been observed which is covering nearly all seasons of the year, it is assumed that, all vessels have the same weather conditions as wind and sea states.

4. Findings

Actual field data of Ro-Ro fleet used in this study. Data of reference periods and evaluation periods described in ISO 19030 compared to measure and evaluate hull performance. 2 different technology of foul release coatings and 5 different technology of self-polishing coatings tested.

4 vessels used as a control sample to evaluate what would be result if self-polishing coatings applied to spot blasted hull. Table 2 presents results of these vessels together. Results indicated that, if hull spot blasted and self-polishing coating applied, hull performance goes worst after first year to next drydock. Fuel consumption increases dramatically and speed of vessel decreases. Therefore, full blasting is very critical for maintaining hull performance and avoiding increase of fuel consumption.

Table 2. Performance of self-polishing coated and spot blasted vessels

SELF POLISHING COATING + SPOT BLASTING APPLIED VESSELS' PERFORMANCE				
	Comparison of last year before and first year after dry-dock		In-service Performance	
	Speed Loss %	*Fuel Consumption mt/hr*	*Speed Loss %*	*Fuel Consumption mt/hr*
VESSEL 3	-0,84%	3,57%	-2,87%	13,80%
VESSEL 6	1,33%	-5,82%	-3,70%	17,88%
VESSEL 7	0,12%	-0,54%	-3,10%	15,13%
VESSEL 8	-1,43%	6,38%	-2,65%	13,13%
Average	-0,20%	0,90%	-3,08%	14,99%

Vessel 4 was the best test vessel where self-polishing coating and foul release coating applied with full blasting at consecutive dry-dockings in 2013 and 2015. It was possible to separate additional effect of foul release coating on individual ship. She sailed 2 years with fully blasted and self-polishing coating applied hull, then sailed again with fully blasted and 1st type of foul release coating applied hull for 1,5 years. When we focus on dry-docking performance of this vessel, foul release coating provided extra 9,42 % fuel consumption reduction and 2,21 % speed increase in respect to self-polishing coating. Below Figure 1 represent speed loss changes of vessel 4.

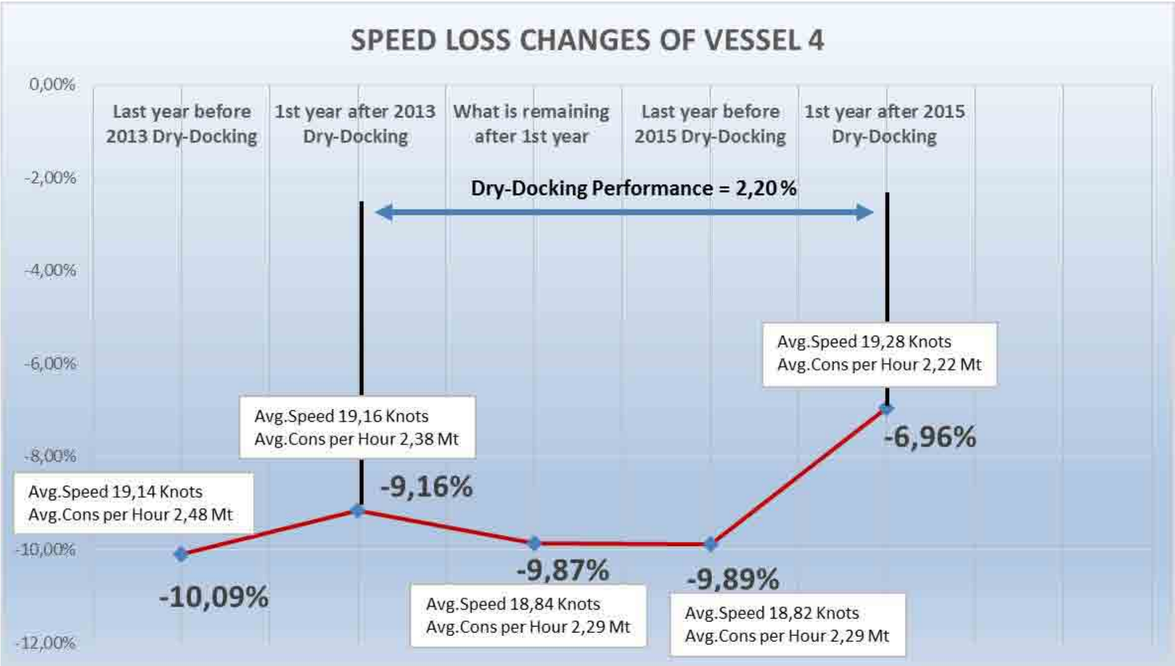

Figure 1. Speed loss changes of Vessel 4

Vessel 7 was only the sample where we could have chance to evaluate dry-docking performance of self-polishing coatings. We compared results of first year after 2013 dry-docking and first year after 2016 dry-docking where hull was completely coated with new coating. Results indicates that hull performance is reducing on every docking cycle and approximately 12 % fuel consumption increase proofs how hull condition is deteriorated dramatically without full blasting.

Table 3. Performance of Self polishing coated and full blasted vessel

DRY-DOCKING PERFORMANCE OF VESSEL 7		
	Dry-docking Performance	
	Speed Loss %	*Fuel Consumption mt/hr*
VESSEL 7	-2,52%	11,90%

2 different technology of foul release coatings tested on 7 vessels. Results indicated that, foul release coatings performed well. Fuel consumption of all vessels reduced 7,5 % in average regarding dry-docking performance results. Also, ships' speeds increased up to 2 %. Vessel 6 and Vessel 8 which also propellers modified and results were not satisfactory, effected average of foul release coating performances negatively. We suppose new propellers had negative effect on ship performance due to we couldn't observe expected efficiency of foul release coatings on these vessels.

Table 4. Dry-docking performance of Foul Release Coated vessels

DRY-DOCKING PERFORMANCE OF FOUL RELEASE COATINGS		
	Speed Loss %	***Fuel Consumption mt/hr***
VESSEL 1		
VESSEL 2		
VESSEL 3	3,00%	-12,40%
VESSEL 4	2,21%	-9,42%
VESSEL 5	1,94%	-7,93%
VESSEL 6	0,49%	-2,01%
VESSEL 8	1,42%	-5,97%
Average	1,81%	-7,55%

Regarding In-service performance comparison of self-polishing and foul release coated vessels, foul release coated vessels performed better that self-polishing coated vessels in respect to speed loss and fuel consumption. Table 5 presents compared data of both coatings.

Table 5. In-service performance comparison of self-polishing and foul release coatings

IN-SERVICE PERFORMANCE COMPARISONS				
	Speed Loss %		**Fuel Consumption mt/hr**	
	SELF POLISHING	***FOUL RELEASE***	***SELF POLISHING***	***FOUL RELEASE***
VESSEL 1		-1,77%		8,06%
VESSEL 2		-0,82%		3,60%
VESSEL 3	-2,87%	0,28%	13,80%	-1,26%
VESSEL 4	-0,71%		2,98%	
VESSEL 5	-2,25%	-2,55%	10,70%	11,73%
VESSEL 6	-3,70%		17,88%	
VESSEL 7	-3,10%		15,13%	
VESSEL 8	-2,65%		13,13%	
Average	-2,55%	-1,22%	12,27%	5,53%

Application of foul release coatings reduced fuel consumptions of test vessels, increased speed and improved operational efficiency.

5. Conclusion

This study reviewed the results of new hull coating technologies for high speed RO-RO vessels and analyze the potentials to decrease fuel consumption as well as speed loss. The actual field data of 8 high speed RO-RO vessels has been studied according to *the* new standard ISO 19030 - Ships and marine technology, Measurement of changes in hull and propeller performance.

This study confirmed below results:

- Foul release silicone technologies seems performing well for 2-3 years of period for high speed Ro-Ro vessels. We don't have available data to say something for longer periods.
- Only 1 vessel was full blasted and tested with Self-Polishing coating. It is required to evaluate results of more samples which are full blasted and self-polishing coated in order to separate effect of full blasting and coating, also for better comparison of self-polishing and foul release coatings.
- 1st type of foul release coating technology performed well on all tested vessels.
- 2nd type of foul release coating technology performed well for both test vessels during first year after dry-dock. But regarding in-service performance results, it performed well only on 1 vessel and did not on another.
- Full blasting is very critical and important for hull performance. If ship's hull only spot blasted, even if it's completely coated with any self-polishing coating, ship's hull performance reduces dramatically. Most of the ship operators do not want to carry out full blasting for economic reasons and they do only spot blasting to reduce dry-docking cost. However, this approach causes more fuel cost and reduced operational efficiency of ships.
- It is observed that self-polishing coatings perform well max 1 year for high speed Ro-Ro vessels unless it is applied together with full blasting which increases this beneficial period. And it is observed that all self-polishing coated vessels arrived to next dry-dock with a fouled hull.
- It is observed that; hull fouling also occurs for the foul release coated vessels which causes reduce of hull performance but reduction was not worst as self-polishing coated vessels. Photos taken just after entering the dry-docks confirms foul release coated vessels' hull were in good condition.

As this study is about results of different hull coating technologies applied to high-speed Ro-Ro vessels under different conditions, the results of the same coating technologies may differ on different ship types and under different operational conditions. With the implementation of ISO 19030, we expect that more studies will be carried out for evaluating hull performance changes with real field data which literature needs more studies in this area. It is clear that uncertainty of real field data will be always high unless they have carried out according to ISO 19030 Part 2 requirements which requires various sensors and data logging system. It is the fact that most of vessels don't have these sensors and data logging system. Therefore, this kind of studies will be helpful for ship owners, paint producers, academicians and all related parties.

It would be very useful if the ISO to strengthen the standard with new methods to cover voyage base methodology for liner vessels. Part 3 requires daily collected data to analyze. However, it would be more beneficial for liner vessels to compare results of each voyage or each leg if the vessel is trading on the same line for a period which covers required analysis duration.

ISO 19030 have been recently published on the 15th of November, 2016 and all parties offering performance monitoring systems have been started to implement their systems according to requirements of the standard.

We believe the results of this study will highlight performance of todays' antifouling technologies even there will be some uncertainty due to analyzed data collected from arrival, departure and noon reports of test vessels instead of collecting them directly from required sensors and a data logger. For the future studies, it would be more beneficial to carry out analysis of sister vessels which have sensors and logging systems required as ISO 19030. Uncertainty will be very low and results would be more useful for all parties cares with hull performance solutions.

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