MS-E2177 Seminar on Case Studies in Operations Research, 2018

ABB Marine: Models of vessel hull and propeller fouling

Project Plan

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Background

There has long been a recorded history, dating back to 1862, on the unwanted effects and mitigation strategies of the phenomenon called fouling (Townsin, 2003; Demirel et al., 2013). Fouling is associated with organic growth (known as biofouling) and/or mechanical damage which has a negative effect on the submerged parts of a vessel. A fouled hull and propellers can have a significant effect on the profitability and performance in the marine transportation industry due to a frictional resistance that is known as frictional drag. The frictional drag can decrease the speed of vessels and can lead to increased fuel consumption and emissions (Schultz 2007; Kovanen, 2012). It has been shown that fuel consumptions can increase up to 40 % despite a low degree of fouling (Kovanen, 2012). Thus, the economic and environmental impacts are significant; marine transportation consumes approximately 300 million tonnes of fuel per year and increases the amount of carbon dioxide and sulphur emissions (Demirel et al., 2013). Furthermore, corrosion can destroy the coating of a fouled hull, and lead to increased environmental impact (Kovanen, 2012). These forces are driving ship owners and operators to find ways to accurately predict the fouling of hull and propellers, in order to increase fuel efficiency and mitigate environmental effects. For example, by investigating both efficient and ecological friendly hull coatings, and the optimisation of hull and propeller maintenance scheduling.

The majority of existing research (Schultz, 2007; Atlar, 2008; Taylan, 2010; Kovanen, 2012; Meng et al., 2016) has focused on identifying and observing factors affecting the fouling rate of growth, and their impact on fuel efficiency. A fouling variable depends on many factors, such as environmental conditions, the operating profile of a vessel, and maintenance operations (Table 1). However, fouling is a challenging factor to quantify precisely due to a wide range of existing variables which must be taken into consideration. In addition, the measurable changes in the fuel consumption due to the increased frictional resistance – the fouling – are slow to appear (Kovanen, 2012). Therefore, direct measurements of the fouling are difficult to implement frequently, and measured results can be challenging to connect with the impact of hull resistance or propeller efficiency. As a result, existing empirical studies have focused on indirect methods to estimate and predict the degree of fouling by analysing operating data that reveals used speed and propulsion power and prevailed environmental conditions.

Table 1 Variables affecting vessel fouling (Kovanen, 2012)

Environment	**Maintenance operations**	**Vessel**
Salinity	*Utilization Rate*	*Hull surface*
Temperature	*Itinerary & Speed*	*Antifouling*
Location	*Brushings*	*Surface Color*
Time of year	*Dry docking*	
Illumination		

From Table 1, the environment group includes salinity of the water, the temperature of the water, the location of the vessel, the time of year and illumination variables. The influence of sea temperature to fouling is known to be higher in warmer sea areas than colder ones (Stevens, 1937), especially the warmth of the Caribbean Sea. In particular, Kovanen (2012) shows that the sailing route Alaska-California-Caribbean decreases fouling momentarily when California is reached but increases rapidly after arriving in the Caribbean Sea. Cold waters and variation in salinity may be influential variables. Therefore, route optimisation, itineraries and other maintenance operations variables play a significant role as ways to decrease fouling (Kovanen, 2012). The existing research is not limited to these variables, with various viewpoints on the factors affecting fouling. For example, Atlar (2008) classifies marine foulers into animal and plant foulers (Figure 1), whereas, Taylan (2010) divides marine biofouling into micro and macro foulers.

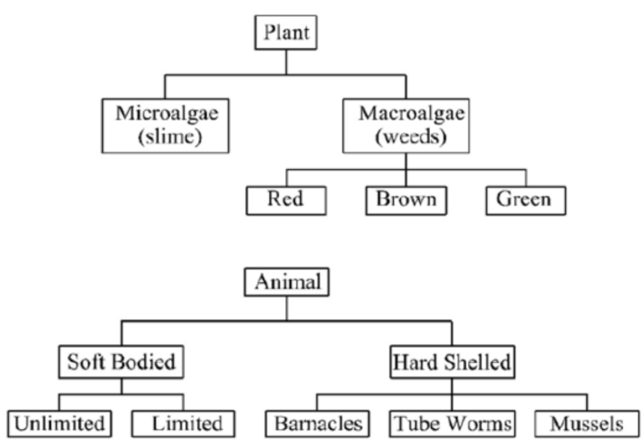

Figure 1 Classified marine foulers (Atlar, 2008)

Major efforts have been taken to enhance maintenance operations and vessel material design in order to overcome the fouling phenomenon. For instance, different antifouling technologies, such as special coating materials, paints and environmental-friendly hull scrubbing technologies, have been developed to reduce the growth of fouling. Periodic cleaning of submerged parts of a vessel is another antifouling tactic. By selecting the right type of treatment, such as a high-pressure cleaning in the dry dock, it is possible to reduce fouling by 5 %. Furthermore, if the right antifouling coatings are used, the marine transportation sector could save roughly 60 billion dollars and remarkably reduce the amount of emissions (Demirel et al., 2013). However, cleaning can also have a negative effect on fouling as cleaning techniques can damage the coating of the vessel, and thus accelerate the growth of fouling. Moreover, if a vessel has long idle periods, which can include dry docking, the effects of fouling can worsen (Kovanen, 2012; Demirel et al., 2013). Therefore, existing knowledge is needed to find an appropriate cleaning method and frequency for optimising dry docking intervals as a counteractive approach against the fouling growth. (Kovanen, 2012).

It is also vital to understand the technical characteristics of a vessel and their effects on performance. Many efficient trim optimisation tactics, such as position and angle of the propeller and the extent of the wetted surface of a hull, are used to improve efficiency and lower operational expense (Kovanen, 2012). Such variables must be taken into account when calculating the level and effect of fouling.

Objectives

The main objectives of this research project can be divided into three sections. Firstly, based on operating data of a cruise ship, the overall level of fouling will be estimated, with the quantified impact on propulsion power demand. We approach the problem by assuming that the fouling of the hull and the fouling of the propeller are non-distinguishable from each other, an approach taken by many in the literature. Secondly, we calculate the individual impacts of hull and propeller fouling of the cruise ship. This is a somewhat novel approach, as it may require propeller cleaning not to of taken place between hull cleanings and vice versa, which there is often too little data for. Due to this, we may lack the appropriate data to carry out these calculations accurately. However, the methodology of how one could achieve this distinguished fouling impact will be at least described, with details of the data needed to complete the calculations. The third objective of this project is to develop a method that enables one to optimise the scheduling of hull and propeller maintenance, with the overall aim of minimising operational costs.

Regression techniques will be implemented to investigate the impact and co-interactions of various variables on the rate of fouling, with estimates of fuel consumption for given periods before-and-after cleaning as a way of calculating the level of fouling. These methods will be utilised in the implementation of objectives one and two. For objective three, a maintenance optimisation model will be developed. This mathematical model will aim to find the optimum balance between the benefits of hull and propeller cleaning, which in our case is the reduction of fouling impact, and the costs which we wish to minimise. There will obviously need to be other constraints taken in to account, such as the availability of the ship for maintenance, and the different types of cleaning. Once the optimisation model is complete, sensitivity of the model will be assessed with the sub-optimal schedules as possibilities and the corresponding impact these schedules have on the overall objective value.

As stated above, the second project object may be difficult to fulfil, therefore we have decided that priority will be given to the first and third objectives as they present the majority of the workload.

Tasks

The following tasks are expected to be carried out during the project:

1. **Project planning**

   The first task is to discuss with the clients about the background and the objectives, and how the problem will be approached. The client also provides the material for the project. After that practical issues within the team will be discussed.

2. **Literature review**

   As the topic is a new field of study for each team member, reading articles about biofouling is necessary in the beginning of the project. Through a literature review we familiarise ourselves with the topic and possible models that could be used in the project.

3. **Project plan report**

   Project plan report will be written and presented.

4. **Data preprocessing**

   The data received from ABB Marine must be preprocessed by eliminating errors and possibly modifying it.

5. **Model construction**

   A suitable regression model will be decided, and the model will be programmed with R. The model needs to work effectively to be able to deal with a large amount of preprocessed data. The optimisation model for scheduling of cleaning events will be implemented.

6. **Interim report**

   Interim report will be written and presented. Interim report will include changes in the project plan and the status of the project.

7. **Validation and verification**

   The model will be tested to ensure it works as wanted with the data. Results will be analysed. Sensitivity of the optimisation model will be tested.

8. **Final report**

   To conclude the project, written report and final presentation will be prepared. Final report includes everything made in the project.

Schedule

The Gantt chart shown in Figure 2 illustrates the graphical depiction of our project schedule, with the light green bars representing completed tasks and the light blue bars representing remaining tasks, with milestones in darker shades. The chart will be regularly updated to ensure that we stay on schedule, any tasks that are unexpectedly prolonged will be displayed in red.

Resources

Many different stakeholders, such as the project team, ABB Marine contact people Aleksi Eskelinen and Janne Pietilä, and Aalto University Professor Ahti Salo will be utilised to complete the ABB Marine research project. Moreover, existing literature related to fouling, ABB Marine data and the statistical software RStudio (2017) will be critical resources for achieving the objectives of the research project. The project team has the main responsibility for the completion of the research activity, and a project manager was selected to plan and control the project. Resource scheduling was applied to optimise available resources. Thus, a Gantt chart was needed for the planning and illustration of the timeline of the project in order to manage limited resources efficiently.

Risks

Table 2 identifies the possible risks that could affect the final outcome of the project, together with the likelihood of occurrence, the evaluation of impact to the project, and mitigation measures to avoid such risks.

Table 2 Project risk factors

Risk factor	**Likelihood**	**Risk outcome**	**Impact**	**Mitigation measures**
Member absence	*Complete absence is extremely low, short absence is high*	*Increased workload for team if long absence, momentary increase for absence team member if short absence.*	*High for long absence, low for short*	*Keep to schedule, and inform team members as soon as absence is known*
Excessive workload	*Moderate - high*	*All objectives set will not be achieved*	*Moderate*	*We have decided to concentrate on objectives 1 & 3 as they are the most important and most likely to be completed within the project schedule*
Distinguishing hull and propeller fouling	*High*	*Objective 2 will not be achieved*	*Low – moderate*	*Same as above*
Quality of data	*Moderate – high*	*More time than scheduled to preprocess the data, delaying subsequent tasks*	*Moderate – high*	*Extra preprocessing time scheduled to cover delays*
Optimisation model not implemented	*Low – moderate*	*Objective 3 will not be achieved*	*High*	*Clear scheduling of regression model to be completed with time to implement optimisation model*
Overly simplified model assumptions	*Moderate*	*The accuracy of the models will suffer*	*High*	*Check with client to ensure assumptions are reasonable*

Task	Week Start	Duration
Project planning	*1*	*2*
Literature review	*2*	*3*
Project plan report	*3*	*5*
Data preprocessing	*6*	*6*
Model construction	*10*	*7*
Interim report	*12*	*3*
Validation and verification	*16*	*3*
Final report	*14*	*6*

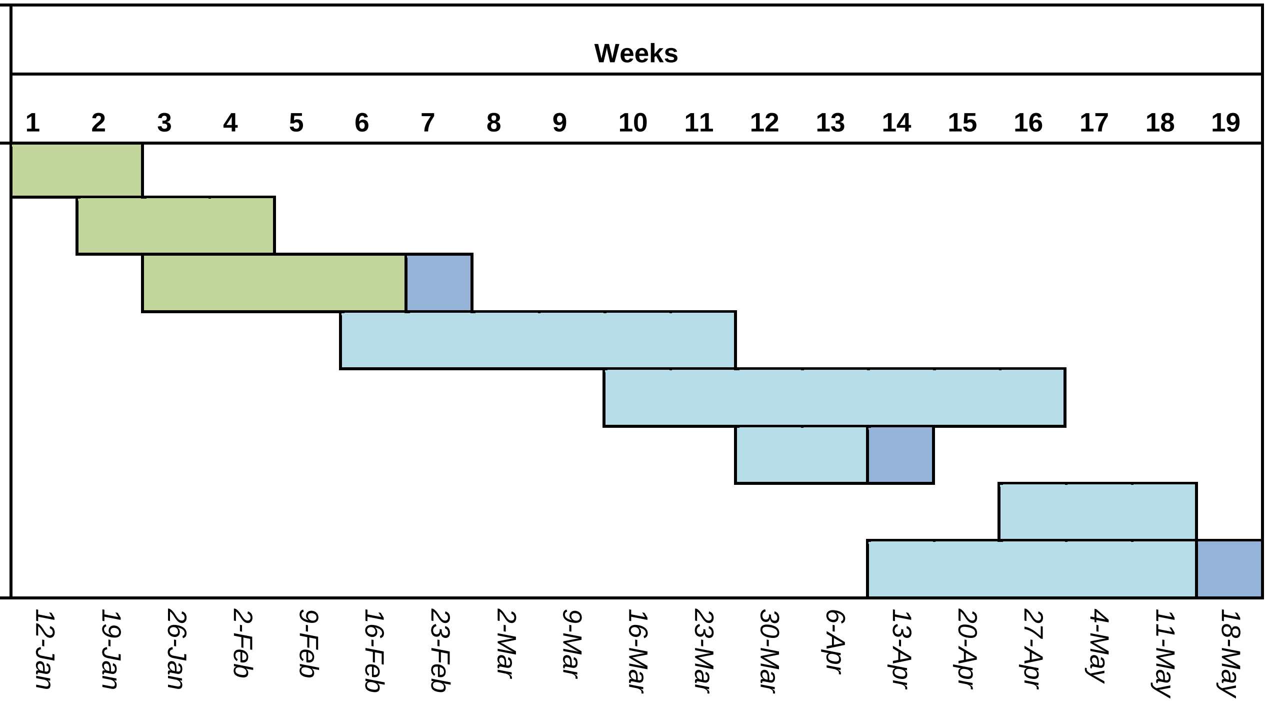

Figure 2 Schedule ABB Team

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