Hull Medic™ Business Case

Executive Summary

As a ship’s hull condition degrades due to marine fouling, more power and fuel are needed to maintain service speeds. A by-product of the increased fuel consumption is increased Green House Gas emissions. Rising fuel costs, hull maintenance expenses, and mounting environmental regulations make hull condition monitoring a crucial tool for prudent ship operators to eliminate energy waste due to hull fouling, reduce carbon emissions, and eliminate the carriage of invasive species between ports.

The Hull Medic method uses a ship’s propeller as a power absorption dynamometer, allowing the propeller as a measuring instrument to accurately estimate both water speed and shaft power. The resulting propeller model can be used to detect hull fouling by comparing ship performance over time against a standard “clean-hull” baseline.

This business case is based on a customer’s pilot study to evaluate the effectiveness of a foul-release hull coating over a year-long period. A test ship was instrumented with the necessary sensors and data acquisition system that allowed its propeller to be calibrated as a power absorption dynamometer. High-accuracy models were calibrated from data immediately following a drydock painting period and then used to track ship performance in terms of KPIs of power/fuel penalties and speed loss. The test ship became heavily fouled while sitting at birth over warm summer months in 2010. When the ship returned to active service, fuel penalties on the order of 25-35% were experienced across the ensuing four months of operation, after which time the owner performed a hull cleaning. Performance data collected subsequent to the cleaning indicated that optimal performance had been restored.

Due to schedule constraints, the test ship had to continue operating with a fouled hull. After repeated Hull Medic reports indicating severe fuel penalties, divers were sent to inspect the hull and verified that it was indeed substantially fouled. The customer performed a hull cleaning at the next opportunity. As a result of operating the test ship over four months with its hull fouled, the Total Fuel Penalty incurred during those four months (i.e. the cost of wasted fuel) was estimated at $550,760. Had the customer been able to take immediate action to clean the hull when Hull Medic first detected large performance penalties, the payback on the Hull Medic system/service would have been less than one month.

The total cost in wasted fuel from operating four months with a fouled hull was $550,760. Equivalently, about 1880 tons of CO² emissions could have been avoided.

Early action to clean the hull when large fuel penalties were first detected would have provided a payback of less than one month.
Effects of Hull Fouling on Speed-Power Performance

Figure 1 below shows the effect of hull fouling on a ship’s speed-power performance. This is a typical speed-power curve. While varying somewhat from ship-to-ship, shaft horsepower (SHP) is essentially a cubic function of ship speed through the water. The black-colored curves represent the clean hull/clean propeller condition.

As the hull and/or propeller fouls, the curve shifts up to the left. For the purposes of ship performance monitoring, there are two ways to interpret this change in speed-power performance. One way is to consider how much more power is needed to maintain the same service speed, say 22 knots, as indicated in Figure 1-A. In this example, sailing with a clean hull at 22 knots requires around 22,500 SHP. With a fouled hull, it will require around 26,000 SHP to go the same speed. The delta power is referred to as the Power Penalty and represents the additional power needed to overcome the added drag on the hull.

The other way to interpret the performance loss is to look at what happens to speed if a constant power is maintained. The example in Figure 1-B shows about a one knot speed loss due to fouling for a constant power of 22,500 SHP. Most practical ship performance analyses always quantify the effects of hull fouling in terms of power penalty or speed loss, or both. The power penalty has a direct relationship to excess fuel consumption, hence it can be considered equivalent to a fuel penalty.

![Figure 1 – Effects of Hull Fouling on Speed-Power Performance](image)

Propeller Power Absorption Model

The technical background of the propeller power absorption models used for Hull Medic are described in reference [1], which can be downloaded from MACSEA’s Web site. During this study, approximately two months of ship performance data was collected immediately following ship drydocking and was used to calibrate the propeller models.
Figure 2 below illustrates why ship performance monitoring is a difficult activity. There are many ship and environmental factors effecting ship performance that are difficult to measure and quantify.

Figure 2 – Ship & Environmental Factors Effecting Ship Performance [Ref 2]

Ship resistance is not directly measureable. The environmental factors influencing resistance include wind, waves, currents, water depth, water temperature and density. Ship factors influencing resistance include hull condition (fouling and roughness), propeller condition, propeller pitch (for CPP ships), draft, trim and rudder activity. Transient operating conditions, such as speeding up or slowing down, also come into play.

Separating out the effects of these individual factors has been the subject of many decades of research. The general approach has been to derive theoretical or empirical models for each factor and then apply those models to make resistance corrections to a standard baseline condition, and allow the factor of interest to vary, in our case hull fouling over time. The separate models are commonly developed for each component of resistance through scale model tank testing.

Besides not being able to directly measure ship resistance, there are some problems with using resistance as a basis for ship performance monitoring:

- Not all practitioners include all components of resistance, making power prediction results inconsistent,
- Resistance component interactions are often ignored, and
- Ship-model scaling effects accuracy, which is often unknown or unreported.

As a result, the ship performance analysis details may not be very transparent to the customer, which why it is sometimes considered to be “Black Art”.

© MACSEA Ltd, 2012
Rather than correcting for these factors with models of unknown accuracy, a practical approach is to simply filter out data not meeting standard baseline conditions, which we are free to define.

We choose clean hull and propeller, calm weather, and the average draft and trim conditions at which the ship normally operates. By calibrating the propeller with a data set filtered to these conditions, and by only performing an assessment of hull fouling at these same conditions, the onset of hull fouling can be readily detected. All that is required to detect hull fouling are similar “Points of Comparison” naturally occurring during the ship’s normal operating cycles.

During Hull Medic commissioning, data base filtering is applied to eliminate data not meeting the predefined baseline conditions. From the resulting dataset, the propeller models are then calibrated, hence the models represent clean-hull, calm weather ship performance. For periodic hull condition monitoring, the same database filtering to the baseline conditions is applied. Hull Medic’s calibrated propeller power absorption models are thus used to compute the power penalty and speed loss over time. The models estimate what the ship’s speed and power performance should be if the hull were clean. The difference between the model estimates and the measured values represents the speed and power penalties. Since there is a strong correlation between power and fuel consumption, the power penalty can readily be converted into excess (wasted) fuel consumption and cost.

![Diagram](image)

**Figure 3 – Calibrating Hull Medic’s Propeller Power Absorption Models**
Hull Medic™ Business Case

Model Accuracy

In this case study, the Hull Medic models proved to be extremely accurate in predicting ship speed and power performance. Figure 4 below compares model-estimated values of shaft horsepower (SHP) to those measured by the ship’s torque meter across the baseline dataset. The average model error across the entire 3326 record data set was only .04% of the maximum power range.

Hull Medic’s high-accuracy models allow earlier detection of hull fouling, more accurate quantification of performance penalties, and lower cleaning costs by the prevention of mature fouling. Hull cleaning can be performed in less time and thus at less cost when the fouling is light.

Figure 4 – Hull Medic Predictive Accuracy Across 3300 Record Set (99.96%)
Rapid Fouling of Test Ship Due to Inactivity

Foul release coatings contain no biocides to prevent hull fouling. Their anti-fouling feature is provided by a low-friction surface onto which marine organisms have difficulty attaching. If vessels are stationary for short periods of time, some early fouling may occur, but there will be a weak bonding between the fouling organisms and the coating surface. The young organisms are likely to be sloughed off by the hydrodynamic forces acting on the hull when the vessel transits at a sufficiently high speed. This type of coating can be a good choice for active vessels that are constantly moving.

For other types of vessels that spend a significant amount of time in port (e.g. naval vessels), foul release paint may not be the best choice for fouling control. Once the fouling matures, strong adhesion to the hull can occur that may overcome the effectiveness of the paint’s foul-release characteristics. The fouling can remain intact even at high vessel speeds and can only be removed through hull cleaning. For the test vessel involved in this study, this appears to have happened, as is evident in the speed-power curve progression shown in figure 5 below.

The test ship came out of drydock with its new foul-release coating in August 2009. Initial performance data was collected and propeller calibration model baselines were established in November 2009. Speed-power performance remained as good as new from December 2009 through early June 2010, as indicated by the green and red data shown in figure 5 below. The ship remained in port from early June 2010 through early September 2010 and her hull became significantly fouled in the warm summer waters off the US East Coast.

![Figure 5 – Rapid Degradation in Speed-Power Performance Due to Hull Fouling](image-url)
When the ship began operating in September 2010, Hull Medic indicated a 35% power/fuel penalty, as shown in the blue curve in figure 5. Similar performance penalties were indicated in the October 2010 data as well (see yellow curve in figure 5).

To verify Hull Medic’s performance predictions before ordering a hull cleaning, the customer sent divers down to inspect and photograph the hull’s condition. Figure 6 is a diver photograph taken in early November 2010 that documents the extent of fouling over the entire underwater hull surface. Hull Medic had detected the fouled condition approximately two months earlier.

A diver inspection verified the hull fouling detected by Hull Medic two months earlier.

Due to schedule commitments, the ship operated for two more months in the fouled condition. The hull was cleaned in January 2011, which restored speed-power performance back to the clean-hull condition. The key question next is “How much did it cost in excess fuel consumption to operate the ship with a fouled hull over a four-month period?”
Cost Analysis of Fuel Penalties

When the test ship returned to normal operations in September 2010, Hull Medic indicated that the average power penalty for the month was an astounding 35%. Figure 7 illustrates this penalty as compared to the clean-hull power prediction provided by Hull Medic. Hull Medic indicated that, on average, 35% more power (and fuel) was required to achieve normal vessel operating speeds.

![Figure 7 – Monthly Power Penalty Due to Hull Fouling](image)

The average power penalties for the entire four months during which the ship operated with a fouled hull are shown in figure 8 below.

![Figure 8 – Avg. Monthly Power Penalties (%) While Operating with Fouled Hull](image)
Hull Medic™ Business Case

Cost Analysis Methodology

There is a strong correlation between power and fuel consumption. Power penalties due to hull fouling were considered as equivalent fuel penalties. Since an engine isn’t 100% efficient at converting fuel into power, these analysis results are considered to be conservative.

The analysis methodology involved first gathering the historical monthly fuel consumption data covering the fouling time period. Data included quantities consumed and cost, based on customer’s purchase price. Only underway fuel consumption was considered. The percentage power (fuel) penalties detected by Hull Medic were then used to calculate the monthly fuel penalty in dollars, as illustrated in figure 9 below. The monthly fuel penalty dollar amounts were then summed across the four month interval that ship operated with fouled hull to compute the total fuel penalty.

Figure 9 – Calculating Excess Fuel Cost Due to Hull Fouling

Figure 10 below shows the historical monthly underway fuel costs and the calculated excess fuel consumed due to hull fouling, based on the penalties indicated by Hull Medic.

Figure 10 – Underway Monthly Fuel Costs and Fuel Penalties Due to Hull Fouling
Hull Medic™ Business Case

Figure 11 below compares the monthly excess fuel cost to the cumulative excess fuel cost over the four-month period that the test ship operated with a fouled hull. Within the five month time period from September 2010 through January 2011, a total of $550,762 was estimated as the cost of operating with a fouled hull. This particular ship’s operating profile during the time period showed that it was at sea only 50-70% of the time. Additional operating time would have made the fuel penalties due to fouling even higher.

![Figure 11 – Monthly & Cumulative Fuel Penalties Due to Hull Fouling](image)

Conclusions

- Fuel penalties due to hull fouling can be significant.
- The performance penalties detected in this case study were in the 25-35% range due to the extent of fouling, but even a light slime can cause penalties in the 10% range [3].
- The foul release coating was substantially higher in price than the owner’s traditional ablative coating. Instead of providing the advertised savings, the owner incurred the additional cost of the coating plus a $550,760 fuel penalty. The owner is now faced with a choice of adopting a regimented hull cleaning program or repainting the vessel with a coating more appropriate to its operating profile.
- Without the ability to accurately measure and quantify performance losses due to hull fouling, ship operators will have difficulty justifying the selection of one coating over another. The losses incurred in this case study could have been reduced dramatically had action been taken to clean the hull immediately after the large power penalty was
detected. The cost of Hull Medic, as well as periodic hull cleanings, could have easily been recovered by the savings in fuel penalty avoidance.

References

