Predicting performance, promoting transparency

Intertrac®Vision: a new tool to predict the impact of fouling control coatings on ship efficiency

AkzoNobel's marine coatings brand, International® has a long history of providing effective fouling control solutions and services to the marine industry. Given the operational pressures that ship operators face in today's increasingly competitive market it is clearly important for budget holders to make an informed choice of fouling control coating for their ships. To facilitate this, International® has developed Intertrac®Vision, a new predictive tool which delivers improved predictions of vessel performance over a drydock cycle. The new approach builds on the previous work of Dr. R.L. Townsin and the Hull Roughness Penalty Calculator (HRPC) and encompasses the following important factors:

- Global fouling challenge
- Trading route of the vessel
- Operational Profile of the vessel
- Vessel type and size
- Choice of fouling control coating and scheme selection
- Substrate condition & preparation
- Hull condition management

Among the benefits for ship operators are improved powering predictions, fuel oil consumption predictions, CO_2 emissions predictions and cost benefit analysis related to the choice of different coating and surface preparation scenarios.

Why do we need an improved vessel performance prediction tool?

When a ship operator makes an investment in a fouling control coating, the expectation is that the coating will provide reliable and consistent performance over an entire drydock cycle. In simple terms, a successful fouling control coating is one that provides fouling protection and minimises any frictional resistance and powering increase over the entire drydock cycle. Before making a decision, evidence of historical performance is usually reviewed, normally derived from past experience of hull coatings used on similar ship types, speed ranges and operational profiles. Very often this information is presented as observations of coating performance over time and where possible supported by data for in-service ship performance. Whilst this type of historical evidence is important, it does not always provide the ship operator with sufficient detail to perform a reliable cost benefit analysis of the different coating options for their specific ships. Intertrac®Vision has been developed to meet this need.

Predicting future performance can be challenging due to the number of key variables which directly influence performance and the ability to predict the changes in these key variables reliably and accurately over time. For any given ship, of a particular hullform type and size, there are numerous variables to consider: ship speed; operational profile (activity); engine efficiency; propeller efficiency; fouling control coating choice and efficacy; surface roughness (of hull and propeller); damage in-service; weather conditions (wind, wave, currents); shallow water; crew behaviour; and fleet operation guidelines / instructions, to name but a few. Variations in some of these factors, e.g. weather will affect the day to day operation of the ship. As Intertrac®Vision is a tool to predict performance over relatively long timescales, it does not take into account such short term variations but does take into account those variables which change over much longer timescales, e.g. hull condition.

An aspect of this to consider is the choice of fouling control coating that is applied to the underwater hull area. This represents a significant sub-set of the key variables influencing ship efficiency, as the frictional resistance of the underwater hull surface of a ship can contribute between 50 – 90% of the total resistance experienced. Therefore, maintaining a smooth and clean hull is important and selecting the optimal fouling control coating can help maximise ship efficiency over a drydock cycle. However, as even the best fouling control coating is unlikely to prevent all fouling - on all ship types under all conceivable operational profiles - it is also necessary to consider the potential risk of fouling explicitly when selecting a fouling control coating.

By considering the impact of potential coating selection on ship efficiency we can explicitly develop predictions that provide cost / benefit and environmental impact analyses for each fouling control coating and scheme. This allows operators to make more informed coating selection choices by taking into account vessel type, trading route and activity for their particular vessels.

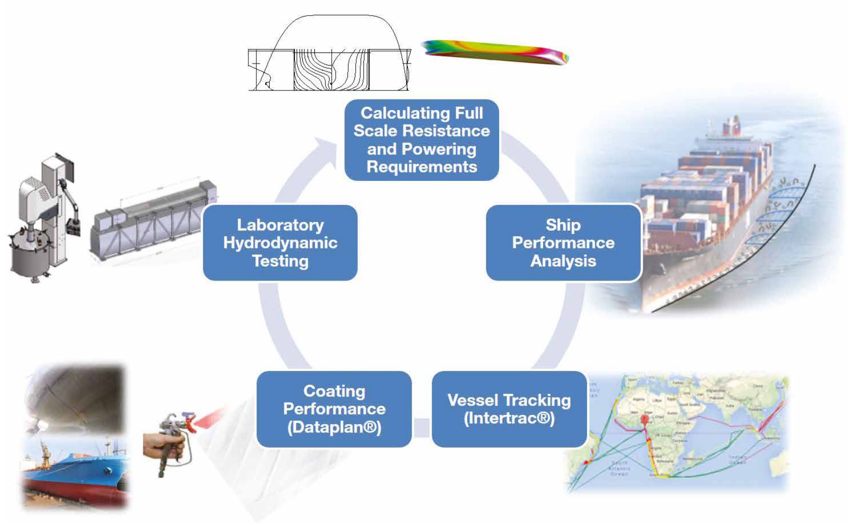

Fig 1: Improved and refined models of how fouling control coating choices influence vessel operational efficiency

Previous Approaches

No ship's hull is hydrodynamically smooth and naval architects have long recognised the general impact of surface roughness on vessel powering requirements. The work by Townsin in the 1980's was particularly valuable. Townsin's approach attempted to quantify the impact of Average Hull Roughness (AHR). This approach was accepted by the ITTC in 1990 and is still commonly used to predict the powering penalties associated with changes in hull and coating roughness over a drydock cycle, relative to a hypothetical hydrodynamically smooth surface. Building on this seminal work, International® developed a Hull Roughness Penalty Calculator model in 2003. The HRPC is a software model that predicts ship powering as a function of the predicted increase in underwater hull roughness combined with the risk of fouling associated with different fouling control coating types over a drydock cycle.

The original Intertrac® system was developed in 2011. This system overlays a vessel's route, speed and location data with a comprehensive fouling challenge dataset, enabling coating specifications to be tailored specifically to suit an individual vessel's operations and trading routes. The original Intertrac® system is both a valuable coating selection tool and a diagnostic tool linking past coating performance with a ship's operational history. However, in isolation, it is of limited use as a quantitative predictive tool for ship powering requirements.

These approaches helped to provide valuable insights into the potential performance implications of different hull and coating conditions and remain useful as general guides. In today's increasingly competitive market, vessel operators require clearer guidance on the potential performance benefits of fouling control coatings for their specific vessels so that they can make the optimal coating choice.

The New Approach: Intertrac®Vision

Intertrac®Vision builds on the solid foundation of the earlier models developed by Townsin and the HRPC. Through collaboration with leading academics and commercial institutes in conjunction with our internal research we have developed improved and refined models of how fouling control coating choices influence vessel operational efficiency (Fig 1). These improved and refined models, which underpin Intertrac®Vision, are subject to a pending patent application.

This new approach has led to a number of refinements and improvements including:

1. Prediction of the total roughness change over a drydock cycle, based on:

- A new total roughness model incorporating hull and coating micro, macro and fouling roughness;
- A new understanding of how the choice of coating affects micro roughness;
- A new model linking substrate preparation and coating application choices to macro roughness;
- New coating-specific fouling roughness models;
- A new predictive approach of how biological factors affect coating performance;
- A continually growing database of in-service coating performance;
- An enhanced understanding of the impact of vessel operational profiles, including hull cleaning events, on coating performance.

2. Correlation of total roughness, total ship resistance and powering requirements, based on:

- New Computational fluid Dynamics (CFD) resistance and wake field flow models for different representative hullforms including bulkers, tankers and container ships which reflect over 85% of the world's fleet;
- Incorporation of these CFD models in optimised ship powering requirement calculations;
- Derivation of speed / power curves as a function of total roughness;
- An enhanced understanding of how ship powering requirements are influenced by the total roughness.

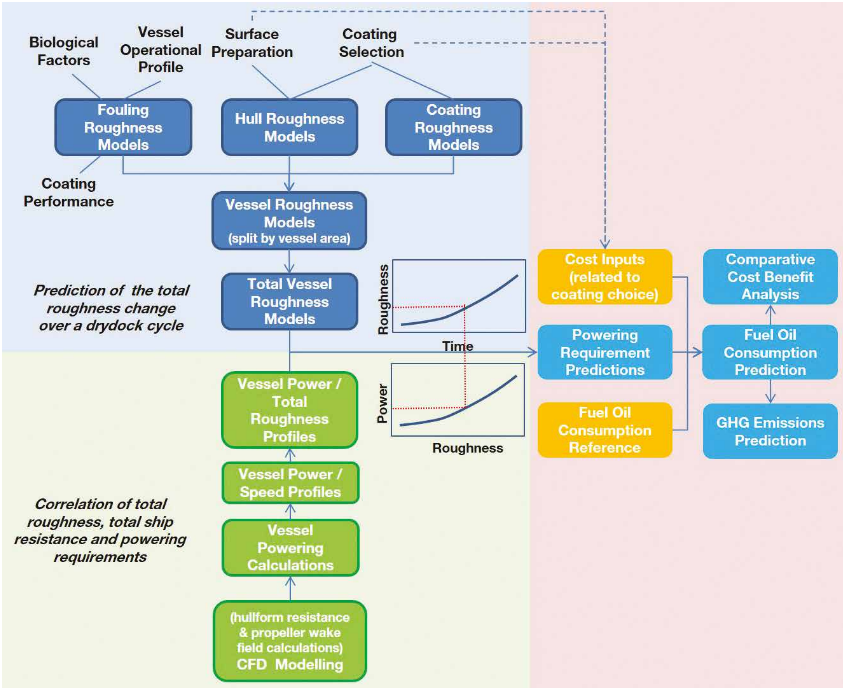

Fig 2: A Simplified schematic representation of Intertrac®Vision

Prediction of the total roughness change over a drydock cycle

Arguably the most valuable improvements that Intertrac®Vision incorporates relate to the new total roughness model, the new coating-specific fouling roughness models and an enhanced understanding of the impact of vessel operational profile on coating performance.

A new total roughness model

Intertrac®Vision makes use of a new total roughness model which considers the cumulative impact of micro, macro and "fouling roughness". The starting point for this was the updated model for predicting the average hull roughness (AHR) of ships, recently proposed by Stenson et al. This considers the impact of micro and macro roughness elements on the ship's hull separately. In general the macro elements relate to the underlying substrate roughness or hull roughness and the micro elements relate to the coating roughness. However, in order to consider the total roughness we must also consider the impact of the "fouling roughness". By fouling roughness we mean the physical roughness that would give an equivalent frictional resistance to a particular type and extent of fouling. In line with Schultz's seminal work on ship powering requirements this is expressed as a sand grain roughness, k_s. By using Townsin's standard correlations with AHR we can also express the micro and macro roughness as k_s and so readily combine the three parameters to quantify the total vessel roughness.

As indicated above the total vessel roughness is highly likely to change over the drydock cycle, for example due to damage to the coating causing an increase in macro roughness, polishing / smoothing of a SPC or LPP coating causing a decrease in micro roughness, or due to the possibility of limited biofouling causing an increase in fouling roughness.

The risk of a vessel fouling over a drydock cycle is associated with several important coating and ship operational factors as illustrated below.

Lower risk of Fouling	Higher risk of Fouling
High Vessel Speeds	Low Vessel Speeds
Short static periods	Long static periods
Shorter drydock cycles	Longer drydock cycles
Cold water temperatures	Warm water temperatures
Deep sea trade	Coastal trade

Developing an enhanced understanding of the impact of vessel operational profiles including coating performance has been a key stage in the evolution of Intertrac®Vision's new fouling roughness models. Information regarding coating performance is obtained by the correlation of the information from our existing Dataplan and Intertrac® systems.

Intertrac® interrogates satellite and terrestrial AIS data and captures date and time stamped information regarding a vessel's position, speed, bearing and draft, etc. This allows us to derive a detailed picture of the vessel's operational profile including its trading route, activity, speed distribution and static periods over any selected time period from January 2009 (when AIS data provision was first made mandatory by the IMO). The model considers 64 separate marine eco regions and characterises the relative risk of fouling in each region for any particular coating choice, taking into account the amount of time the vessel spends in each region and further adjusted for the seasonal variation in the fouling challenge. These new coatings performance models allow more reliable predictions of fouling roughness and how this changes over an entire drydock cycle for different coating selection options.

Additionally, it is common practice to apply different fouling control coatings to different vessel areas. For example, for economic or performance reasons, different coatings will often be applied to the flat bottom, the underwater vertical sides and boot-top areas. A feature of Intertrac®Vision is that the total fouling roughness model also considers the individual contributions and collective contributions of different coating choices on different areas of the vessel.

As stated earlier, even the best fouling control coatings are unlikely to prevent all fouling, on all ship types under all conceivable operational profiles. This is reflected in the fact that the absolute in-service performance of a fouling control coating is often strongly influenced by the operational profile of the vessel to which it is applied. In a further refinement of the model, the impact of coating choice and operational profile is explicitly considered via a series of potential "performance scenarios". These performance scenarios have been derived from a detailed statistical analysis of actual in-service coating performance and have been introduced to allow a more transparent review of the range of performance that may be delivered by each potential coating choice. Intertrac®Vision incorporates three default performance scenarios:

- a performance profile reflecting the probable high performance level on the majority of vessels (typically 70% or more);
- a lower performance profile, reflecting the lower performance level that is likely to occur on a subset of vessels (typically 20% or less);
- a third performance profile, reflecting the significantly poorer performance level that is unlikely to occur except on a very small subset of vessels (typically 10% or less).

It is expected that these default scenarios will be relevant to the majority of combinations of coating choice and operational profile but the Intertrac®Vision model has built-in flexibility to introduce alternative performance scenarios as required. However, as the first default scenario reflects the probable high performance level that will be achieved on the majority of vessels, it is expected that this scenario will have the greatest relevance to ship owners and operators.

Correlation of total roughness, total ship resistance and powering requirements

The powering requirements for a vessel are intimately linked to the resistance of the ship's hull to movement through the water. This resistance comprises a number of key components, the most important of which are the frictional resistance, wave-making resistance and pressure resistance. Generally the frictional resistance is much larger than the wave-making resistance and typically comprises 50-90% of the total ship resistance for most commercial ships at normal operating speeds. As the frictional resistance is induced by shear stress over the surface of a hull, a key factor affecting the total resistance is the roughness of the hull. The higher the hull roughness, the higher the frictional resistance and the higher the power required to maintain ship speed. As a result, more fuel will be burned and more greenhouse gas will be emitted.

In collaboration with MARIN (Maritime Research Institute Netherlands), International® has generated a series of predictive algorithms for ship powering requirements for representative hullforms including bulkers, tankers and container ships (Fig 3) which reflect over 85% of the world's fleet (UNCTAD/RMT/2014).

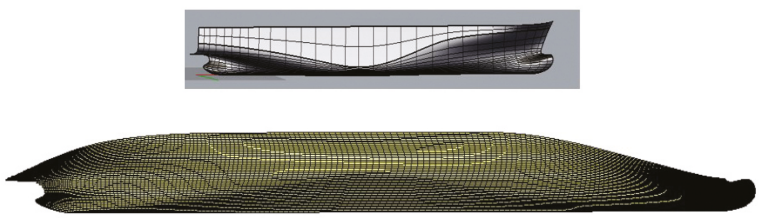

Fig 3: Typical hull form for a 10,000 TEU container vessel

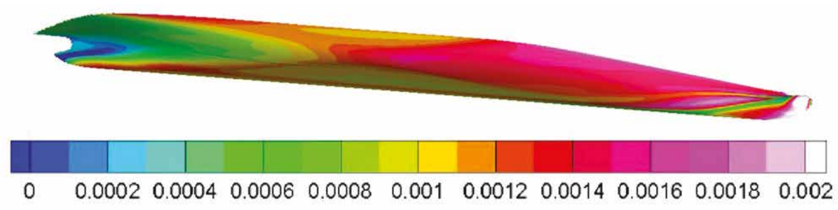

Fig 4: Typical hull form for a 10,000 TEU container vessel: wall shear stress coefficient visualisation for a particular speed and roughness

CFD gives insights into flow patterns and responses of surfaces to flows that are difficult, expensive or even impossible to study using physical experiments. Due to constraints of cost, time and environmental factors, it is not practical to carry out full scale vessel tests to quantify ship parameters in the design. Instead model scale tests, such as towing tank studies are routinely employed to generate form drag information and optimize hull design and operational parameters, all of which can be readily and reliably scaled up to full ship scale. However, certain parameters such as frictional resistance are less reliably related to full ship scale. Although empirical formulae such as the ITTC method can be used to estimate full scale resistance (ITTC, 2008), the CFD models embedded in Intertrac®Vision allow frictional resistance to be calculated for generic hullforms, taking into account the macro, micro and fouling roughness components (Fig. 3).

The effect of hull roughness and vessel speed on the wake field to the propeller can also be derived from the CFD calculation. A higher hull roughness increases the boundary layer and leads to a higher wake fraction in the propeller plane. Due to this, the propeller encounters water with a lower velocity and subsequently the propeller loading becomes higher. A higher loading leads to a lower efficiency. Thus, a higher hull roughness leads to a higher resistance but also to a lower efficiency. It is observed that when the roughness increases, the increase in wake fraction is very limited. Only when the hull is very heavily fouled does the wake fraction increase significantly.

MARIN's DESP software package was used to compute the powering requirement for each hullform for the hypothetical hydrodynamically smooth condition and any given total roughness. DESP, which is based on the Holtrop-Mennen approach, is capable of calculating the power needed to propel a ship with a certain resistance at different speeds. After selection of the propeller type and dimensions the required thrust is calculated using the calculated resistance and a statistically determined thrust deduction. Interaction coefficients such as effective wake fraction and relative rotative efficiency are also determined statistically and together with the calculated open water efficiency of the selected propeller the overall efficiency is calculated. Intertrac®Vision combines all this information to generate a prediction of the required power which we believe is more accurate than previous powering models that are based on the simpler ITTC approach.

The impact of the predicted powering requirement on fuel oil consumption (FOC) can then be derived by making the common general assumption that power and fuel are directly proportional over the relevant range. This FOC prediction can be expressed relative to an appropriate reference consumption from a ship in-service with a known hull condition. Alternatively, if suitable in-service reference data is unavailable, the FOC prediction can be made relative to an estimated FOC for a given hull condition.

What Intertrac®Vision delivers

The coating performance models embedded within Intertrac®Vision combine an assessment of total roughness, based on micro, macro and fouling roughness components, with CFD modelling of total resistance for different hullforms. This enables predictions to be made of the impact of fouling control coatings choices on ship operational efficiency. The key default outputs of Intertrac®Vision for each potential coating selection and substrate preparation choice are:

- a powering requirement prediction over the full drydock cycle;
- a fuel oil consumption prediction over the full drydock cycle;
- a fuel oil cost prediction over the full drydock cycle;
- a full cost benefit analysis covering the full drydock cycle;
- a prediction of GHG emissions over the full drydock cycle.

Testing and validation of Intertrac®Vision

Intertrac®Vision incorporates a new sophisticated model to predict the impact of fouling control coating choices on ship operational efficiency. This new model has been tested in conjunction with University College London and several commercial ship operators and the predicted powering requirements generally correlate well with in-service data. These results validate the overall approach and establish confidence that Intertrac®Vision provides improved predictions over previous models.

Further testing continues and this will build up the dataset of in-service data for a wider range of ship types and operational profiles. Our expectation is that this increased dataset will allow further refinements and improvements in the underlying model to be made, leading to a further evolution of the Intertrac®Vision platform.

Summary

The impact of fouling control coating choice on vessel performance is well recognised and the ability to make reliable predictions on vessel performance is of critical importance. Ship owners and operators are sometimes sceptical about coating performance claims and there is a genuine need for more accurate and transparent prediction models to be developed. Intertrac®Vision is a new ship powering prediction model that builds on previous approaches, developed by International® in collaboration with leading academic and commercial research institutes, ship owners and operators. The model combines an assessment of total roughness (comprising micro, macro and fouling roughness components) with CFD modelling of total resistance for different hullforms, in order to make more reliable predictions. Specifically, the key outputs of Intertrac®Vision include powering requirement, fuel oil consumption, fuel oil cost, GHG emission predictions and full cost benefit analysis for each potential fouling control coating choice over the full drydock cycle. Intertrac®Vision will allow ship owners and operators to make informed decisions regarding fouling control coating selection from both an economic and environmental perspective. International® seeks to work collaboratively with interested third parties and ship operators to further develop Intertrac®Vision and support future improvements in ship efficiency.