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WHY YOU SHOULD MEASURE SHAFT POWER AND THRUST

White Paper

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Abstract

The present white paper aims to alert the marine professionals dealing with ship performance for the benefit of having a tool like OPTIPOWER, an integrated shaft power, thrust and torque meter capable of segregating the hull from the propeller and main engine inefficiencies. The paper is based on the long field experience of TecnoVeritas on ship performance analysis.

Despite of the fuel lower price in the generality of the ports, the freight rates are thin and to run a fleet efficiently requires the monitoring of the performance of the vessels. The great maxima states that "the one that does not measure, has only a vague idea" and on this vague idea is most or at least a good part of the vessel profitability.

Also, the competitiveness on most routes require well managed vessels in terms energy efficiency, i.e., in terms of fuel usage, giving a positive image and actual business advantage. Finally, new rules and regulations are just about to apply, calling for a very conscientious operation of a sea any going vessel.

Ship performance analysis is in our days of utmost importance for a successful operation, but this practice requires a number of tools to help managers to decide upon technical data.

Some of the most important ship operation parameters are the fuel consumption, but also the way that fuel is being converted into useful energy and therefore work.

Fuel tanks are chemical energy storage devices, engines are converters of chemical energy into mechanical energy, shafts are energy transmitters and finally propellers are converters of mechanical energy into hydraulic energy.

It is on this energy chain where energy inefficiencies lay, and necessarily it is in each one of that chain components that conversion performance needs to be applied in firstly.

Typically a small to medium size container ship overall energy efficiency is in the best of the cases around 40%, this means that 60% of the fuel burnt is wasted, dumped into the sea, and air. As the energy chain deteriorates its energy conversion performance, the overall energy efficiency lowers and the vessel running costs and air pollution increases.

Effective tools for vessel energy conversion chain efficiency monitoring

Img 1. Expensive control and monitoring systems, need to be complete.

Despite nowadays the monitoring systems on board are more extensive and complete than their predecessors of 20 years ago, most of the vessels do not have means for adequately measure the energy conversion chain main components.

Fuel Tanks	Chemical Energy
Main Engine	Mechanical Energy
Propeller	Hydraulic Energy
Hull	Mechanical Energy

$$\eta = \frac{E_{mech}}{E_{che}} \qquad \eta = \frac{Torque * Speed}{\dot{m}_{fuel} * NCV}$$

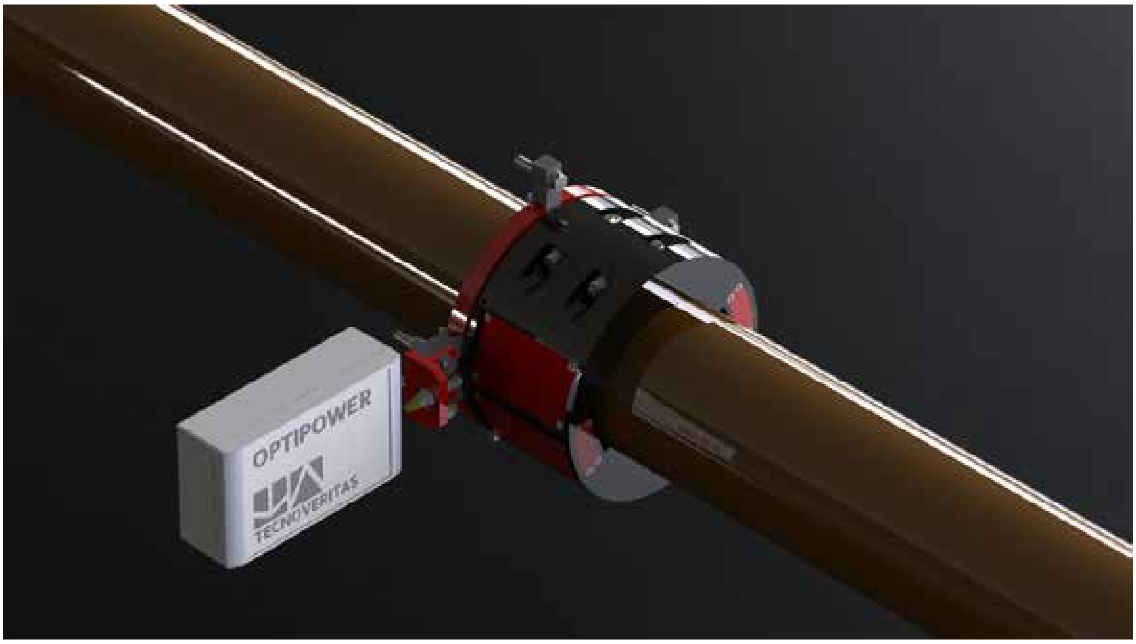
$$\eta = \frac{E_{che}}{E_{hyd}} \qquad \eta = \frac{\dot{m}_{fuel} * NCV}{Pressure_{hyd} * Velocity}$$

$$\eta = \frac{E_{hyd}}{E_{mech}} \qquad \eta = \frac{Pressure_{hyd} * Velocity}{Thrust * Speed}$$

Therefore there is a need to identify which of the main energy converters is performing away of its optimum, and correct such deviations through predictive maintenance.

Despite the existence of other ways of measuring main engine power, the use of a shaft torque meter and a flow meter brings great advantage, as a balance of energy may be produced, and power delivered to the propeller may be calculated with reasonable accuracy, therefore ship performance may be carried out. However to carry a thorough analysis of the ship performance, the simultaneously reading of shaft torque and its speed and thrust will extract the best data for ship performance analysis, this evidently complemented by an accurate flowmeter, for example of the Coriolis type.

TecnoVeritas has developed Optipower an integrated shaft power, torque and thrust meter, delivering information through most of the industry protocols, including the proprietary NMEA0183.



Img. 2 The Optipower Integrated Shaft Power, Thrust, Speed, and Torque meter.

Using **OPTIPOWER**, can identify and segregate where the inefficiencies are, by defining and monitoring some Key Performance Indicators (KPI), such as:

Ship speed over water SOW as a function of propeller absorbed power P_D;

$SOW = f(P_D)$

Ship speed over water SOW as a function of propeller developed Thrust T;

$SOW = f(T)$

Propeller developed thrust T as a function of propeller absorbed power P_D;

$T = f(P_D)$

Ship speed over water SOW as a function of engine power P_b;

$SOW = f(P_b)$

Or simply, monitoring the above mentioned parameters ratios as a function time. For example:

$KPI = \frac{SOW}{P_D} = f(\text{time})$ In case this ratio decreases over time, then you may have a dirty or damaged propeller, or a fouled hull;

$KPI = \frac{SOW}{T} = f(\text{time})$ In case this ratio decreases over time, then you have certainly a fouled hull;

$KPI = \frac{SOW}{T} = f(\text{time})$ In case this ratio decreases over time, then is time to clean and polish the propeller, of check if pitch schedule remains unchanged in case of CPP's.

N.B.: Although, the procedure looks straight forward, a great care of data treatment needs to be put forth, as not all data is good for performance analysis, which is the same to say meaningful.

Another white paper on BOEM-S software and Big Data treatment will be focusing the raw data treatment, to obtain valuable information.

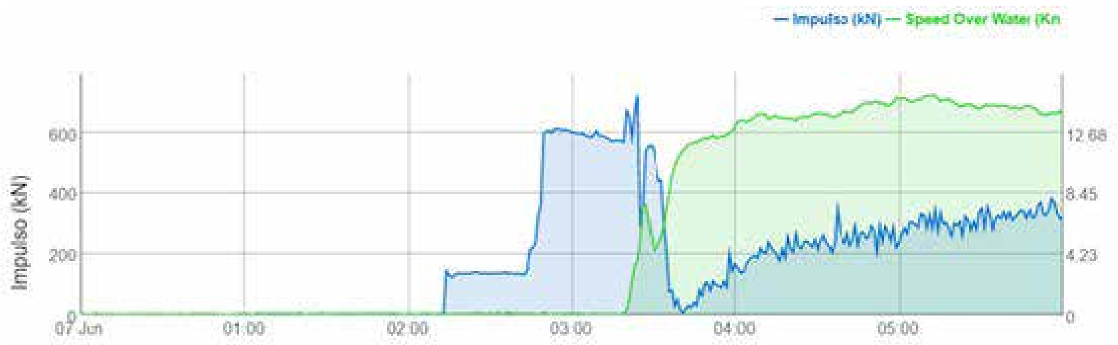
There are other KPI that have been used, although none is so direct and produces such a direct correlation as the complementary use Power, Speed and Thrust.

There is a deficient understanding of the thrust and speed relationship, and therefore a certain difficulty in understanding an interpreting the thrust measurements.

Understanding Thrust and Power

In fact, as mentioned above, the propeller is an artefact that converts mechanical energy delivered to it, into thrust, and it is the balance between thrust and all forces that act upon the vessel, that generates the vessel movement forward. It is the second law of Newton. Among the forces acting on the vessel, are the wind resistance, hull resistance, and others.

$$V_s = \frac{1}{m_{ship}} \int_{t_1}^{t_2} T(t)dt$$



Img. 3 Graph showing Thrust and Speed Over ground as a function of time for a ship initiating a voyage in calm waters.

In fact, the variation of speed through the water in a time interval, equals the force acting upon the hull, divided by the mass of the vessel. This is way, when looking at a thrust speed graph, thrust is usually much higher when the vessel starts to move, lowering when it reaches a stable speed as it can be seen on the graph above image 3. As it can be seen on the above graph, the thrust is very high at engine start, and as the vessel gains speed, the thrust starts to stabilise just below 200 kN. At the end of the day, the power absorbed by the hull is equal to the force actin upon it times the speed of the hull.

$$P_{hull}(kW) = T(kN) \times V_S(\frac{m}{s})$$

Conclusion

The use of OPTIPOWER, allows the complete understanding where performance inefficiencies are, and the maintenance of the vessel energy conversion systems always in a tiptop condition, by identifying where care is needed.