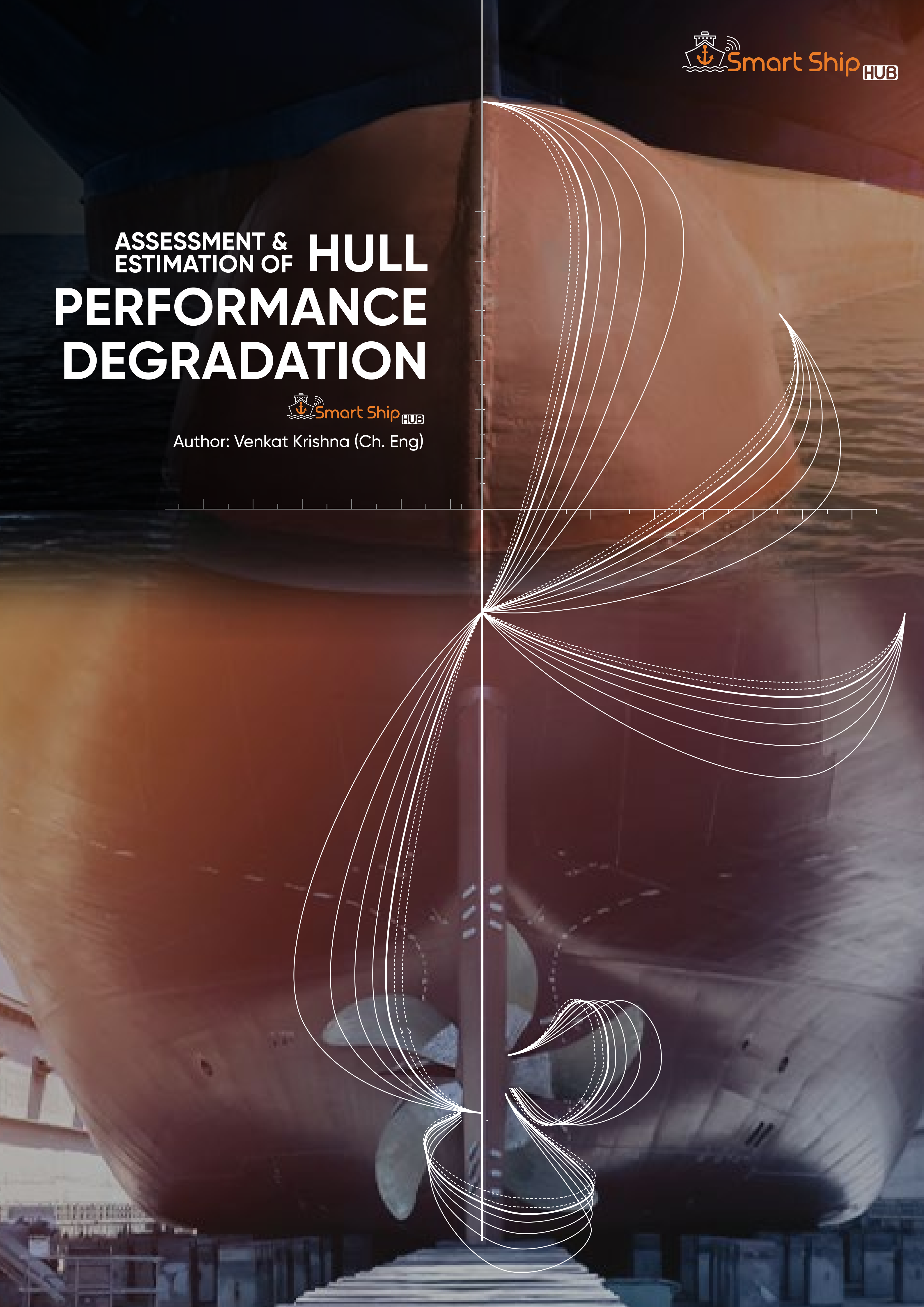

ASSESSMENT & ESTIMATION OF HULL PERFORMANCE DEGRADATION

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Introduction

Hull and propeller performance refers to relationship between the condition of a ship's underwater hull and propeller and the power required to move the ship through water at a given speed.

Hull and propeller performance are related to variations in power, because ship hull resistance and propeller efficiency are not directly measurable quantities.

ISO 19030 suggests two basic performance indicators.

ISO 19030 Performance Indicators:

ISO 19030, outlines two general principles for the measurements of changes in hull and propeller performance indicators for hull and propeller maintenance, repair and retrofit activities. These two principles/indicators are:

Power Deviation:

The deviation between the actual measured shaft power and the theoretical from a vessel's baseline, for the same speed.

Speed Loss:

The deviation between the actual measured vessel's speed and the theoretical from a vessel's baseline for the same power.

Moreover, ISO 19030-2 describes in detail the primary and secondary parameters that a HFDCS should collect for calculating these indicators.

Hull and propeller performance are related to variations in power, because ship hull resistance and propeller efficiency are not directly measurable quantities.

Parameters required:

Primary:
The defined primary required collected parameters are:
- Speed Through Water
- Delivered Power

Secondary:
The defined secondary suggested collected parameters are:
- Shaft revolutions
- Relative wind speed/direction
- Speed over ground
- Heading
- Rudder angle
- Water depth
- Static draughts (fore & aft)

From these values the calculation of the **"Power Deviation"** and/or the **"Speed Loss"**, requires also the selection/availability of the relative baseline. From vessel's sea trials, three are the most common provided baselines (in some cases though, only two – ballast/laden – are available).

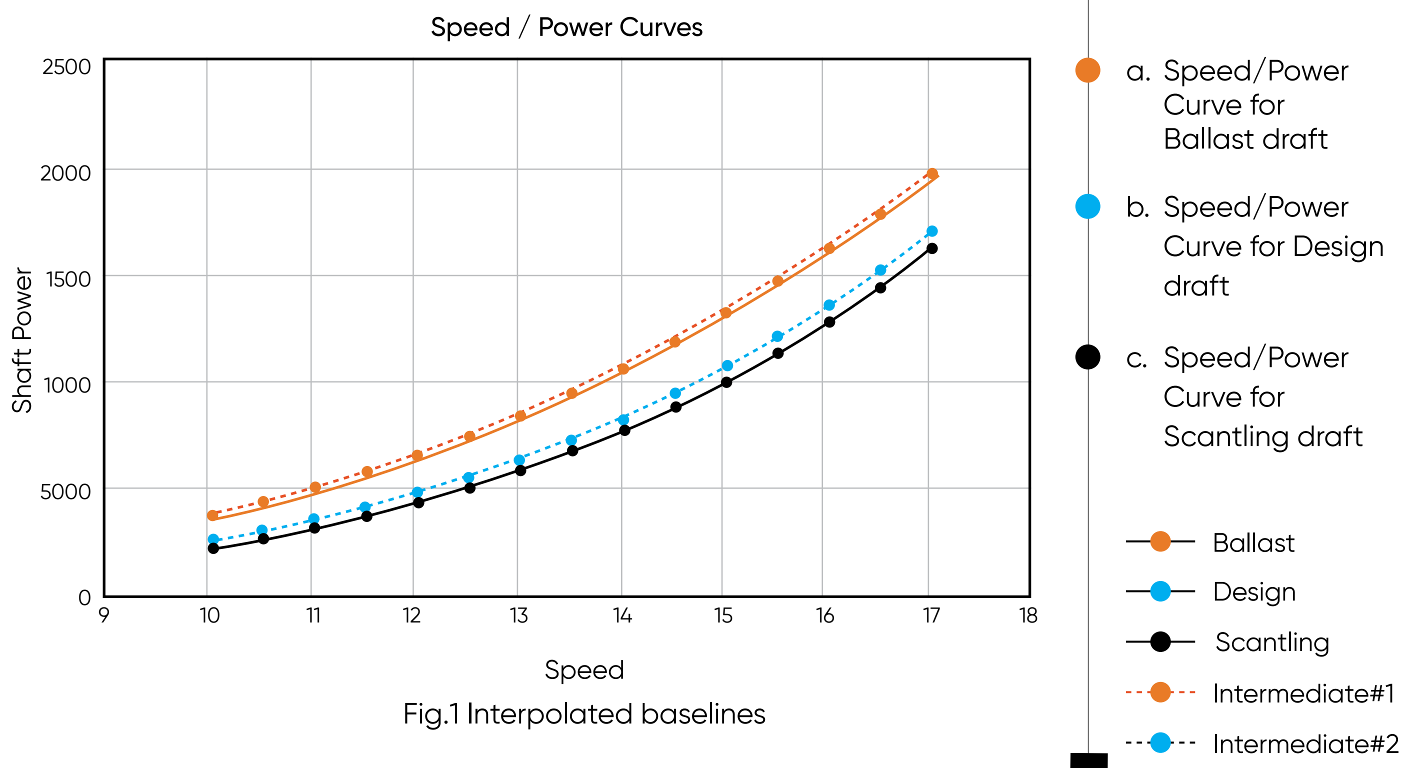


Fig.1 Interpolated baselines

In order to select the correct baseline, the knowledge of vessel's actual draft is imperative.

Most of the times, the actual vessel's draft is not coinciding with one of the above, so interpolations are required for the selection of the best fitted baseline for intermediate drafts.

Filtering of Data:

All collected data, should also be filtered under the conditions that table A.1 of ISO 19030-1 describes and more specific for:

- True Wind Speed of less than 7.9 m/sec
- Absolute difference of (SOG – STW) less than 1 knot
- Sea depth criteria – usually for depth higher than 50m
- Vessel's speed within limits according the available baselines

ISO 19030 Performance Indicators outputs:

Under the above described conditions, the HFDCS calculates continuously both of these two performance indicators.

When vessel's resistance is increasing (mostly due to hull & propeller fouling), the vessel in order to achieve the same speed requires higher shaft power (power increase), or at the same shaft power, the vessel is achieving lower speeds (speed loss). So:

Power Deviation (%): Positive values/Increasing by time (positive trendline)

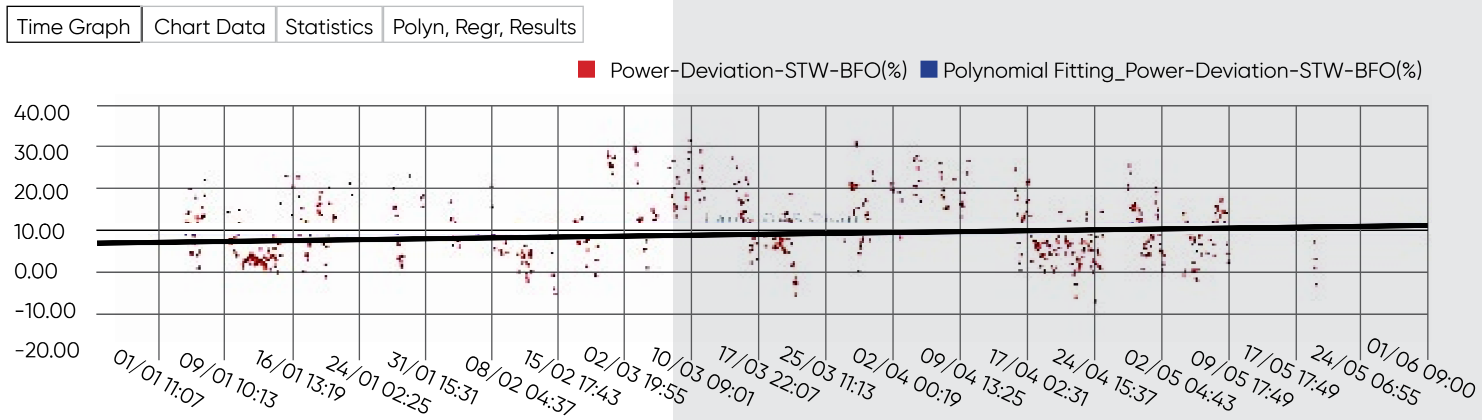


Fig.2. Power deviation

Speed Loss (%): Negative values/Increasing (in absolute values) by time (negative trendline)

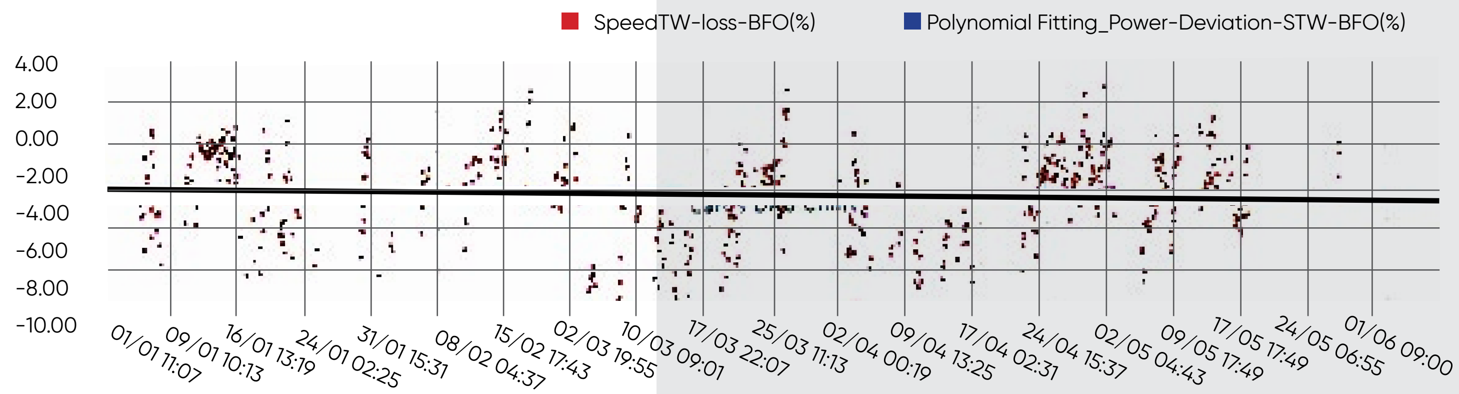


Fig.3. Speed Loss

Accuracy of collected data:

All sensors and equipment that are measuring the above required for the calculation's parameters, usually are very accurate with the exception of the drafts. The sensors that are measuring vessel's drafts are often very susceptible to fault measurements due to external factors (sensors age, water salinity, calibration etc.).

For this reason, though, in many cases – since the automatically collected data for the vessel's draft from an installed HFDCS cannot be considered reliable – these data are being entered manually to the HFDCS, as direct entries, or through external systems as an EPR software, AIS data, noon reports etc. However, again in all these cases, the vessels' drafts estimation by vessels' crew – especially when the vessel is underway – include many uncertainties and they deviate significantly from the actual.

For this reason, without having accurate draft measurements (especially for older vessels), the Outputs of these indicators – and not only – may provide wrong conclusions regarding vessel's Previous performance, as well as predictions for vessel's future performance.

Alternative Indexes for Estimating Hull Performance Degradation:

In addition to the performance indicators that ISO 19030 describes, alternative indexes have been extensively used in order to provide an estimation of vessel's performance degradation.

The most used of them are:

Percentage of slip:

Slip is considered as the difference between the speed of the engine and the actual speed of the ship. It is always calculated in percentage.

Positive slip is influenced by various reasons such as fouled bottom or hull part which offers resistance to the movement of the ship, environmental factors such as water current and wind against the ship direction.

The slip may be negative if the ship speed is influenced by following sea or wind.

If the propeller had no slip i.e. if the water which the propeller 'screws' itself through did not yield, the propeller would move forward at a speed of:

VT = P x N

VT is theoretical speed (m/s or in knots)

P is pitch of propeller & N propeller rate of revolution in rev./min. or rev./sec.

Under increased resistance, this involves that the propeller speed (rate of revolution) has to be Increased in order to maintain the required ship speed.

% slip then would be: (VT – V)/V, where V is actual speed of vessel.

While vessel's performance deteriorates through time due to hull & propeller fouling (considering good weather conditions), vessel's slip is increasing.

RPM: Engine's RPM at Maximum Continuous Rating
shp: Operational Engine's Power
rpm: Operational Engine's rpm

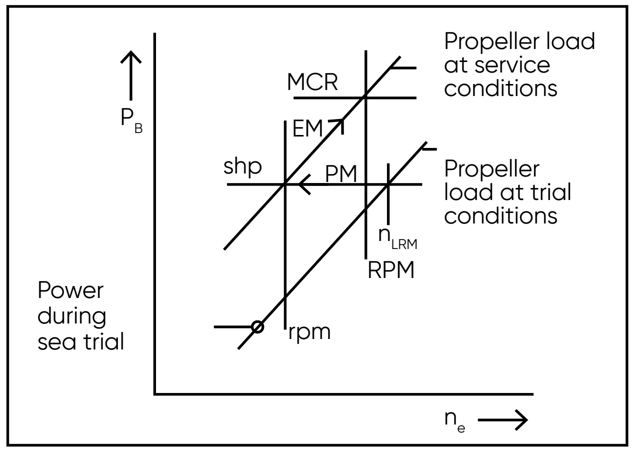


Fig.4. Engine/ Propeller Margins

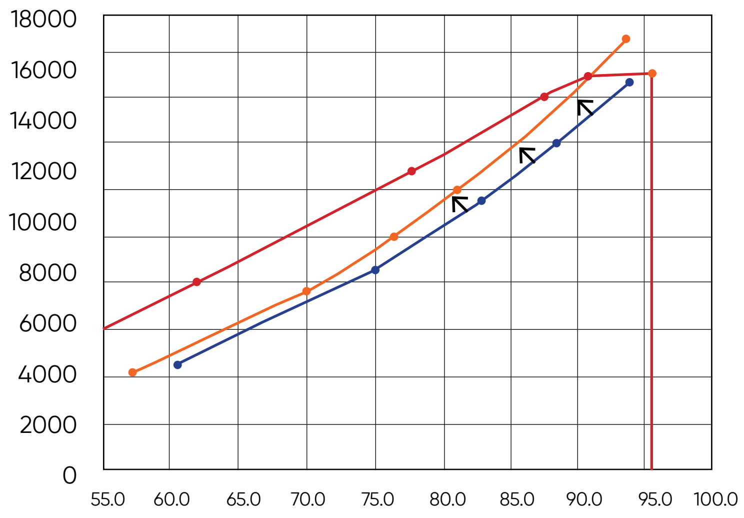


Fig.5. Shift in light propeller running margin during heavy propeller running

Engine (Load) margin & Propeller margin:

Engine load margin (EM) is the available engine load for overcoming additional encountered resistance.

This margin is required to achieve reasonable maintenance intervals of the engine, to enable a higher speed than design speed in case the ship is behind schedule and to cope with increase loads due to more fouling or a higher sea state than in desig condition.

Propeller margin (PM) is the available rpm (or % of rpm) at a specific power for overcoming additional encountered resistance. It relates the engine speed difference between the service propeller curve and the propeller curve at light running conditions.

The vessel, in calm seas and with a clean hull and propeller, has a positive engine load margin and propeller margin, which is needed to overcome any additional encountered resistance.

Considering good weather conditions, due to hull and propeller fouling both these margins will start decreasing.

Combined Power (P)/RPM (N)/Speed (V) analysis for performance deviation:

Through this analysis a concurrent "power deviation" and **"speed loss"** indexes can be calculated from a combined Power (P), RPM (N) and Speed (V) analysis (PNV). For this analysis, again the speed/power curves from vessel's sea trials are considered, together with vessel's shaft rpm. With these three parameters, the parabolic curves of speed vs power can be converted to linear as f (P, V) vs f (V, N). Through this transformation, all data for either ballast & scantling drafts – as well as for all the intermediate drafts – have the same linear trendline in the form of Ax+B3.

Use Case:

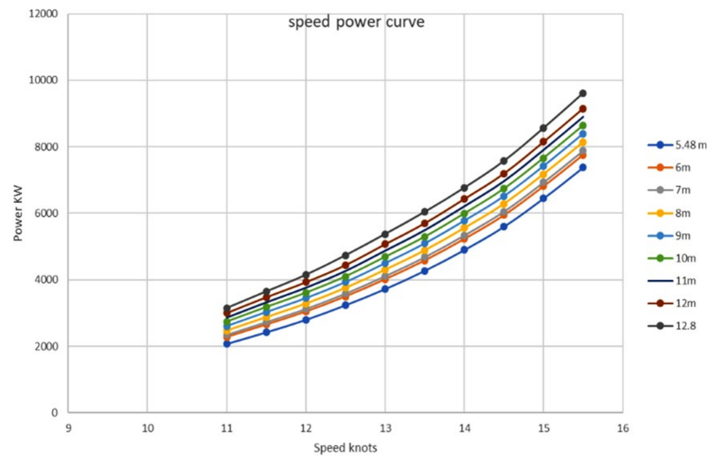


Fig. 6 Original interpolated Sea trial curves

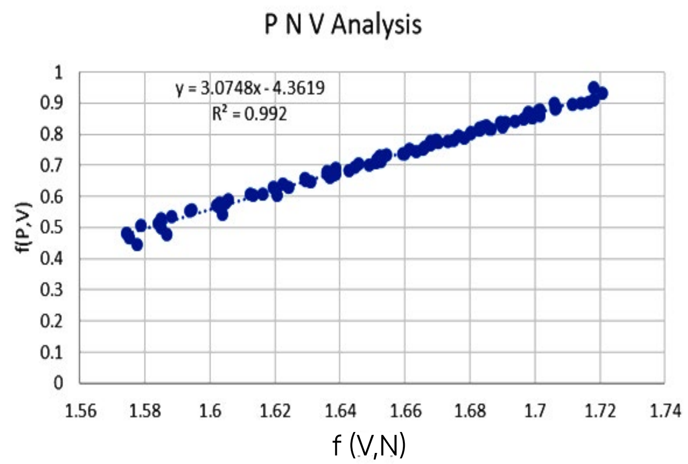


Fig.7 Parabolic to Linear conversion (combined ballast & laden conditions)

Data Selection:

The collected/calculated parameters that were used in the analyses and the calculations were the following, and as suggested by ISO 19030:

- Speed Through Water
- Speed Over Ground
- Propeller Shaft Power
- Propeller Shaft revolutions
- Relative wind Speed/Direction
- Heading
- Rudder Angle
- Water Depth
- Static Draughts (fore & aft)

Data Acquisition:

All data have been collected through High Frequency Data Acquisition System, independent from main vendors. It is a system where wireless/ wired smart collectors are connected on any existing vessel's sensors, SCADA or equipment, for collecting the agreed datasets in a single and integrated approach and transmitting them to a centrally installed server.

Then the collected data can be analysed and presented on vessel's crew – if required, and transmitted – even in real time – to vessel's headquarters for further and more detailed analyses and storing.

The accuracy of all collected data from system is relative to the accuracy of each sensor/equipment providing the specific measurement.

Machine Learning (ML) and Artificial Intelligence (AI) through the high frequency data collections can also decrease significantly the uncertainty of the collected measurements. Sampling rate 15 secs.

Collection of Data – Filtering of Data – Aggregation:

All required data for the calculation of the relevant indexes were collected and used for the calculation of below indexes:

- ISO Power Deviation
- ISO Speed Loss
- Percentage of Slip
- Engine Load Margin
- Propeller Margin
- PNV – “Power Deviation”
- PNV – “Speed Loss

The collected data were filtered initially under the conditions that table A.1 of ISO 19030-1 describes and more specific for:

- True Wind Speed of less than 7.9 m/s
- Absolute difference of (SOG–STW) less than 1 knot
- Sea depth criteria – usually for depth higher than 50m
- Vessel’s speed within limits according the available baselines

Especially for the true wind speed a further filtering was used for wind speed of less than 5.5 m/s (Beaufort 3).

Additionally, to that, for each parameter the outliers have been identified and removed and specific filters have been added, as specified below:

- Speed Through Water: Between 10 & 16 knots
- Speed Over Ground: Between 10 and 16 knots
- Propeller Shaft Power: Between 20% and 100% of MCR
- Propeller Shaft revolutions: Only outliers
- Relative wind Speed/Direction: Only outliers. The filter has been added to the calculated True Wind Speed
- Heading: Only outliers
- Rudder Angle: ± 2.5°
- Water Depth: Higher than 100m
- Static Draughts (fore & aft): Between ballast and scantling drafts

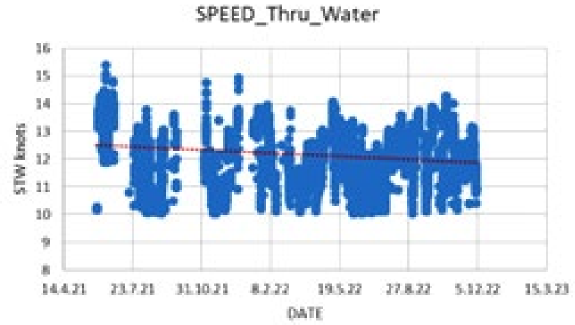
Analysis procedure:

For the analysis procedure below steps were followed:

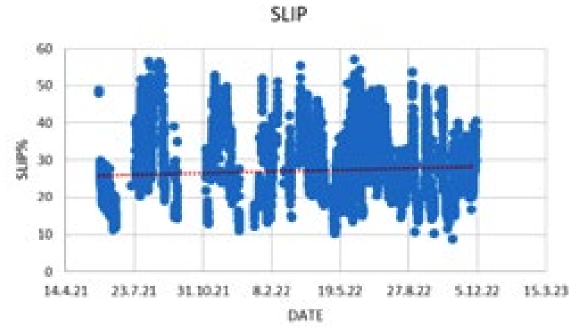
1. For the vessel all above-described performance indicators were calculated for two years’ time period. The calculated results then were filtered and aggregated as described.
2. Relevant time graphs of all indicators were plotted for each vessel together with the derived linear trendlines, presenting the performance degradation of the vessel.
3. Finally, the derived trendlines of the non-ISO indicators were compared with same from the ISO indicators for analogies/ patterns.

Use case: (P N V analysis):

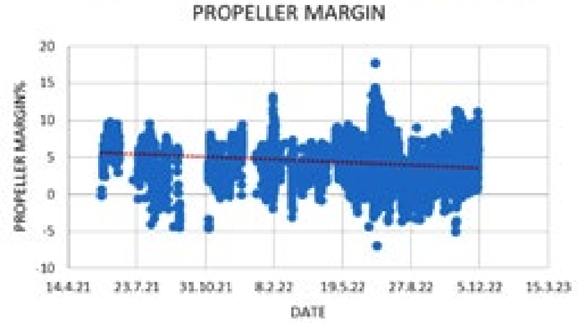
Following representations are displayed for a Bulk Carrier in good weather conditions by applying relevant data filters.



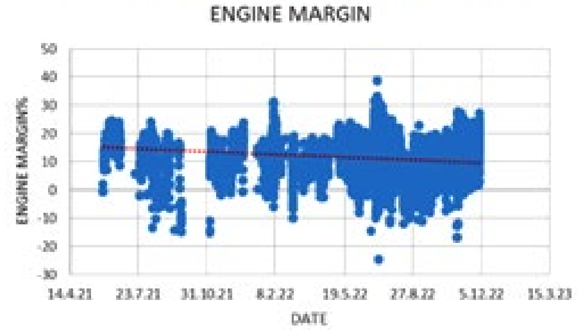
Speed thru' water is observed to decrease over time.
Approx. 5% reduction in STW is observed.



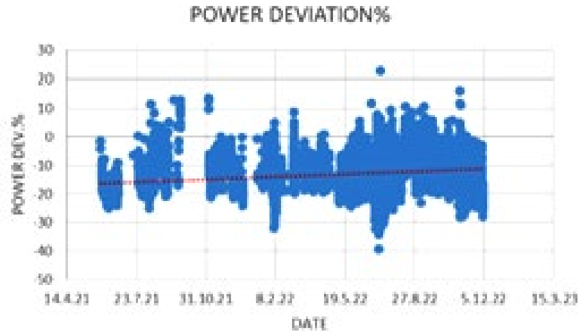
Slip% (apparent slip) is observed to increase over time.
Approx. 4% increase in slip is observed.



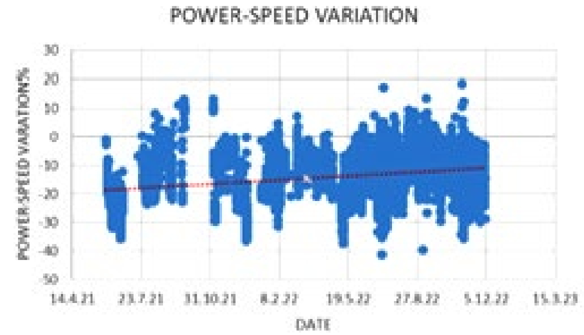
Propeller margin% is observed to decrease over time
Approx. 2% reduction in propeller margin is observed.



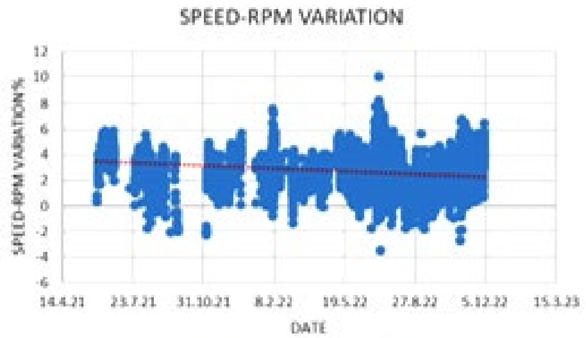
Engine margin% is observed to decrease over time
Approx. 5% reduction in engine Margin is observed.



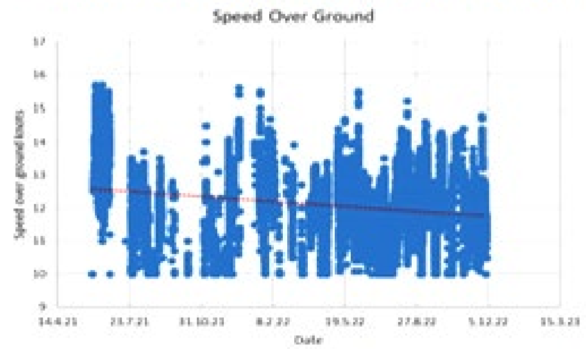
Power deviation% is observed to increase over time.
Approx. 7% increase in Power is observed.



Power-speed variation% is observed to increase over time. **P/V ratio is observed to increase by 8%. (Signifies Increase of Power and reduction of vsl. speeds).**



Speed-rpm variation% is observed to decrease over time
V/N ratio is observed to reduce by @2% (Signifies decrease of vsl. speeds and increase of engine rpm).



Speed over ground is observed to decrease over time
Approx. 7.62% reduction in SOG is observed.

Inference:

As indicated in above representations, clearly a quantified amount of deviations is evident. Based on above evaluations certain informed decisions can be taken.

Hull and propeller cleaning are one such procedure which requires some data to back such decisions. Usually when added resistance increases by @ 15% hull cleaning is recommended.

Using alternate matrices for hull and propeller performance evaluations, speed reductions and increase in power, similar thresholds can be drawn to monitor them using HF data.

Currently Power is observed to increase by @ 7% and speed reduced by @ 5%.

If engine power requirement increases further, say @ 10% hull & propeller cleaning can be exercised.

Conclusion:

After analysing all the above, below conclusion can be derived.

1

In order to have accurate calculations for the suggested ISO indicators, it is required to have accurate draft measurements.

Often though, the relevant sensors are not operating correctly, so especially for older vessels – the calculations of these indicators through a high frequency data collection system are not providing accurate indications for the performance of the vessel.

2

The Propeller Margin and the Engine Margin are independent from vessel's draft and may provide indications regarding the performance of the vessel, but they are also independent from vessel's speed.

3

Vessel's slip is independent from vessel's draft and may provide indications regarding vessel's performance, but it is also independent from shaft power.

From all the above it can be concluded that, the two basic indicators suggested by ISO 19030 – Power Deviation & Speed Loss – are not unique for monitoring vessel's performance.

Alternative indicators can be used in order to have similar or even better/more accurate conclusions.

4

The Combined Power (P)/ RPM (N)/Speed (V) analysis for performance deviation is independent from vessel's draft measurements, while at the same time it takes under consideration all three basic parameters (power, speed, rpm) and it provides similar conclusions to the ISO suggested indicators.

A HFDCS can easily calculate these indicators and depending the selected baseline, accurate conclusions regarding vessel's performance can be derived, so these indicators can be considered as alternative to ISO suggested, especially for vessels where drafts are not known.

References:

1. Suggestion and Evaluation of Alternative Indexes for Estimating Hull Performance Degradation Trendlines Nikolaos Bekiaris, Zacharias Zervos, Ioannis Tolias, Christos Giordamlis, Prisma Electronics, Athens/Greece.

2. ISO 19030-1 (2016), Ships and marine technology – Measurement of changes in hull and propeller performance, Int. Standard Org., Geneva.

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