Prerequisite for optimization

Performance Monitoring is of increasing importance for ship operators. Costs and saving potential can differ depending on chosen strategies. Holger Watter and Michael vom Baur give an overview of tasks and available solutions.

Bunker fuels became a more and more expensive commodity during the last years. Even if HFO prices have dropped below 500 $/ton in November 2014, coming from peak values of 750 $+ earlier this year, the fuel budget is still a dominant part of the ship operation costs, which operators and charterers are trying to reduce as much as possible. There are several means to cut fuel costs. The most common are Slow Steaming, incl. investment to adapt main engine and propeller to new operation, Trim Optimization, in particular for ships with significant bulbous bow, Route Optimization, Innovative hull-coating systems and application of propulsion improving devices (PID), e.g. ducts, fins, contra-rotating propellers.

Whatever you may do, you cannot optimize what you do not measure. In order to justify investments and prove the success of measures taken, some related key performance indicators (KPI) must be monitored and reported. Sometimes the optimum itself is to be determined by measuring during operation of the vessel. Typical KPI are e.g. fuel consumption per nautical mile, fuel consumption per cargo unit x distance or fuel consumption per unit of work [kWh].

In particular in container shipping, the larger time charterers, who pay the fuel but do not have direct operational control, increasingly demand possibilities for performance monitoring (PMO) and consider the availability of PMO systems coupled with operator’s optimization strategies as quality criterion for the selection of ships. On the other hand the operator can use PMO features to reject charterer’s fuel claims, by presenting a recorded reality proof.

PMO enables the proof of prediction for propulsion improving devices (PID) as well as judging whether the actual hull paint condition is still satisfactory or whether cleaning or even new coating would be appropriate. Finally, transparent PMO allows kick-off of competition for lowest fuel consumption between crews of sister vessels in an operator’s fleet.

»Find the needle in a hay stack«
The most basic form of PMO is the classical noon reporting. Once per day a form will be filled on board, containing information about loading condition, speed, sailing distance, fuel consumption and / or shaft power as well as eventually the weather conditions during the past 24hrs. All operators’ inspectors, who have tried to draw conclusions from noon reports, have sometimes been drowned in »clouds of points« in a speed power diagram, in particular when trying to compare different sailing conditions (e.g. with different trim). It is evident that scattered speed power values are not only caused by »comparing apples with oranges« (e.g. probably different weather or small deviations in load conditions) but also by various uncertainties associated with the measurements, ranging from human error, instrument uncertainty, sampling error to possible uncertainty in the modeling of the benchmark reference.

In order to provide some tangible framework in this »cloud of uncertainties«, in particular for measuring changes in hull and propeller conditions, an initiative of the International Standard Organization (ISO) was kicked off (Draft ISO 19030) in 2012. In context with the preparations for
The »secondary parameters« proposed in ISO 19030 are to be considered as a minimum set of influencing conditions, which are to be recorded to enable filtering for comparing »apples with apples« when evaluating voyages. Long term trends, e.g. the increase of hull resistance due to fouling, can be identified by comparing filtered »calm sea/deep water/low rudder activity« data recordings of similar draught + trim conditions against benchmarks such as model test results, CFD computations or results of data recorded during operation (step trials, »permanent trial trip«).

In ISO 19030 Part 3 alternative methods (Proxis) will be mentioned, e.g. determining speed by SOG instead of STW readings. For all methods uncertainty evaluations (expected accuracies) will be provided, thus ISO 19030 will enable a profound »effort vs. benefit« comparison for ship operators. The total uncertainty of the selected performance indicator (e.g. speed loss at constant power, fuel consumption per nautical mile, power per ton x mile, etc.) can be evaluated with statistical error propagation.

First evaluations of long term speed logging, comparing STW vs. SOG, show that in most cases there is no average arbitration effect between SOG and STW even over a long evaluation period and for worldwide sailing. It should also be highlighted that a difference in speed of only 0,1 kts is for most ships at moderate speeds equivalent to a power difference of > 2 % and thus of a significant magnitude. ISO 19030, which is planned to be a voluntary guideline, will provide a General Introduction in Part 1 with the physical context and formulae described in the »Default Method« in Part 2. The following parameters have been proposed to be measured and recorded in this »Default Method«, which has been considered to be the most accurate approach:

- »Primary Parameters«: Speed through Water (StW), Shaft Torque and rpm, Time and Date (GPS, »time stamp«)
- »Secondary Parameters«: Speed over ground (SoG / GPS), Heading, Draught fore + aft (static), Dynamic trim, Relative Wind speed + direction, Water depth, Water temperature, Rudder angle / activity

The accuracy of performance monitoring with NR can be dramatically increased by long term considerations, however, any CM method is clearly superior to using Noon Reports, even if applied during a shorter evaluation period.

The second most critical factor for the accuracy of performance monitoring is the speed measurement. It has been clearly shown in the above mentioned uncertainty considerations that precise speed through water (STW) measurements must be the basis of all performance monitoring, since speed over ground (SOG) as displayed by GPS is always influenced by currents.
tion methods, considering instrument uncertainty (mostly stated by the maker: precision, drift, bias, non-linearity), sampling error (sampling frequency, averaging), human error (during reading, measuring and recording) and possible uncertainties related to the benchmark model (model tests, CFD, sea trials), e.g. interpolation between different draft / displacement and trim values.

For simple monitoring methods, mainly based on manual observations and noon reporting, the total uncertainty of the performance indicator can easily be >15%. In order to prove effects of e.g. trim optimization, propulsion improving devices or special hull paint systems the resolution of performance monitoring must be much higher (at least <3–5%). Low total uncertainty can only be reached with continuous monitoring (CM) systems, based on best available accurate sensors for all relevant influence factors and software with decision methods, considering instrument uncertainty (mostly stated by the maker: precision, drift, bias, non-linearity), sampling error (sampling frequency, averaging), human error (during reading, measuring and recording) and possible uncertainties related to the benchmark model (model tests, CFD, sea trials), e.g. interpolation between different draft / displacement and trim values.

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According to the actual plans and progress Draft ISO 19030 may be distributed for the official stakeholder discussion and formal acceptance procedure in spring 2015.

Sensors and on board data
Even the best monitoring software would lead to uncertain results, if the data sources were not reliable and of best quality (=garbage in => garbage out). Following sensors are recommendable for accurate performance monitoring:

- Sensors for Draft ISO 19030 primary measurement parameters: Shaft Power Meter (incl. Shaft Torque + Shaft revolutions), Doppler Log (STW)
- Sensors for Draft ISO 19030 secondary measurement parameters: Anemometer, GPS, Gyro Compass, Pressure type Draught gauges, MEMS-based Electronic inclinometers and DGPS-systems for dynamic trim, Echosounder (Water Depth)
- Other Sensors: Fuel Flowmeters (Volume Counters + Density Meters, Mass-Flowmeters) and Ship Motion Measuring Systems (MEMS-based)

To provide best results all sensors should be installed in a way that they are as least biased as possible by the vessel’s influences on the parameter to be measured and in a location easily accessible for regular inspection, maintenance and exchange. Some key sensors are:

**Shaft Power Meter (SPM)**
SPM should be removable, insensitive against usual conditions at the shaft (vibration, dust/oil, heat, etc.) and boast a zero-check as well as self-testing functions. Strain gauge based SPM systems have some special disadvantages, e.g. lifetime application and ageing. Some makers are offering combined torque + thrust measuring features, however, since a large part (up to 50%) of the measured shaft compression can also be caused by temperature changes, which have to be computationally corrected, the uncertainty of such thrust meters is rather high.

**Doppler logs (STW)**
In normal ship operation the speed log is rarely paid as much attention as necessary for accurate performance monitoring. IMO A.824(19) »performance standard for devices indicating speed and distance« stipulates a maximum error of 2% or 0,2 kn, which is pretty rough for performance monitoring purposes. The top graph shows that recorded STW values often fluctuate considerably. May be in the future more precise logs will be available on the market, since measuring flow by the Doppler principle is possible with higher accuracy, as we know from oceanography. In any case the log transducer should be placed at a location carefully selected considering the flow around the hull, to avoid disturbances by instable flow layers.

**Draught / trim / motions**
Draught sensors should be pressure type however, they work at zero or very slow speed only. Thus the draught indicated is the static part and does not include dynamic trim or squat effects. Since the difference between static and dynamic trim can easily exceed some decimeters even for large vessels, measuring the dynamic trim is recommended, which can then also provide squat correction. This can be done either by using appropriate MEMS-based »electronic inclinometers« (more than one sensor, to cope with the hull bending, or (even more accurate) by applying a DGPS based system with two precise GPS antennae. MEMS-based systems can in principle also record the ships motions and thus provide a filter criterion which would be even better than the present Draft ISO 19030 proposal.

**Fuel flow meters**
A proper energy balance needs the fuel mass consumption. Most flowmeters installed today are volume counters derived from water meters. For such sensors the frequent pressure pulses / back flush phenomena in fuel systems are a challenge, since many of them are not able to distinguish the direction of the flow and thus produce partly erratic results. More sophisticated volume counters, e.g. those originally developed for the chemical industry, can cope with pressure pulses and should be preferred. However, to know the fuel mass consumption, temperature and density also have to be measured. A direct way to measure mass flow is via a flowmeter according to the Coriolis principle, which is available today in the marine industry at a relatively low cost and of which already several hundred are installed on ships. It should be well noted, that the accuracy of flowmeters changes considera-
bly with the distance to the design point. Flowmeters designed for flow rates at MCR are often quite inaccurate at slow steaming consumptions, thus the selection of the flowmeter size should be carefully adapted to the intended operation profile.

**Rudder activity**
Even small rudder angles <5° change the ship’s resistance and the propeller curve considerably, dependent on type and profile of the rudder. Consequently frequent rudder activity for course keeping, as caused by certain autopilot settings, may have significant influence on the actual performance indicator. Thus rudder activity is an important secondary parameter to be logged and considered in comparing different data sets.

**On board data integration / logging**
For simple monitoring of speed and power continuous data logging on board is relatively straightforward. However, a continuous performance monitoring system only becomes a reliable tool with a broad set of logged »secondary parameters« with low uncertainties. Electronic information / signals for those secondary parameters can be received from the ships automation and navigation systems as well as from individual devices. It is obvious that the integration of such data into a continuous data base with uniform time stamp requires both, experience and dedication for data integration with many players involved (by far not a trivial task!) and sophisticated data base and software solutions.

**Technical development**
Key performance indicators (KPI) are of interest for the crew on board to obtain operational feedback also in context with optimizations tasks as e.g. trim. The simpler onboard performance monitoring solutions are often developed around shaft power meters by the respective makers (e.g. Kyma, Lemag, TSX / Seatechnik, Maihak (Hoppe Marine), VAF, MAC, TX Marine, etc.). Such systems sometimes offer limited data transfer data to shore by a simple CSV file (Excel) as e-mail attachment. Meanwhile in particular the larger operators wish to have all logged data available ashore (and this in real time), e.g. for fleet analysis and charterer information. This opens a new challenge: to combine a high sampling frequency of many parameters (needed for low uncertainty) with a compact data volume feasible for real time shore transmission (e.g. 1 x per minute).

Some years ago first providers such as Eniram offered software solutions and analyses as a service, hosting the logged and transferred data on the provider’s servers. Other fleet management software concepts followed, provided by e.g. Marorka, Propulsion Dynamics, BMT Smart, NAPA (now Class NK), DNV GL and Interschalt Bluetracker (now in partnership with Hoppe Marine). Large automation makers such as Kongsberg (K-Chief, now in coopera-

tion with Marorka) and ABB (EMMA) offer performance monitoring functions as part of their »vessel management« solutions, with few experiences yet. Speaking to a number of operators, there seems to be quite some reluctance to store sensitive operational data »in the cloud« (at the software providers’ servers). Furthermore, operators often want to be able to perform all kind of analyses themselves, based on the logged and transferred data.

We have shown in the above, that performance monitoring can be in many ways, ranging from classical noon reporting to automatic continuous data logging and real time shore display. High resolution / low uncertainty requires higher investment in sensors and systems, while low end solutions may also require more dedicated staff for evaluation to reach at least acceptable uncertainty levels. Today costs for performance monitoring systems range from some 30,000 $ per vessel for very simple SPM-based solutions up to 200,000 $ per vessel for a highly sophisticated fleet management solution. Even the higher end of the price range can be quickly amortized by savings in fuel cost by e.g. trim and route optimization or some successfully rejected charterer’s fuel claims. Each operator will have their own view and decision regarding the level of performance monitoring they wish to carry out and it will undoubtedly become an ever more important part of operators’ tasks in future.

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Screenshots of a Fleet Management System

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