WHY DYNAMIC DRAUGHT MEASUREMENT IS IMPORTANT?

HOPPE MARINE WHITEPAPER

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>> THE PROBLEM WITH HYDROSTATIC PRESSURE SENSORS

A vessel is subjected to various hydrodynamic effects when navigating. These effects are caused by vessels speed dependent pressure variations, which are increasing with the square of the speed, like figure 3 shows. This phenomena leads to significant deviations of the draught and trim when measured with hydrostatic pressure sensors.

In normal daily operation, an incorrect evaluation of the relationship between engine power and trim condition can cause significant increase in fuel consumption and costs, which could be avoided with the correct monitoring of the vessels operational data to optimize speed and trim.

>> WHAT ARE DYNAMIC DRAUGHTS NEEDED FOR

It is only with a proper dynamic draught and trim measurement that ship performance can be continuously monitored and compared. These are key parameters which can make a difference in all the calculations that need to be done to achieve the Key Performance Indicators of the trim optimization process. With this information at hand, better decisions to plan docking intervals can be made, downtime due to unexpected maintenance can be reduced and a predictive investment plan can be created for the maintenance of vessels.

Regular performance reports and trend data analysis optimizes hull and propeller monitoring, allowing a condition-based problem identification and corrective measures. This not only provides the possibility of increasing the energy efficiency and be compliant with environmental standards but also allows to reduce the operational costs and perform comparative energy efficiency analysis of a fleet. The possibilities are virtually endless.

And the more accurate the dynamic floating condition measurements are, the more meaningful the vessel's characteristic power increase diagram will be, giving sound decision making information for engine power and trim optimization, opening the way to reach the required goals in GHG emissions, fuel and cost reduction. If one takes a closer look at the diagram in Fig. 1, it becomes more clear that two neighboring values

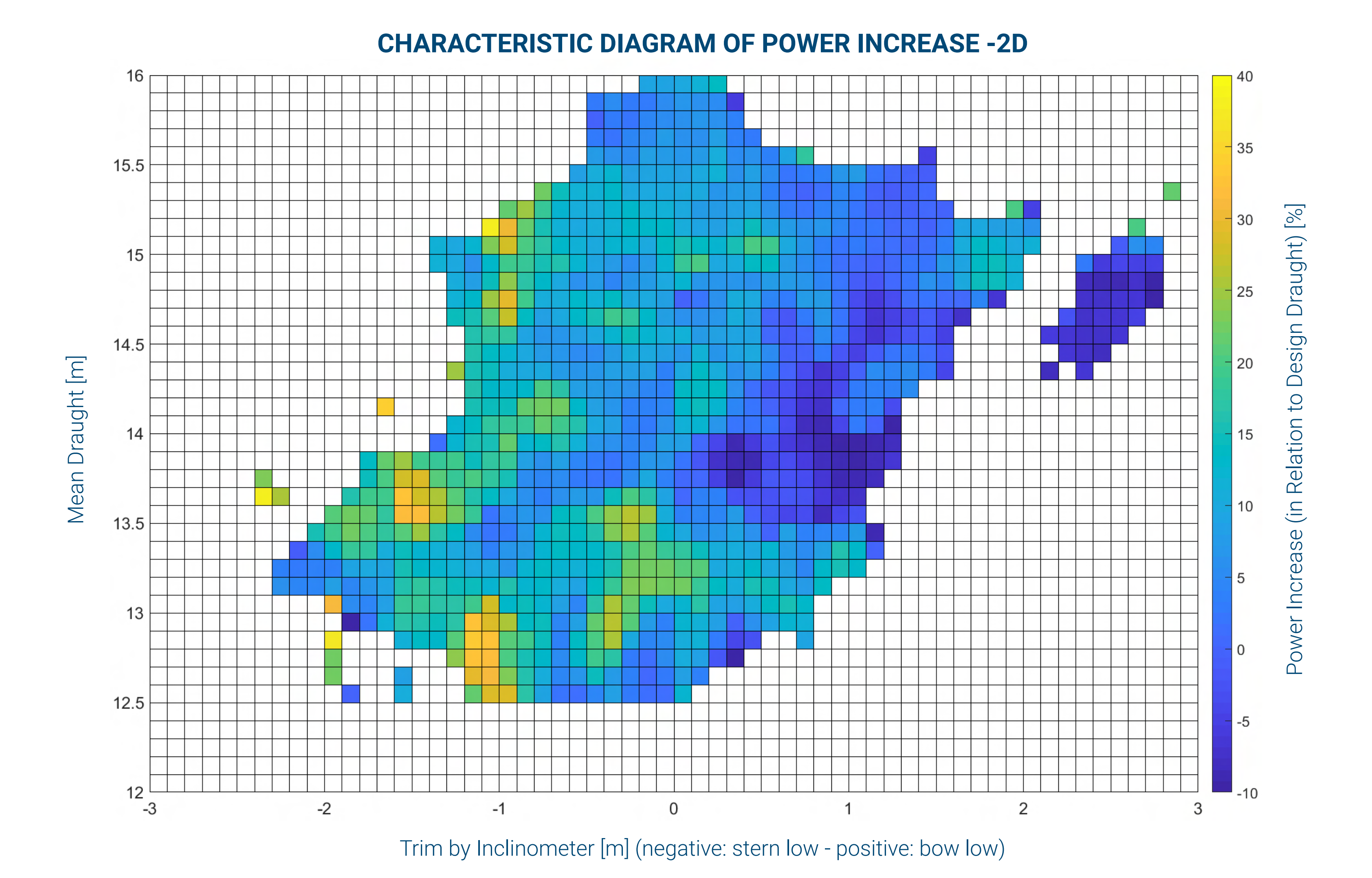

Figure 1 - Relative power increase over mean draught and trim

corresponding to different trim conditions - one indicating high relative power consumption in relation to 100 % MCR power and design draught and the other a relative power reduction - can be very close to each other.

Just imagine the influence that an error in the trim measurement could cause in the interpretation of this diagram. Even worse, it could also have a completely negative impact and generate corresponding expenses compared to the original plan.

[*" Under dynamic conditions, the water flow around the hull can be very complex. "*]

>> THE DYNAMIC CORRECTION

Under dynamic conditions, the water flow around the hull can be very complex. The flow depends on the hull shape, appendages, the speed through water and turbulences. But as a simple example, let us consider the total pressure on a streamline in an incompressible flow. Bernoulli's law states that the total pressure - the sum of atmospheric, hydrostatic and dynamic pressure - must remain constant:

$$\underbrace{\Delta p}_{\text{static}} + \underbrace{\rho \cdot g \cdot \Delta h}_{\text{hydrostatic}} + \underbrace{\frac{1}{2} \cdot \rho \cdot \Delta V^2}_{\text{dynamic}} = \text{Const.}$$

A characteristic pressure distribution of a vessel is shown in Fig. 2.

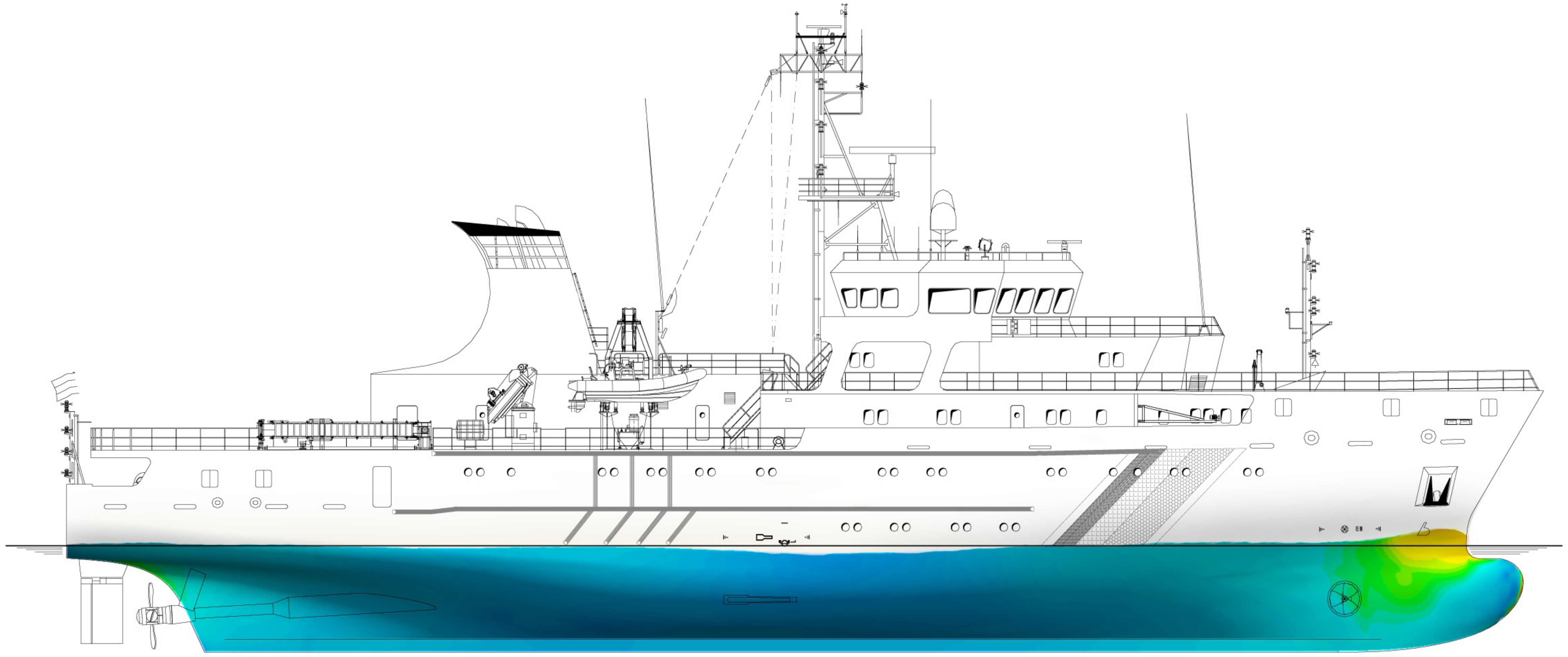

Figure 2 - Pressure distribution around a hull simulated with CFD.

Near the forward shoulders the flow will be accelerated and the dynamic pressure will increase, causing a reduction in the static pressure in these areas. Due to the effect of the propeller pressure field, the static pressure near the stern is less affected by the dynamic flow. Overall, the dynamic influences are strongest in the forward part of the hull. The amount depends on the installation position of the sensors but a pressure sensor subjected to this influence will tend to indicate different measurement values when a vessel is underway, compared to static conditions. This results in a false indication of the draughts and thus, the trim. If for example, the forward draught sensor measures a higher pressure than would result from the actual draught in the static case, this will lead the ship's officers to believe that the vessel has a trim by the bow since it does not correspond to the real floating condition. This mislead situation can also cause an increased hull resistance if an attempt is made to compensate this false trim by ballasting.

Fig. 3 illustrates this problem. This series of draught measurements collected from a 350 m cruise liner over a two-year period shows the difference between the dynamic and the static draughts measured from the forward pressure sensor in relation to the speed through water. Deviations of more than one meter can be seen, which would have a massive negative influence on any trim optimization if hydrostatically measured draughts were used.

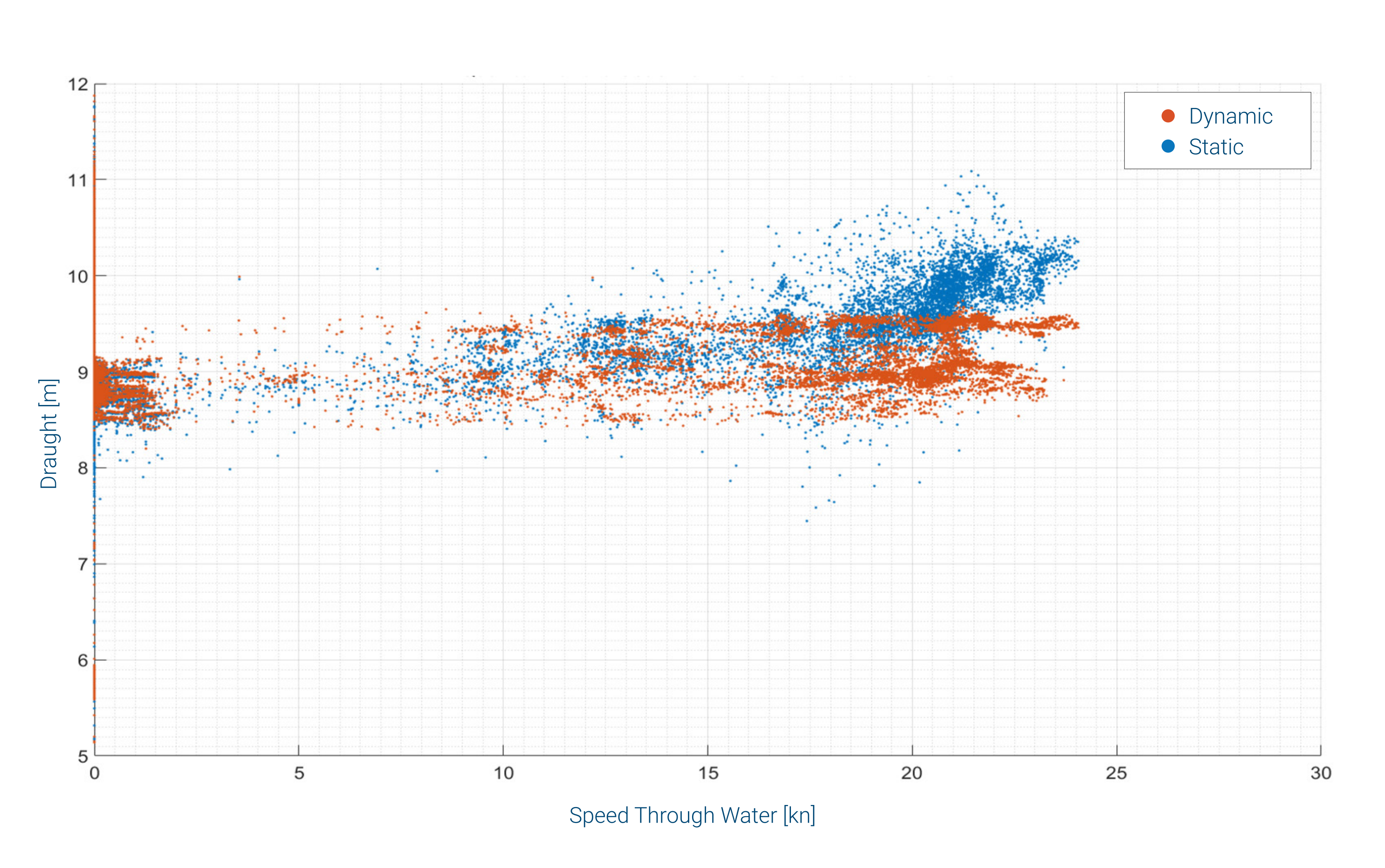

Figure 3 - Difference between static (blue) and dynamic (red) draughts of a 350 m cruise liner

Instead of relying on the pressure based draught sensors, two inertial measurement units derive the dynamic trim and at the same time apply deflection and torsion corrections to the measurements, with the assumption that the displacement of the vessel does not change. It is not subjected to the hydrodynamic effects mentioned before.

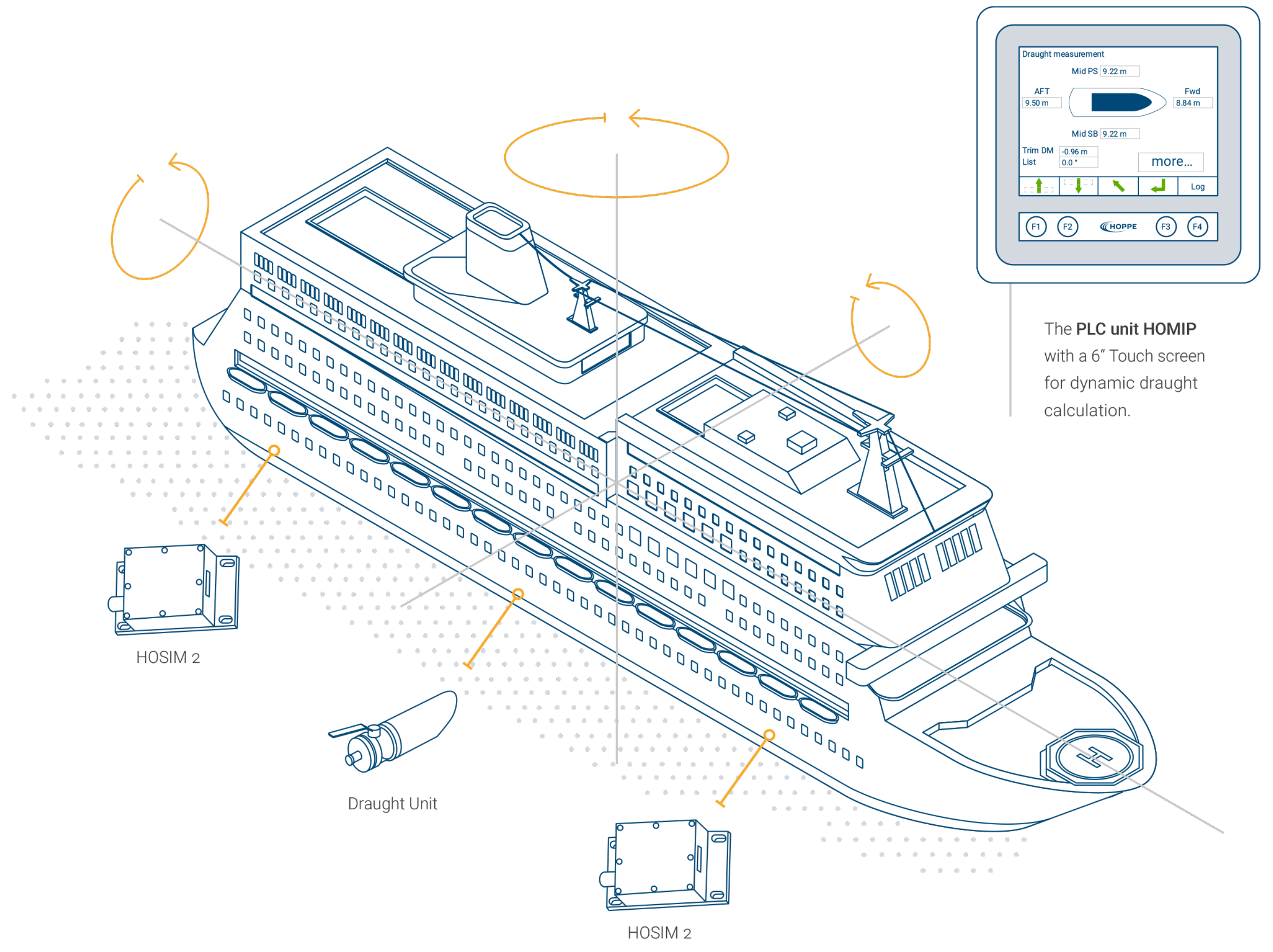

Figure 4 - Two additional inertial measurement units and a PLC are needed to upgrade an existing draught measurement system

In order to upgrade an existing draught measurement system two inertial measurement units are additionally used to calculate the floating condition of the vessel, see Fig. 4. It tackles the problem in two different modes: static and dynamic. The static mode is active for very low speeds or while the vessel is at stand still. The system switches to dynamic mode automatically when the speed through water exceeds a certain limit. At standstill, the floating condition of the vessel is determined mainly by four draught sensors and validated with additional information from the inertial measurement units. Assuming that the displacement of the vessel does not change or changes only to a negligible extent between two standstill periods, the floating condition is corrected during the voyage only on the basis of the inertial measurement units, taking into account trim, deflection and torsion.

For validation purpose, three bending lines are calculated in the static mode. One based on the four draught sensors and the other two use our HOSIM2 inertial measurement units as well as the forward and aft draughts. Thus, the system is capable of self validation through comparison of these three different bending lines as well as a check against the typically maximum expected deflection of the vessel.

>> HOW TO PROFIT FROM A DYNAMIC DRAUGHT MEASUREMENT

The Dynamic Draught Measurement allows the dynamic draughts on every point of the vessel to be determined. Nicolas Harcke with his naval architecture background and deep insight within the funded B ZERO research project summarizes: *“This plays an important role in determining the correct Under Keel Clearance (UKC), thus contributing to a safer navigation. And it will enable a local trim measurement on every tank position and increase the accuracy of the trim correction of a tank, before these values can be trusted and used by other systems on board.”*

But the most important use of these values is in the correction of the draught and trim calculation before data processing and validation. The inertial measurement units HOSIM2 can be easily retrofitted in a vessel that already possesses a normal hydrostatic pressure based draught measurement system and that is one of the biggest advantages of a dynamic measurement system: It is a low cost solution and offers a powerful trim optimization possibility with the use of data collected during normal service operation of the vessel.

The vessel’s characteristic power diagram makes it possible to determine, according to each operating and loading condition, the trim value where the total resistance of the vessel is the least. This reflects in a less engine power loss compared with the design engine power/speed curve if the vessel is kept in the optimal trim condition. Unfavorable trim conditions should as far as possible be avoided, so that the vessel can benefit from the information that this important optimization tool provides. In combination with a Voyage and Performance optimization tool, that also takes into account voyage charter costs and engine specific fuel oil consumption per navigated distance (SFOC/nm), this knowledge can significantly contribute reducing the operational costs.

With an accurate database of primary and secondary parameters, a more meaningful data comparison of a fleet can be drawn for example for energy and operational costs reduction and be the foundation of future investments, maintenance and dock planning.

> ***“ Dynamic Draught Measurement provides the foundation for successful trim optimization. ”***

Dynamic Draught Measurement provides the foundation for successful trim optimization. Based on the current floating condition, taking into account the deflection and torsion, indispensable information is thus provided to operate the shipping of tomorrow more efficiently. Any ship that already has a standard draught measurement system can be retrofitted with two additional sensors and some software at a very low cost. Such a system not only optimizes smooth water operation but also provides vital safety-relevant information in heavy weather, such as the current motion and deformation behavior as well as accelerations along all three spatial axes, interpolatable over the entire length of the ship.

Coupled with Hoppe’s solutions for Ship-to-Shore data transmission and the customizable rule-based notification service, the shore-based fleet management can be informed about conditions that were previously unknown. This provides a deeper insight into the actual ship operation on board and ashore than ever before.

ABOUT THE AUTORS

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Nicolas studied mechanical engineering as well as ship and maritime technologies in Rostock. His focus was on numerical simulations and propeller theory. After completing his master’s thesis at the Hamburg Ship Model Basin (HSVA), he joined Hoppe Marine GmbH in 2018.

As System Digitalization and Innovation Manager, he is in charge of various projects in the field of dynamic floating measurement, digitalization and autonomous shipping.

Brunno Amorim
Nautical Officer

Brunno graduated in nautical studies in Rio de Janeiro in 2010. He worked as a cadet on container ships for Maersk Line and then spent five years as a second officer in anchor handling in the Brazilian offshore business.

In Germany, he continued his nautical studies in Elsfleth by obtaining his master’s certificate and is now working as a student trainee at Hoppe Marine, where he will be writing his bachelor’s thesis in the coming winter semester.