Performance Monitoring

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***Abstract*—This paper describes the performance monitoring systems and software. The environmental and financial reasons and regulations are discussed, after a brief introduction to performance monitoring. Then, the factors that affect performance monitoring in a ship are described, as well as the characteristics of performance monitoring systems and software. In the next chapter the software of kyma is presented, as it is described in the site of Kyma, ending with conclusions about performance monitoring and energy efficiency management.**

I. Introduction (*Heading 1*)

One of the most important issues that concerns the maritime community, especially in the past few years, is the establishment of stricter environmental measures aiming at the treatment of the climate change. Energy efficiency can reduce fuel consumption as well as greenhouse gas emissions (http://www.energia.gr)

Ever soaring fuel prices make ship performance an important issue in shipping. Coming regulations on ship emissions furthermore stimulate operators to reduce the ships fuel consumption. Using in service performing monitoring trends become visible of the ship performance. From fleet comparisons it is known that the fuel consumption of sister ships on the same trade may vary up to 10%. Optimum trim, routing, speed control, autopilot and propeller pitch setting and propeller cleaning can reduce fuel bills by more than 5%. Therefore, besides detailed monitoring of vessel performance, detailed analysis is required to compare the performance of individual vessels and draw conclusions. (http://www.marin.nl)

Although Maritime transport today is the most energy efficient means of transporting goods per ton-mile, in the absence of policies, shipping emissions can increase rapidly compared to other sectors.

The IMO Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) aim to regulate and improve the energy efficiency of new and existing ships.

At the same time, ship owners are increasingly looking for energy efficient ships in order to limit fuel consumption and increase profit. (http://www.bureauveritas.com)

The potential for reducing emissions in the shipping sector is considerable. A lot of the technology is already available and some is relatively easy to implement: slow streaming, improved voyage planning, trim optimization, hull coating and propeller cleaning. There is a wide variety of means for improving the performance of already existing vessels; main engine tuning, propeller and rudder upgrades, fin and duct energy saving devices, are some of them. Solutions and treatments are applied depending on the type of ship, and individual saving measures cannot simply be added together. The main drawbacks for implementing specific measures and technology, concerns the lack of knowledge , as well as the cost of installation for different types/sizes/routes.(www.rina.org.uk)

In the longer-term, improvements in shipping efficiency will be achieved through the integration of innovative technologies on new vessels; optimal performance across an operational profile, not just a single "design point". The shipping industry may even have to consider a more radical approach to reduce overall GHG emissions such as towing kites, wind engines, solar energy, nuclear, etc. As a fairly conservative industry it will want to see full scale demonstrations of the potential of these technologies before adopting them. (www.rina.org.uk)

II. Regulations concerning performance monitoring)

Maritime is responsible for up to 4% of the total human – made CO2 emissions worldwide, a number that is equivalent to the emissions of a small country. Ships are responsible for almost 5% of the fuel consumption worldwide. Fuel consumption at bunkers is the most crucial factor of their journey cost, as it reaches 50% of their total cost, even larger than the sum of the crew's salaries

It is made clear that apart from environmental reasons, controlling the power efficiency of a ship is also of financial importance. The contracts made between owners and charterers take very seriously into account the expenses for a trip. So , there is no question as to how important is the containment of the fuel oil consumption, not only for the common interest , but also for the ship owners and charterers

As far as the energy efficiency or performance are concerned, there is no specific definition but, descriptively, it can be stated that a ship is efficient when the trip's goals are achieved with the minimum cost. So, the energy efficiency of a ship is a crucial factor concerning its function, for environmental as well as financial reasons. (Bialystocki, & Konovessis, 2016)

The efficiency of a vessel is interfaced in the speed – power curve which demonstrates the speed of the ship in comparison to the power provided by the engine. The more power the engine provides, the more the fuel consumption is increased. The speed – power curve is shown in the figure below and an efficient ship has to follow it as much as possible.

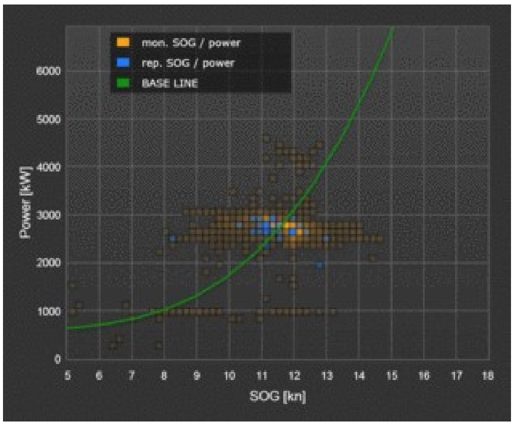


Figure 1: speed – power curve (www.kral-usa.com)

In 1997, the International Convention for the Prevention of Pollution from Ships (MARPOL) was enriched with a new annex. The regulations for the Prevention of Air Pollution from Ships (Annex VI) aim to decrease emissions from ships (SOx, NOx, ODS, VOC shipboard incineration) and minimize their impact on the environment in terms of air pollution. Annex VI entered into force on 19 May 2005 and a revised Annex VI with significantly tightened emissions limits was adopted in October 2008 which entered into force on 1 July 2010. (www.imo.org)

In 2011, IMO established compulsory technical and operational energy efficiency measures which are aiming to significantly reduce the amount of CO_2 emissions from international shipping. Thesemandatory measures (EEDI/SEEMP) entered into force on 1 January 2013.

IMO has adopted important guidelines to aid implementation of the mandatory measures to increase energy efficiency and reduce GHG emissions from international shipping, enabling the regulations on EEDI and SEEMP to be gradually implemented by Administrations and industry.

The world trade is expected to grow in the forthcoming years and the emissions from maritime are expected to play an important role in the destabilization of global temperatures and so IMO has been considering further technical and operational measures to enhance the energy efficiency of ships. (www.imo.org)

IMO adopted a resolution on Promotion of Technical Co-operation and Transfer of Technology relating to the Improvement of Energy Efficiency of Ships and is focusing its efforts on technical co-operation and capacity building to ensure smooth and effective implementation and enforcement of the new regulations worldwide. To that effect, IMO has been undertaking a series of workshops in all regions of the world on implementation of the measures to address GHG emissions from international shipping. (www.imo.org)

In 2012, international shipping was estimated to have been responsible for about 2.2% to the global emissions of carbon dioxide (CO_2). International shipping is the most energy efficient mode of mass transport and only a modest contributor to overall CO_2 emissions. However, a global approach to further improve its energy efficiency and effective emission control is needed as sea transport will continue growing together with world trade. (www.imo.org)

The global nature and complex operation of the international shipping makes it impossible to charge the CO_2 emissions to any national economy. Therefore, IMO has been trying to contain the greenhouse gas (GHG) emissions from international shipping, recognizing the worldwide magnitude of the impact it has concerning the climate change. (www.imo.org)

For the reasons that were described above and mostly for the environmental issues, certain regulations have been established concerning the ship performance monitoring. The most important of them are described below

A. Energy Efficiency Design Index (EEDI)

The Energy Efficiency Design Index (EEDI) was made mandatory for new ships and the Ship Energy Efficiency Management Plan (SEEMP) for all ships at MEPC 62 (July 2011) with the adoption of amendments to MARPOL Annex VI (resolution MEPC.203(62)), by Parties to MARPOL Annex VI. This was the first legally binding climate change treaty to be adopted since the Kyoto Protocol. (www.imo.org)

The EEDI for new ships is a vital technical measure and aims at promoting the use of more energy efficient (less polluting) equipment and engines. The EEDI establishes a lower energy limit per capacity mile (e.g. tonne mile) related to the ship type and size segments. Since 1 January 2013 new ship design needs to meet the requirements that have been proposed. The level will be altered and tightened every five years, and so the EEDI is expected to stimulate continued innovation and technical development of all the components influencing the fuel efficiency of a ship from its design phase. The EEDI is a regulation which is not of technical nature, which means that it leaves up to the owner what kind of technology they are going to use so as to achieve the target of the EEDI. As long as the required energy efficiency level is attained, ship designers and builders are free to use the most cost-efficient solutions for the ship to comply with the regulations. The EEDI provides a specific figure for an individual ship design, expressed in grams of carbon dioxide (CO_2) per ship's capacity-mile. and is calculated by a formula based on the technical design parameters for a given ship. A ship is more efficient when the value of the EEDI is smaller. (www.imo.org)

The CO_2 reduction level (grams of CO_2 per tonne mile) for the first phase is set to 10% and will be tightened every five years to keep pace with technological developments of new efficiency and reduction measures. Reduction rates have been established until the period 2025 and onwards when a 30% reduction is mandated for applicable ship types calculated from a reference line representing the average efficiency for ships built between 2000 and 2010. The EEDI is developed for the largest and most energy intensive segments of the world merchant fleet and embraces emissions from new ships covering the following ship types: tankers, bulk carriers, gas carriers, general cargo ships, container ships, refrigerated cargo carriers and combination carriers. In 2014, MEPC adopted amendments to the EEDI regulations to extend the scope of EEDI to: LNG carriers, ro-ro cargo ships (vehicle carriers), ro-ro cargo ships; ro-ro passenger ships and cruise passenger ships having non-conventional propulsion. These amendments mean that ship types responsible for approximately 85% of the CO_2 emissions from international shipping are incorporated under the international regulatory regime. (www.imo.org)

B. Ship Energy Efficiency Management Plan (SEEMP)

While the EEDI concerns newly built ships, IMO has developed another tool to measure and control GHG emission from the already existing shipping fleet known as Ship Energy Efficiency Management Plan. (www.marineinsight.com)
The Ship Energy Efficiency Management Plan (SEEMP) is an operational measure that establishes a mechanism to improve the energy efficiency of a ship in a cost-effective manner. The SEEMP also provides an approach for shipping companies to manage ship and fleet efficiency performance over time using, for example, the Energy Efficiency Operational Indicator (EEOI) as a monitoring tool. The guidance on the development of the SEEMP for new and existing ships incorporates best practices for fuel efficient ship operation, as well as guidelines for voluntary use of the EEOI for new and existing ships (MEPC.1/Circ.684). The EEOI enables operators to measure the fuel efficiency of a ship in operation and is an operational indicator contrary to the EEDI which is a technical specification, although both of them are expressed in the same manner. Measuring the fuel efficiency using the EEOI, enables the operator to gauge the effect of any changes in operation, e.g. improved voyage planning or more frequent propeller cleaning, or introduction of technical measures such as waste heat recovery systems or a new propeller. The SEEMP urges the ship owner and operator at each stage of the plan to consider new technologies and practices when seeking to optimize the performance of a ship. (www.marpol-annex-vi.com)

When developing / revising a SEEMP, the process should follow a cyclical process (Plan-Do-Check-Act): (www.dnvgl.com)

PLANNING includes ship- and company-specific measures, human resource development and goal-setting, while bearing in mind the need to minimize on-board administration.

Important considerations: This is the most crucial phase of the SEEMP development and should reference company goals and processes, ship-specific features in technical and operational spheres, training, competence and timelines.

IMPLEMENTATION includes attention to establishing an appropriate system that allows for each selected measure to be rolled out according to the plan.

Important considerations: Any 'system' can involve a mix of tools, processes and record keeping that, when combined, will enable the implementation of specific energy efficient initiatives. A communication plan that identifies who is responsible for each step in the process will both increase awareness and the likelihood of sustainable activity.
The SEEMP may be part of the vessel's Safety Management System mandated by the ISM Code. It can form the cornerstone of a broader energy management initiative, or it can be kept separate, focusing on compliance only.

MONITORING describes the establishment of a system utilizing various tools, existing and new, that can provide a qualitative and quantitative basis for self-evaluation and subsequent performance review.

Important considerations: This is perhaps the hardest area to activate in a consistent manner. The interaction of the right tools, systems and processes is crucial for measuring achievement and ensuring sustained improvement. Many organizations collect data from a wide range of sources, but not all manage this information systematically so that they know how well they are performing or whether they are on track.

SELF-EVALUATION, IMPROVEMENT AND REVIEW complete the continuous improvement cycle by assessing the effectiveness of implemented energy efficiency actions, identifying ways to improve associated processes and formerly reporting to stakeholders.

Important considerations: Plan to communicate both 'good' and 'not so good' news to interested parties. This will increase *awareness and build trust in the program and activities. In addition, seek regular feed-back from others via meetings, presentations and emails to check and validate plans as they unfold.*

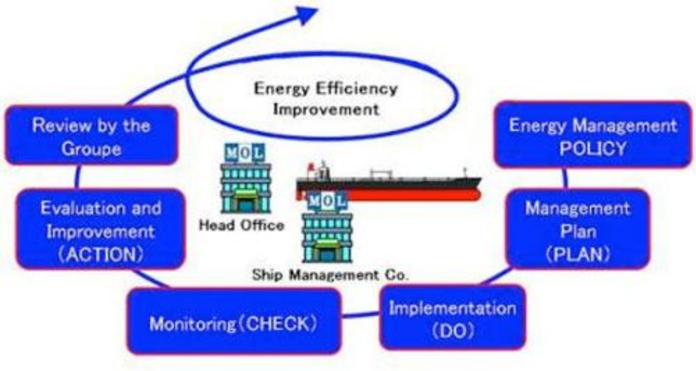


Figure 2: SEEMP cycle **(www.marineinsight.com)**

C. ISO 19030

The part below is taken from the ISO 19030-1 document

"*Hull and propeller performance refers to the relationship between the condition of a ships underwater hull and propeller and the power required to move the ship through water at a given speed. Measurements of changes in ship specific hull and propeller performance over time makes it possible to indicate the impact of hull and propeller maintenance, repair and retrofit activities on the overall energy efficiency of the ship in question.*

The aim of this standard is to prescribe practical methods for measuring changes in ship specific hull and propeller performance and to define a set of relevant performance indicators for hull and propeller maintenance, repair, retrofit activities. The methods are not intended for comparing the performance of ships of different types and sizes (including sister ships) nor to be used in a regulatory framework.

This International Standard consists of three parts:

- *The first part outlines general principles for how to measure changes in hull and propeller performance and defines a set of performance indicators for hull and propeller maintenance, repair and retrofit activities;*
- *The second part defines the default method for measuring changes in hull and propeller performance and for calculating the performance indicators. It also provides guidance on the expected accuracy of each performance indicator;*
- *The third part outlines alternatives to the default method that result in lower overall accuracy but increases the applicability of the standard. It also provides guidance on the size of the impact on the accuracy of each performance indicator.*

The general principles outlined, and methods defined, in this International Standard are based on measurement equipment, information, procedures and methodologies which are generally available and internationally recognized.

In the submission to IMO it was estimated that the potential for fuel savings and GHG emissions reductions related to improvements in hull and propeller performance was between 7 and 10 per cent across the world fleet. This translates into around 0.3 per cent of all man made carbon emissions and 30 billion USD in fuel savings.

ISO 19030 will contribute towards the realization of this potential by making it possible to accurately determine the impact of hull and propeller related maintenance, repair and retrofit activities on the fuel efficiency of the ship in question. The standard will also make it possible for buyers and suppliers of technologies and solutions aimed at improving hull and propeller performance to enter into performance based contracts based on a contractually acceptable measurement methodology."

III. FACTORS THAT AFFECT VESSEL AND FLEET PERFORMANCE

There are certain factors that affect the performance of a ship or a fleet as a whole. These factors are going to be mentioned and analyzed in this chapter, as well as the way they influence the vessel performance

A. Trim

Trim Optimization is a cheap as well as easy way of improving ship performance. . It does not require any hull shape modification or engine upgrade. The optimization can be done by proper ballasting or choosing of proper loading plan

The optimum trim of a ship for given current speed, loading and sea state lessens its hydrodynamic resistance to the minimum possible, reducing propulsion energy requirements and hence fuel consumption. (Fathom Focus, 2014)

"Although trim optimisation tests are considered less important than standard power performance model tests they can provide substantial savings and a return on investment between one and six months, depending on vessel type, operation and number of vessels in the series. The energy savings as a result of trim optimisation have been proven also by Hansen and Freund (2010), where the influence of water depth on possible gains has also been described." (M. Reichel, A. Minchev & N.L. Larsen , 2009)

Simply put, optimum trim is the trim angle at a certain condition (displacement or speed) in which the propulsion power that is demanded, is lower than for any other trim angle at that condition. (Fathom Focus, 2014)

As mentioned above, this method was previously not given the required importance or was thought to be too expensive and therefore has only recently been starting to be applied, offering substantial savings. It is with these savings that hull forms are being studied in order to provide bow and stern modifications to achieve the least resistance. It is important to ensure that the water level at the bow and stern are as close to the designed level as possible. If these water levels are even slightly different, water resistance can increase dramatically and hence fuel consumption rises. (Fathom Focus, 2014)

Trim optimization includes hull form as well as cargo distribution, ballast and consumables which can all affect the way the ship functions. It is therefore important to collate as much information to allow the best combination of draft and trim in relation to cargo, with the addition or reduction of ballast depending on the amount and location of said cargo. (Fathom Focus, 2014)

In the past, ships were optimized for one speed and one draft. But during a ships life time it sees a lot of different speeds and drafts. One only has to think of the shipping industry's switch to slow steaming over the past years, in an effort to better control costs, as an example of our the "one speed, one draft" concept has gone by the way side.(www.hapag-lloyd.com)

The trim of a ship describes its floating position in length direction, namely if the bow or the aft of the ship is deeper submerged into the water. The trim can have a significant impact on a vessel's energy demand for propulsion during sailing. The most efficient trim for a particular ship depends on its design, operational draft and speed. (www.hapag-lloyd.com)

Figure 3 : Trim optimization (www.hapag-lloyd.com)

B. Speed Profile

"In recent years, increasing fuel prices, depressed market conditions and environmental issues as regards air emissions from ships have brought a new perspective to ship speed. If this perspective had not received much emphasis in the past, this is not so today, and it will receive even more attention in the future. In addition to being efficient from an economic perspective, a ship also has to be environmentally friendly as regards air emissions. To that end, significant regulatory activity is already taking place within the International Maritime Organization (IMO) and other bodies. Such activity aims to cover the whole range from technical to operational to market-based measures and a wide spectrum of emissions, from greenhouse gases (GHGs) such as carbon dioxide (CO2), to non-GHG gases such as sulphur oxides (SOx), nitrogen oxides (NOx), particulate matter (PM) and others. Because of the non-linear relationship between speed and fuel consumption, it is obvious that a ship that goes slower will emit much less than the same ship going faster. It that sense, the impact of a change in ship speed on both ship operating costs and emissions can be quite dramatic. This can be manifested at two levels, the design level and the operational level." (Psaraftis & Kontovas , 2014)

The practice of 'slow steaming' reduces propulsion power requirements significantly. It is understood that if you double the speed of a ship, the increased power requirements is increased by a factor of at least 8. Conversely, if you reduce the speed to 90% of the design speed, then the ship would only require 75% of the power. Thus reducing ship speed by 10% can achieve savings of around 20% in fuel. (Fathom Focus, 2014)

Although slowing down may reduce fuel consumption, the cargo transportation must be taken into account. This is because reduced speed means more time taken to transport, hence less cargo per unit time. To balance this factor it may require more ships to sail ensuring that the same volume of freight is delivered on time. In addition, running an engine below its design point can reduce its specific fuel oil consumption (SFOC, the fuel consumed to achieve a given power output) and running the ship below its design speed can reduce its hydrodynamic efficiency. (Fathom Focus, 2014)

Therefore, there are a lot of factors to be taken into account when deciding the speed profile of a vessel, including the charter rate, scheduled arrival time (and any flexibility in allowable arrival time), engine rating and condition, ship design speed, current fuel price and potentially the need to avoid adverse weather conditions. SPM systems can be used to solve the problem concerning these many interacting factors and enable the operator to get a more sophisticated understanding of the particular ship's speed/fuel characteristics in different conditions. (Fathom Focus, 2014)

C. Weather

The weather (wind and waves) will together with ocean currents affect the power needed to propel a ship at a given speed over ground. Therefore, it is important to take these factors into consideration when planning a voyage and to try to minimize the impact.(http://glomeep.imo.org)

Weather routing mainly consists of selecting the optimum course from start to finish, providing the safest passage and on-time arrival whilst taking into account wave, wind and current conditions that will be experienced on the voyage. (Fathom Focus, 2014)

When the distance of the voyage is long, the ship has more flexibility to follow different routes and choose the optimum one. Also longer voyages most often include time spent in unsheltered waters where the influence from weather is making weather routing important. Therefore, the biggest potential could be realized in intercontinental trades and for larger ships. (http://glomeep.imo.org)

In the past decade, routing systems have evolved from finding the fastest and safest route to instead finding the safest and most fuel efficient route. (Fathom Focus, 2014)

D. Hull and propeller condition

Hull and propeller performance refers to the 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. Measurements of changes in ship specific hull and propeller performance over time makes it possible to indicate the impact of hull and propeller maintenance, repair and retrofit activities on the overall energy efficiency of the ship in question. (Fathom Focus, 2014)

Hull an propeller condition is a decisive factor that affects the ship's performance and this is clearly indicated by the fact that the ISO 19030 concerns exclusively the hull and propeller condition after maintenance

Hull fouling increases the roughness of the hull and thereby its resistance through the water. Hull cleaning or re-coating can be carried out at fixed intervals, but these may not be the optimum intervals given the speed at which hull fouling is occurring on a particular ship which will vary with the type of coating applied, the areas of operation and the time spent anchored or in port. In addition to hull fouling, propeller service degradation will also reduce propulsive efficiency. Propellers suffer from physical surface roughness created by corrosion, cavitation, erosion and impingement attack. Failure to properly maintain propellers in the form of overspray from hull coatings, excessive and aggressive grinding/polishing and nicked edges can also reduce the efficiency of propellers. Even though a fouled propeller has less negative impact on the ship's efficiency than a fouled hull, it can still increase fuel consumption by about 6 - 8%. (Fathom Focus, 2014)

E. Engines

Marine engine on ships are used for 2 main purposes – for propelling the ship and for generating electricity, which assists in powering the ship's propulsion plant. The efficiency of any machinery on board ship is directly related to its performance. In order to get the best out of marine engines, it is very important to monitor their performances and take measures to achieve an efficient combustion. Ensuring this will not only reduce generation of pollution from engines but also the overall operating cost of the ship. (www.marineinsight.com)

In general, any problems related to the engine will reduce the efficiency of the engine, and there is thus considerable overlap between safety/maintenance systems and modern tools that are designed specifically to optimise the engine performance by small adjustments to settings of fuel rack, injection rate etc. (Fathom Focus, 2014)

F. Machinery

All machinery onboard ships consume energy and thus can be tuned to perform at their optimum efficiency. Dated systems, for example, can be upgraded or replaced to reduce the power consumption. (Fathom Focus, 2014)

G. Route

Similar to weather routing, selecting the shortest and less energy consuming route, is a major factor that affects ship performance. By less energy consuming, is indicated a route that, apart from safety and tides, includes avoidance of shallow water.

H. Hotel Functions

Electrical power onboard ships is becoming ever more important and there are several means by which to assure its continuous availability. A few SPM systems are able to monitor the energy consumption of hotel functions such as lighting, communications, climate control, refrigeration, water desalination and treatment and entertainment. Where these work in conjunction with machinery monitoring, they are able to ensure optimal matching of power generated to required load and ensure availability of consistent electricity as well as avoid blackouts. (Fathom Focus, 2014)

IV. General Description of performance monitoring systems

Due to the wide variety of rules and regulations established for the environmental protection concerning maritime, a large number of tools for performance monitoring are now available.

As it has been made clear, managing the energy consumption of a vessel or a whole fleet, not only reduces the GHG emissions but also assists in fuel (and thus money) saving for the ship owner companies.

The performance management systems are used in order to monitor and control the factors that affect the vessel performance

Ship performance monitoring consists of data collection, data analysis, reporting and sharing the information. It provides the decision making parties with all the necessary information to comprehend the real – time fuel consumption. Data analysis and reporting need to be executed in every single ship of the fleet as they provide useful indicators concerning the overall energy design of the vessel. (Lloyd' s Register, 2011)

A. Data Collection

Data collection can be made possible using sensors and mechanical equipment. Data need to be collected for every factor that affects ship efficiency as mentioned above. The means to acquiring each type of data differs, depending on the factor that is examined

For trim the data is known beforehand as the type, size and weight of the cargo are already known

For the speed profile the data can be collected real – time using sensors during the trip. However, in order to optimize the speed profile, previously acquired data (from past trips) are necessary. This does not affect the data acquisition process but it indicates the importance of data storage for further use

Weather routing is a whole different part of maritime. The data are collected by weather forecast, offered by different providers.

The engine and machinery performance data, as well as those concerning the hotel functions can be collected by sensors on board. These sensors are not necessarily provided by the software provider but they are usually compatible, no matter the provider of each.

B. Analysis

The main use of the ship performance monitoring software is the analysis of the collected data. As mentioned before, the data collection can be made by sensors or even manual input. The sensors are a different part of the system than the software. The software's most important role and use is the data analysis which, following the stage of reporting and sharing, is what leads to the necessary information for the final decision making.

C. Reporting

Another very important role of the ship management software is reporting the results of the analyzed data. Reports need to be frequent and at intervals that have been strictly decided by the party responsible.

D. Sharing the information

A lot of the ship performance software companies (if not all) offer the potentiality of sharing the information acquired from the reports, inside the vessel, as well as ashore. However, it is also possible for another software to be used for the information sharing

V. THE SOFTWARE OF KYMA

KYMA offers a complete performance monitoring software which consists of separate programs, some of which form the performance monitoring program, while others are combined with it, either for measurements and data input, or for data sharing, interfacing and analyzing. All the data and information in the present chapter have been collected and copied from kyma official website and the brochures available in it (www.kyma.no)

A. Kyma data logger

Kyma Data Logger (KDL) is an on-board system for the continuous logging of sensor data. The data are logged every 15 seconds and are automatically sent ashore at regular intervals , where they can be further analyzed or interfaced
The KDL is connected to the vessel LAN system to permit the following types of data transfer:
• Possibility for automatic sending of raw data to Kyma API solution (requires a separate annual subscription to Kyma API solution)
• Possibility for automatic sending of raw data (CSV format) to owner's own system as email attachment
• Possibility for remote access using TeamViewer to simplify future upgrades or service requirements.

Typical logged values:

- M/E Shaft Power
- M/E Shaft Speed
- M/E Shaft Torque
- M/E Shaft Thrust
- M/E, G/E, Blr. F.O. Flow
- M/E, G/E, Blr. F.O. Temp.
- M/E, G/E, Blr. F.O. Type
- Speed Through Water (Log)
- Draft Aft
- Draft Fwd.
- GPS Time
- Ship Lat/Lon by GPS
- Ship course by GPS
- Ship speed by GPS
- Wind Dir. Rel.
- Water depth

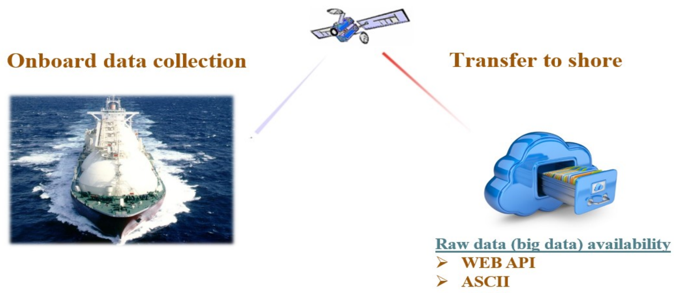


Figure 4

B. Kyma Performance Monitoring

Kyma Performance Monitoring a two-step system package

Kyma can supply a total system concept for ship performance monitoring. It consists of two configuration levels, ranging from propeller propulsion data to fully integrated computer measurements of all energy transfer from fuel flow input to ship speed. The two configurations can be installed in a complete set or individually, according to requirements.

- Kyma Shaft Power Meter, KPM.P
- Kyma Ship Performance, KSP

1) Kyma Shaft Power Meter, KMP.P

a) General Description

Kyma Shaft Power meter (KPM) is an instrument for continuous measurement of torque, thrust (option), revolutions and power on a rotating shaft. The instrument is primarily designed for marine applications. The Shaft Power Sensor measures shaft torque and thrust* using strain gauge technique. The instrument consists of an aluminum ring clamped on to the shaft, a stationary unit located next to the shaft and a terminal junction box for signal and power connection. The shaft ring contains electronic components for signal processing and transmission, and will also serve as protection for the strain gauges, which are glued to the shaft surface. The signals are transferred as frequency modulated signals to the stationary unit through contact free transmission. Shaft revolutions are measured by sensing of magnets on the shaft ring. The Kyma Display Unit consist of a flat LCD screen module and a processing unit that can be flush mounted in the ECR console or installed in brackets on the top of the console.

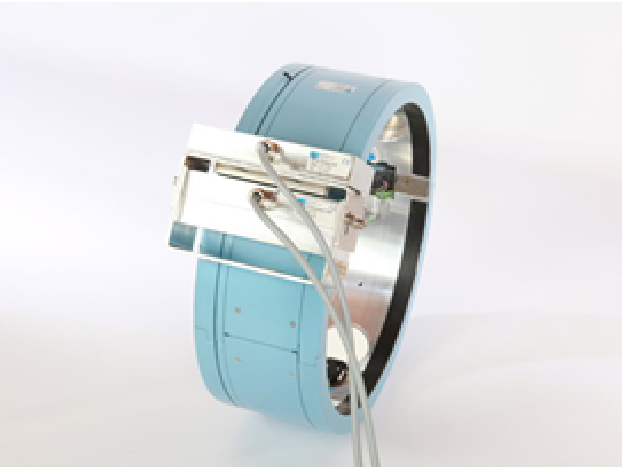


Figure 5

Operator can change the units of measurements between Metric and SI. One serial output connection, RS422, is included as standard. The following propulsion data are recorded by the Shaft Power Sensor and presented on the Kyma Display Unit: Power, Rpm, Torque, Thrust (option), Total Energy Power, Total revolutions

The system is maintenance free and designed for the vessels life time. A zero calibration is the only recommended action to be done by the ship staff. It is an easy operation that takes approx 10 minutes and it should be done approx every 6 months.

There are several advantages with the Kyma systems: • High repeatability and accuracy • Available for multi-shaft installations • No mechanical wear • Not affected by any pollution in the engine room. • Option for Thrust measurement • Option for PDF output of voyage repots on USB port. • Design for use in hazardous areas • Kyma Shaft Power Meter is easy to install both on new vessels and on vessels in operation. The ring is suitable for all shafts above 225mm

Propulsion economy is based on fuel efficiency and ship reliability. To achieve an optimum result you need the best balance between fuel consumption, power output and ship speed. This can be obtained from accurate information provided by high quality instrumentation.

- Reduced fuel consumption

As fuel consumption is a major cost factor, the use of Kyma performance monitoring systems can contribute significantly to an improved bottom line. Hull fouling and propeller roughness indication. Kyma performance monitoring makes it possible to evaluate the economic impact of reduced propeller efficiency and increased hull resistance. It can show the effect of any action taken to improve hull or propeller smoothness.

Figure 6

- Overload protection

Early warning signals provide a further benefit for the continuous monitoring of propulsion components. These can indicate the overload stress on components and thus prevent unexpected breakdown. To achieve optimum operation without overloading can also prolong the operating life of components -giving better total economy and improving there turn on investment.

- Performance evaluation

Contracts for newbuildings are based on performance estimates from model tank testing. Kyma performance ponitoring systems can confirm precisely the contract performance parameters or specify any deviations.

Figure 7

C. *Kyma Ship Performance*

Kyma Ship Performance is the most sophisticated solution for overall vessel performance monitoring. This system integrates the Kyma Power Meter system with advanced Windows™ based PC software that continuously analyses performance data.

The software includes sea-trial or model tank propulsion baselines, which can be displayed graphically, together with the actual condition, in real-time mode. This generates a new information concept expressed as:

- Deviations from baseline conditions.
- Trending of the deviation from the baseline.
- Hull roughness and heavy propeller indication.
- Diagnostic of vessel performance based on excess fuel consumption.

The software has several useful features for efficient ship energy management:

- Noon-to-noon fuel consumption reports.
- Voyage fuel consumption reports.
- Short term and long term trending.
- Instant data display mode.
- Accumulated data display mode.
- Sea trial mode and reports.
- The capability to interface with other computers or monitoring systems.
- Docking interval planning.
- Environmental calculation acc. to IMO Index (EEOI)

Propulsion economy is based on fuel efficiency and ship reliability. To achieve an optimum result you need the best balance between fuel consumption, power output and ship speed. This can be obtained from accurate information provided by high quality instrumentation. Kyma Performance Monitoring provides bridge and engine officers with vital propulsion data for cost-effective operation of the ship. Reduced fuel consumption As fuel consumption is a major cost factor, the use of Kyma Performance Monitoring can contribute significantly to an improved bottom line. Hull fouling and propeller roughness indication Kyma Performance Monitoring makes it possible to evaluate the economic impact of reduced propeller efficiency and increased hull resistance. It can show the effect of any action taken to improve hull or propeller smoothness. Overload protection Early warning signals provide a further benefit for the continuous monitoring of propulsion components. These can indicate the overload stress of components and thus prevent unexpected breakdown. KYMA a.s HAVE BEEN WORKING WITH SHIP PERFORMANCE SYSTEMS FOR MORE THAN 30 YEARS AND ARE ONE OF THE LEADING SUPPLIERS WITHIN THIS FIELD OF TECHNOLOGY Performance evaluation Contracts for new buildings are based on performance estimates from model tank testing. Kyma Performance Monitoring can confirm precisely to the contract performance parameters or to any specified deviations. Environmental information Emission calculation of CO2 and SO2 is included in Ship Performance and EEOI will be continuously calculated. Trim optimization module KSP Trim is an optional software module that can be integrated with the standard KSP system. The purpose of the KSP Trim module is to provide the vessel operator with a practical tool for establishing the optimum trim for the vessel at any load and draft condition. Diagnostic Toolbox An optional trendanalysis toolbox is available for detailed statisticalanalysis of speed loss and performance information. KSP Office WEB Web based optional management tool for evaluating fleet performance with easy and secure access from any internet connected PC or Tablet. P

a) Numerical All logged and calculated parameters can be output to computer monitor and printer. Typical updating time is 15 sec. The following real-time values are available:

b) Graphic mode Presentation of performance curves where the actual condition is indicated as a plot in the graph with numerical indication and deviation from the performance curve. Performance curves are derived from model tank data or sea trial data. • Shaft Power versus Revolutions • Shaft Power versus Ship Speed • Daily Fuel Consumption versus Ship Speed • Specific Fuel Rate versus Shaft Power Trend curves: • Long-term trend capability over the life of the vessel of selected vessel performance data subject to change over time, such as speed loss due to hull fouling and increase of main engine specific fuel rate. • Short-term trending of any five selectable parameters on a selectable time basis of up to 14 days. Resolution is 1 sample pr 15 sec.

1) *Kyma Diagnostics Toolbox*

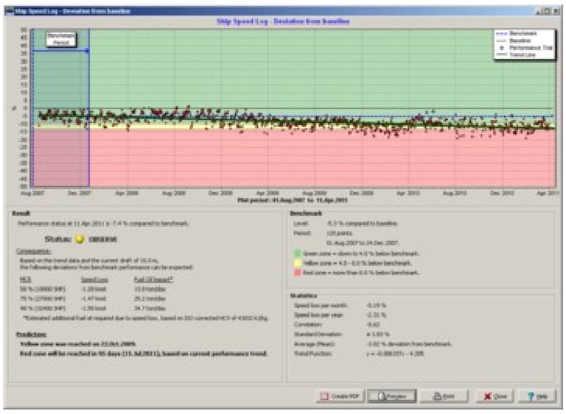


Figure 8

The purpose of the Diagnostics toolbox is to provide an efficient tool to give operator and ship owner a clear message of vessel condition related to hull, machinery or propeller by a Performance status indication.

This software toolbox will include features for setting time of any major event that will cause a break of a trend line. Typical event date will be 'Start of dry docking', 'End of dry docking' ,' Propeller polishing' , 'Start of lay-up' etc. Any of these events will cause a major change in hull/propeller/engine condition, and by having these event settings, the statistical analysis of historical data can be broken up into periods between main events with correspondingly statistical mean trend development in each period.

After last event setting, the system will automatically generate a bench-mark level which will be the basis for checking condition of main engine, propeller and hull with regard to deterioration of performance in last/recent period.

Three levels of deterioration from bench-mark can be set by operator:

- Level 1 is defined as Green zone, and will be in range from benchmark level to -5%.
- Level 2 is defined as Yellow zone, and will be in range from -5 to -10%.
- Level 3 is defined as Red zone, and will be in range from -10% and down.

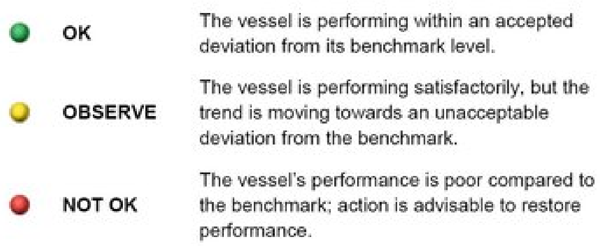


Figure 9

Zone levels are adjustable by operator:

- Vessel performance status is defined by color Green (ok) when statistical mean trend line stays in Green zone.
- Vessel performance status is defined by color Yellow (to be observed) when statistical mean trend line enters Yellow zone.
- Vessel performance status is defined by color Red (not ok) when statistical mean trend line enters Red zone.

Vessel performance status will be indicated by zone color flag in upper right corner of all reports generated by the KSP system.

Operator can then by a glance see the status of the vessel with regard to performance without going into details of numerical calculations and evaluation. A detailed report with all statistical data can be provided at any time for last period performance trend. This report will in addition to the graphical presentation of trend development, also give a prediction at what time yellow (or red) zone will be reached with present development.

This separate software module can be integrated with standard KSP system software

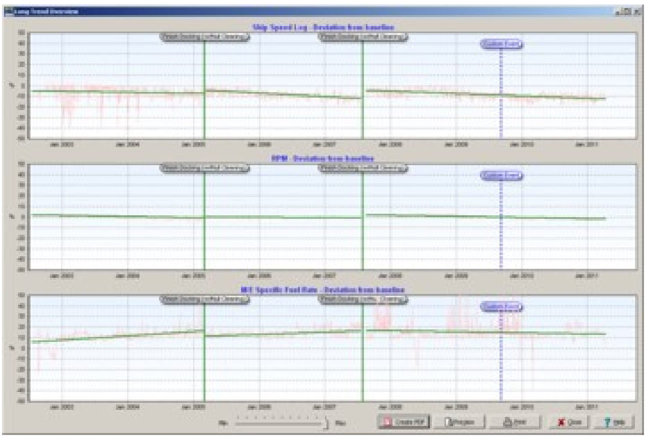
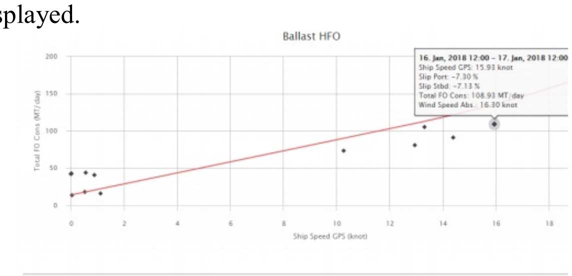


Figure 10

2) CP Module for Kyma Ship Performance

An optional feature of the Kyma Ship Performance system is the CP Module. Using this tool, the performance data collected can be used for detailed analysis and evaluation of how the vessel performs relative to any specific Charter Party contract. A charter party is a contract between a vessel owner and a charterer. The charterer takes over the vessel for either a certain amount of time (time charter) or for a given point-to-point voyage (voyage charter). A time charter party sets out the terms of the contact and the freight rate, which is effectively the price of hire. The charterer will pay for all the running costs of the ship such as the fuel and insurance. The

CP Module utilizes the Kyma Ship Performance System's (KSP) key values for wind, load, draft, speed and fuel etc. These values are measured and logged every 15 sec. and the CP Module generates reports, as required, based on these measurements. A selection of reports is available, where the specific values can be extracted and presented in various different formats. The day-to-day performance (fuel consumption per day) compared to a pre-set contract benchmark line is though the most relevant graph to be displayed.



The above figure shows the actual vessel performance, shown as daily "dots", relative to the contractual conditions, indicated by the red line.

Figure 11

Additional information The Kyma CP Module can be tailored to meet individual users' requirements with regard to specific contractual contents. Typical values would be speed, wind, actual fuel consumption and propeller slip. The software offers the option of setting filter values for the exclusion of time periods beyond the contractually agreed terms as shown in the figure below:

Summary | Charter party data | Export to excel

From date	To date	Actual consumption (ton)	Allowed consumption (ton)	Difference (ton)	Distance (nm)
14. Jan, 2018 12:00	15. Jan, 2018 12:00	42.69	14.21	28.48	0.48
15. Jan, 2018 12:00	16. Jan, 2018 12:00	104.44	113.92	-9.48	315.84
16. Jan, 2018 12:00	17. Jan, 2018 12:00	101.00	125.96	-24.96	354.51
17. Jan, 2018 12:00	18. Jan, 2018 12:00	68.60	86.25	-17.65	231.50
18. Jan, 2018 12:00	19. Jan, 2018 12:00	42.14	14.00	28.14	0.00
19. Jan, 2018 12:00	20. Jan, 2018 12:00	40.70	20.51	20.19	20.55
Summary		399.55	374.84	24.72	922.88

Summary | Charter party data | Export to excel

From date	To date	Total FO Cons Deviation (ton/day)	Ship Speed GPS (knot)	Total FO Cons (ton/day)	Slip Port (%)	Slip Stbd (%)	Wind Speed Abs. (knot)	Included time (hours)	Excluded time (hours)	Excluded data
14. Jan, 2018 12:00	15. Jan, 2018 12:00	28.48	0.02	42.69	0.00	0.00	4.55	24.00	0.00	
15. Jan, 2018 12:00	16. Jan, 2018 12:00	-7.16	13.16	104.44	-2.82	-2.72	12.97	24.00	0.00	
16. Jan, 2018 12:00	17. Jan, 2018 12:00	-26.68	15.93	108.94	-7.34	-7.17	16.19	22.25	0.00	
17. Jan, 2018 12:00	18. Jan, 2018 12:00	-17.75	10.29	73.17	-2.67	0.32	7.48	22.50	0.00	
18. Jan, 2018 12:00	19. Jan, 2018 12:00	28.14	0.00	42.14	0.00	0.00	7.42	24.00	0.00	
19. Jan, 2018 12:00	20. Jan, 2018 12:00	18.12	0.86	40.70	2.90	2.98	4.58	24.00	0.00	
Summary								140.75	0.00	

Figure 12

3) *Generator Engine Optimization Tool*

- Best fuel oil combination
- Best load combination
- Reduce emissions
- Reduce operational cost

Kyma a.s has an optional software module (generator engine load optimizing tool) in the Kyma Ship Performance (KSP) system that can calculate the best load and fuel combinations of the individual generator sets as a function of the current necessary power (i.e. speed) and fuel types available. The optimizing tool receives all the necessary current data online from the different sensors on board (shaft power, fuel oil and/or gas flow, hotel load, current output power engine generator, etc.).

The goal of the module is to operate the generator engines (G/Es) in the most optimal way for the actual sail condition, optimizing the fuel and gas usage, reducing operational cost and atmospheric emissions in consequence.

4) *Kyma Ship Performance Trim Optimization Module*

KSP Trim is an optional software module that can be integrated with the standard KSP system. The purpose of the KSP Trim module is to provide the vessel operator with a practical tool for establishing the optimum trim for the vessel at any load and draft condition. Optimum trim is defined as the trim where a vessel will have the best speed through the water at a given draft and load and is, accordingly, an extremely important parameter with regard to vessel overall efficiency and fuel consumption. The optimum trim is related to the physical design of the hull, and will be the same for identical vessels at the same operating conditions.

Establish Trim The principle applied for establishing optimum trim by the KSP Trim module is to use the KSP system's capabilities for data logging and report generation to carry out a series of trials at various loads and drafts. Each series of trials will find the optimum trim level for the current power and draft. This is done by performing runs at various angles of trim whilst keeping the shaft power and mean draft constant. During each run, the vessel speed through water is recorded in order to determine which trim level gives the highest vessel speed. The summarized results of each run are added to the table as they are completed. When all the trials are complete, the results of the trial series are evaluated, as shown in table below:

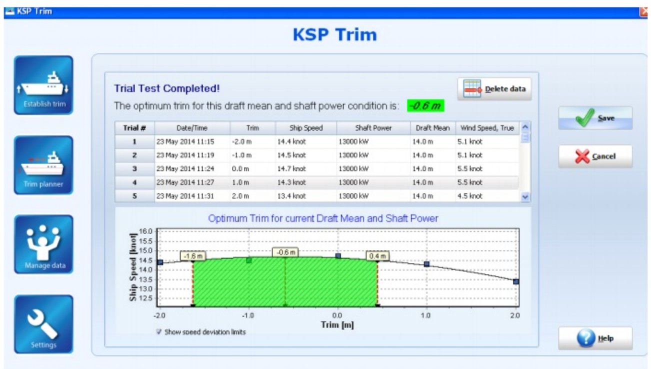


Figure 13

- Trim planner

When the optimal trim has been established, the system can be used as a 'Trim Planner'. The desired shaft power and mean draft values are entered in the 'Trim Planner' and the optimal trim at this condition will be displayed.

- Manage data

All data from each series of trials is stored in the system and can easily be accessed at any time. The optimum trim database can be exported to be used for sister vessels within the same class.

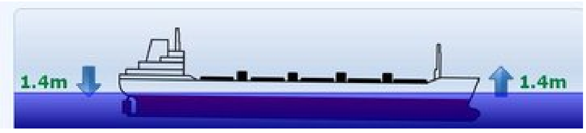


Figure 14

KSP Trim is an optional software module that can be integrated with the standard KSP system.

The purpose of the KSP Trim module is to provide the vessel operator with a practical tool for establishing the optimum trim for the vessel at any load and draft condition.

Optimum trim is defined as the trim where a ship will have the best speed through the water at a given draft and load and is, accordingly, an extremely important parameter with regard to vessel overall efficiency and fuel consumption.

Figure 15

The principle applied for establishing optimum trim by the KSP Trim module is to use the KSP system's capabilities for data logging and report generation to carry out a series of trials at various loads and drafts. The KSP Trim module provides detailed instructions to the operator for carrying out the trials, and will automatically record the required data.

Results are available for review by operator in both numerical and graphical form.

For vessels within a class, having the same hull form and propulsion, the optimum trim chart with regard to load and draft will be the same. This means that the process of running trials to find the optimum trim can be streamlined by the exchange of data between vessels. For this purpose, the KSP Trim module allows its data to be easily imported and exported.

5) *Kyma KSP WDU - Wheel House Display unit*

Ship performance displayed in wheelhouse
The new 10" Kyma Display Unit (KDU-300) for the wheelhouse, C/E office or other location can give you any information available from the Kyma Ship Performance system (KSP).

Instantaneous, averaged and accumulated (day or voyage) values for important values as, for example fuel consumption, shaft power, vessel speed, wind, torque, thrust, +++ can be displayed as both text and/or graphics.

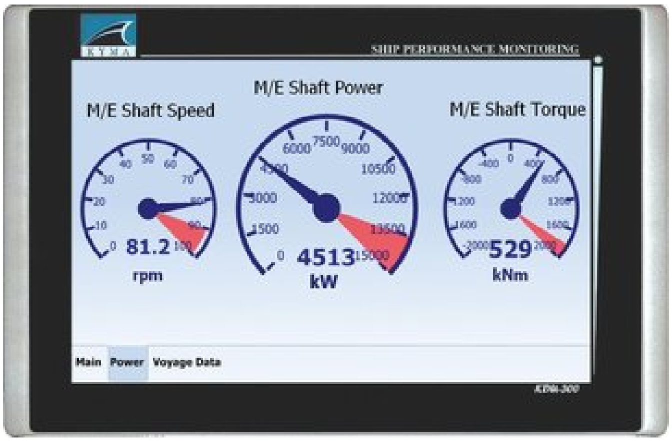


Figure 16

Configurable design and flexibility

- The Kyma WDU is highly configurable so you can choose between different display modes.
- Set up different display pages, like Main, Power and Voyage.

- Choose any combination of analogue meters and digital display.
- Colored sectors may be added to each meter face showing for example the acceptable fuel use limits.
- Screenlight is adjustable and can also switch into a nightmode.

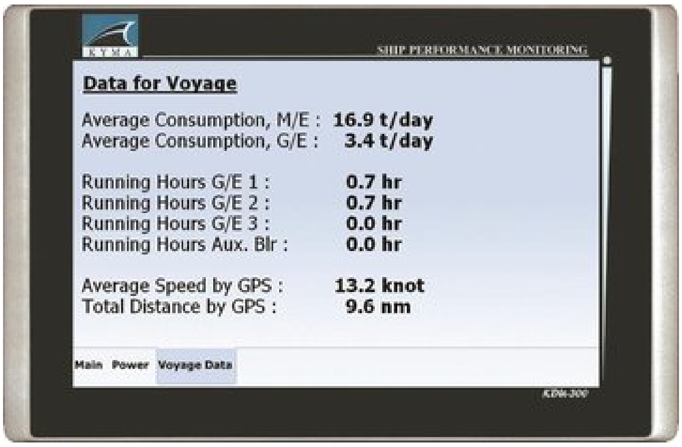


Figure 17

D. Kyma Diesel Analyzer (MIP)

A sophisticated MIP system for engineers to optimize the performance of diesel engines. User friendly software for operation both on board the vessel and at the office onshore. The software is developed from many years experience and feedback from users. Optional measurement of fuel injection pressure.

System benefits

- Reduced fuel consumption
- Engine balancing
- Tuning of ignition timing
- Overload protection
- Improved maintenance
- Reduced spare parts
- Reduced emissions

Information about the engine's operation and condition is displayed both numerically and graphically in the user-friendly software. Curves and bar graphs are used in the presentations, where colors separate and highlight the data. It is also possible to zoom curves for specific details.

An analysis, where data are compared to mean and reference values, provides the user with information about inefficient operation of the engine or cylinder wear.

Measured and calculated values are compared to mean values and reference data. A full-featured text editor included in the software enables the user to add his own comments to the measurements, for instance additional figures, special running condition etc. All information can be printed in the engine condition report, and a Report Wizard makes it easy to create customized report layouts.

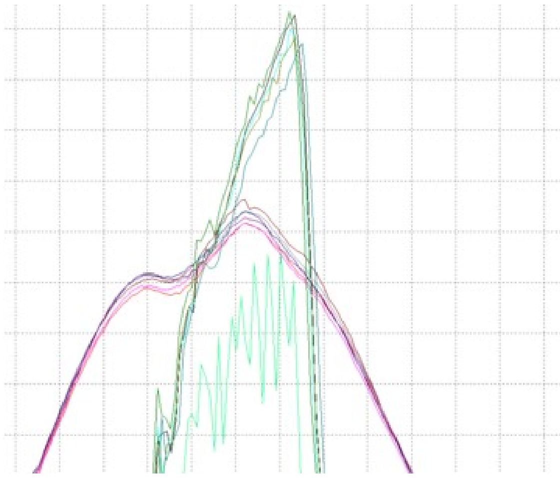


Figure 18

Kyma Diesel Analyzer is a computer based system for monitoring of cylinder and fuel injection system performance on diesel engines. The information can be used for tuning of engine balance, ignition timing, checking of cylinder overload, trending, checking of cylinder wear as well as maintenance planning.

The system can be installed on new buildings and on ship in operation.

Measurements can be done on main engine and auxiliary engines. All measurements is done with a small hand held unit and the information is automatically transferred to the software.

The necessary hardware consists of a portable data logger, electrical junction boxes, sensors and shut-off valves in order to collect performance data form the diesel engines. Optional measurements of fuel injection pressure are available

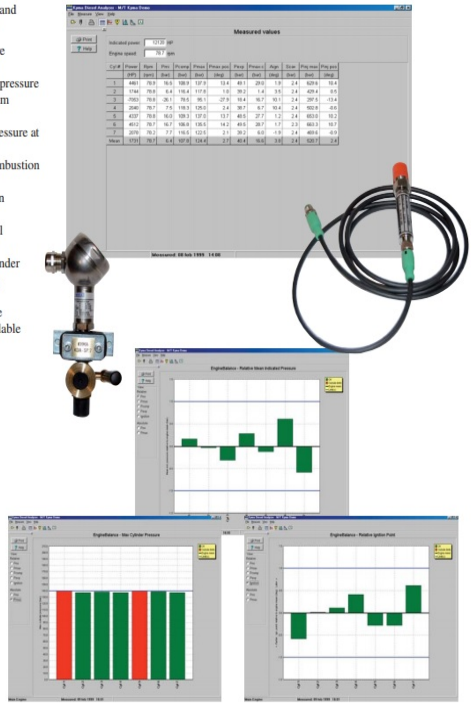
OUTPUT INFORMATION

Information about the engine’s operation and condition is displayed both numerically and graphically in the userfriendly software. Curves and bar graphs are used in the presentations, where colors separate and highlight the data.

Numerical tabulation of recorded and calculated data for one condition:

Pmi	Mean indicated pressure
Pcomp	Compression pressure
Pmax	Maximum combustion pressure
Amax	Crank angle at maximum combustion pressure
Pexp	Expansion pressure (pressure at 40. after TDC)
Pmax-c	Pressure rise due to combustion
Aign	Ignition timing
Pinjmax	Maximum fuel injection pressure
Ainjmax	Crank angle at max fuel injection pressure
Power	Indicated power in cylinder
Rpm	Speed of engine during measurement
Scav	Scavenging air pressure

Trending of all parameters is available



Bar graphs make it easy to check the engine balance, overload or deviation in operating parameters for the cylinders.
Parameters for relative or absolute presentation:

- Mean indicated pressure
- Max combustion pressure
- Compression pressure
- Expansion pressure.
- Ignition timing

The bar graphs are effective tools for tuning of the engine and for maintenance planning.
This makes it easy to identify wrong ignition timing for one or more cylinders.

An analysis, where data are compared to mean and reference values, provides the user with information about ineffi cient operation of the engine or cylinder wear.
A full-featured text editor included in the software enables the user to add his own comments to the measurements, for instance additional fi gures, special running condition etc.
All information can be printed in the engine condition report and also sent on shore.

Cylinder and fuel injection pressures versus crank angle or cylinder volume can be shown simultaneously, so that injection and ignition points can be compared directly. Reference curves and curves from different cylinders can be presented together with these curves making it easy to fi nd deviations. For detailed analysis, any section of the curves can be zoomed. Malfunction will be seen and corrective actions can be taken.

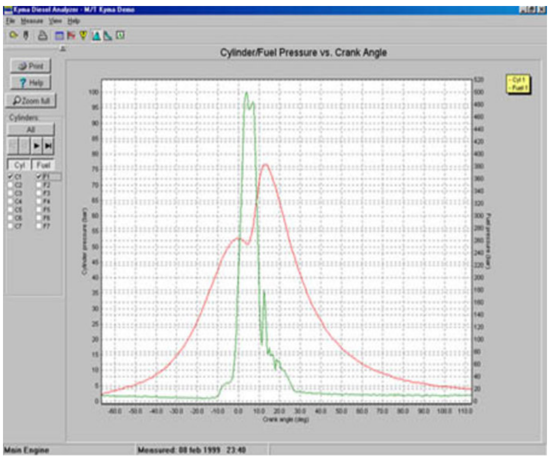


Figure 19

E. Kyma Office – WEB

KSP Office WEB is a powerful web based management tool for evaluating fleet performance. It allows the onshore technical team to follow each individual vessel or a complete fleet with easy and secure access from any internet connected PC or Tablet. The system works with all common browsers.
The easily understood colour-coded presentation of the vessel’s status, together with nautical information, allows the operator to readily identify where a vessel’s performance has dropped significantly below its individually calibrated benchmark state. Kyma AS Åsamyrane 88 B N-5116 ULSET Bergen, NORWAY Tel : +47 55530014 sales@kyma.no www.kyma.no The consistent use of colour throughout makes it simple to identify a vessel’s performance with regard to hull

fouling, propeller condition and degraded main engine performance.
The CP Module of Kyma Office WEB has been described above. Other programs contained in Kyma Office WEB are the MRV Module and Kyma WEB API

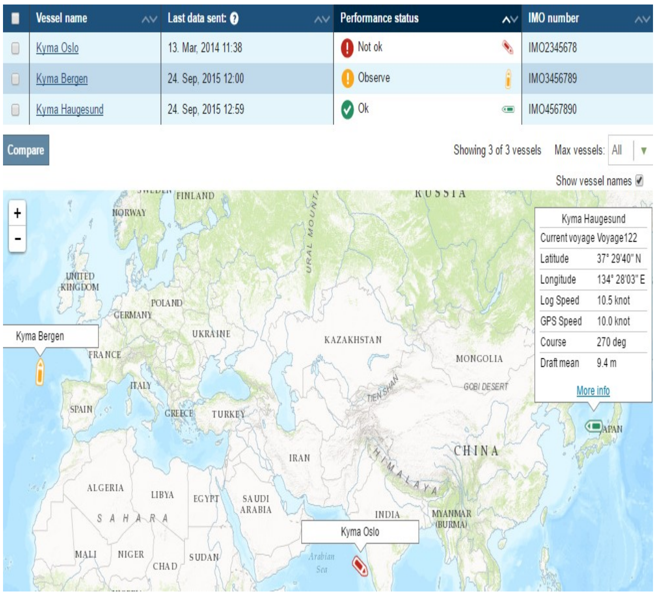
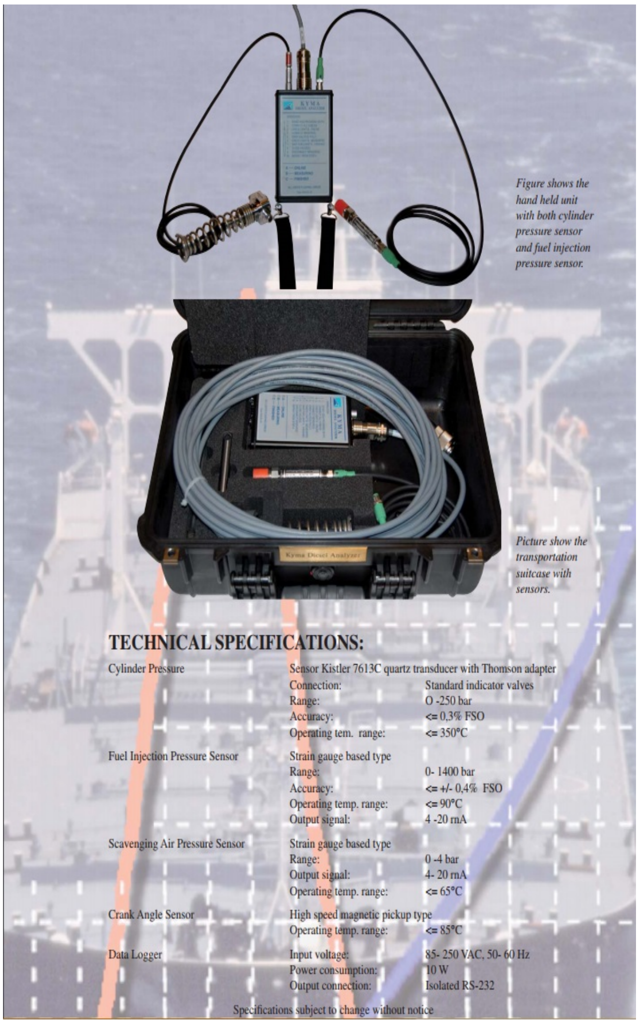


Figure 20



- Kyma Office WEB - MRV module

Kyma Office WEB - MRV module has on June 1st 2017 been certified by Verifavia in compliance with the EU regulation 2015/757, to be set in force by January 2018. The Kyma system is certified for fuel monitoring methods A, B and C. Any preparations, in terms of monitoring plans, shall be verified by August 31st 2017 and is mandatory for all ship owners/operators of vessels > 5000GT, sailing to, from and between EU/EEA ports. Kyma has developed a dedicated tool which offers shipping companies to make the required reports efficiently, based on different means of fuel monitoring. This tool will be available as an optional module to the Kyma Office WEB, either in addition to the Kyma Ship Performance or as a separate and individual feature.

Reports may be generated in spreadsheet (xls) or as CSV-files and/or displayed by use of the Kyma Ship Performance (KSP) WEB system.

Examples

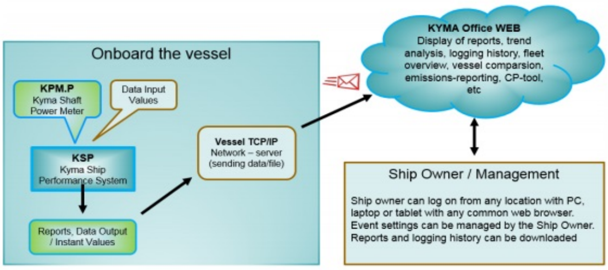


Figure 22

- Web API for Kyma Ship Performance

The Kyma WEB-API provides an interface between the customer's own computer systems and the 'Kyma Cloud' which is a repository for the raw logging data received from the Kyma Ship Performance System on-board their vessels. The WEB-API will provide a secure automatic transfer of the selected data to the customers own computer system.

The data available from the Kyma Ship Performance System on-board is collected from various sources, for example shaft torque, power, RPM, fuel flow, speed log, GPS-data, wind, draft, rudder angle along with any selected vessel-specific inputs and performance metrics calculated by the on-board system such as Specific fuel oil consumption. The data can naturally be combined with data from other data sources within the customer own data system.

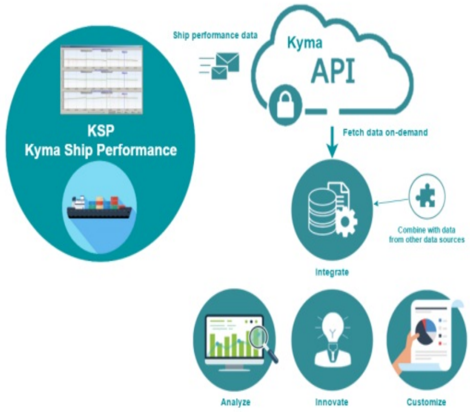


Figure 23

The data available from the Kyma Ship Performance System on-board is collected from various sources, for example shaft torque, power, RPM, fuel flow, speed log, GPS-data, wind, draft, rudder angle along with any selected vessel-specific inputs and performance metrics calculated by the on-board system such as Specific fuel oil consumption. The data can naturally be combined with data from other data sources within the customer own data system.

Additional information The API is provided to allow our customers computer systems on-line access to 'raw' vessel data in order that they can perform any required further analysis and report production. There is no capability to access the 'readyanalyzed' tables, diagrams and reports that would be generated by the Kyma KSP Office WEB product. The API allows the data to be accessed from within the customer's own software systems.

F. Kyma Steam Analyzer

The fuel economy of a steam turbine plant is strongly dependent of the operation and the condition of the plant. Incorrect operation and inefficient components lead to large fuel losses. Performance monitoring systems are excellent tools to analyze the condition and ensure optimum operation. Systems installed on more than 180 steam ships, have documented a fuel saving of 3% to 6%.

Kyma Steam Analyzer (KSA) is an analysis tool for optimum steam turbine plant operation. It consists of an advanced software package for the calculation of heat balance and component efficiencies, engineering support for instrumentation upgrading, and commissioning of the system. The commissioning involves calibration of instruments, engine performance trials and pinpointing of non optimum operation or deficient components.

Kyma Steam Analyzer (KSA) is an analysis tool for optimum steam turbine plant operation. It consists of an advanced software package for the calculation of heat balance and component efficiencies, engineering support for instrumentation upgrading, and commissioning of the system. The commissioning involves calibration of instruments, engine performance trials and pinpointing of non optimum operation or deficient components.

The software run on a personal computer under Windows 7™. The KSA and KSP system can be integrated for operation on the same computer. This means that input data required for the KSA system can collected from IAS system No previous computer experience is necessary for operation.

Each system is tailor-made for the specific plant. The units in the input and the output forms are normally the same as on the local instrumentation.

The system can be used for all normal at sea conditions with stable operation of the steam plant. As this is mainly a diagnostic tool, it is sufficient to do an engine trial once a week or when the vessel schedule permits.

The input data are recorded from the ship's instrumentation and from sensors installed during the delivery of the system, normally from the IAS system. If not all variables are on-line, manual inputs can be applied.

The inputs are fuel (gas) consumption, distillate production, power output, propeller revolution, and physical properties of steam and water for all major components. Data for combustion air and flue gas are also measured.

Based on the input data to the computer, a performance report is printed. The printout shows the condition of the plant and the components compared to design or trial data. The calculations will specify component losses and what they represent in excess fuel consumption. Any non-optimum operation will be specified in the printout. A plant operation check list indicates operating status of normally adjustable parameters. An error check list is printed for a component or parameter out of range.

For the major components graphical presentation is used to express component efficiency relative to a design or trial curve. The deviation from reference is seen both graphically and numerically, including deviation in fuel consumption.

The output information from the system will specify where to find the faults. The program also calculates torque distribution between HP-turbine and LP-turbine with warning for gear overload.

The calculated heat balance and flow diagram shows the physical conditions of steam and water and the mass flows in the plant. Together with the component efficiency calculation and a plant operation check list, this gives the operating engineers the information required to run the plant at an optimum condition.

VI. CONCLUSION

The reasons for implementing performance monitoring and energy efficiency management are of vital importance not only from an environmental point of view, but also from a financial scope

The GHG emissions coming from maritime are a considerable amount, although maritime is the most fuel efficient means of transportation. This has to do with the fact that in the past years there has been a constantly growing demand for ship transportation and this demand is expected to grow even more in the forthcoming years.

This is why regulations and indicators such as the EEDI , the SEEMP and ISO 19030 have been established, aiming to make the current existing vessels, as well as the newly manufactured ones , as energy efficient as possible.

The environmental targets of these regulations have been presented in previous chapters and are interpreted in GHG emissions per tonne mile. Fuel economy and optimum consumption can reduce the GHG emissions as well, offering at the same time profit growth for the ship owner companies due to fuel savings. For as long as the main , if not only, option for fuel in maritime is oil, reducing the cost of voyage, especially at cargo ships, will offer a great advantage for companies that are willing to implement fuel saving technology

According to Fathom Focus, 2014 the fuel savings by the optimization of the factors that influence fuel consumption can be presented as:

- By up to 5% owing to trim optimization
- 13-36% due to speed and throttle optimization
- Up to 4% for weather routing and route optimization
- Up to 10% concerning hull and propeller maintenance
- 2% for Engine performance monitoring
- 0.5% by machinery optimization

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