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WiDE – an example on how digitalization creates value for ship operators

Digitalization & Connectivity

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ABSTRACT

Thousands of data are typically generated by the main machinery onboard and collected by monitoring systems. However, without an efficient aggregation and analysis of these data it is challenging to provide an effective decision support to the shipping companies. WinGD started to incorporate and standardise digital technology into its product developments back in 2018 with the market introduction of the WinGD Integrated Digital Expert (WiDE), which has since then been installed on many vessels. WiDE is fully integrated in WinGD engine product lifecycle and allows not only to monitor the engine performance, but also to pro-actively predict system or component anomalies and offer support through live troubleshooting and diagnostic advice to the crew. The present paper describes how combining the implementation of digital twins created for each specific engine, based on specific geometry, engine control settings and tunings, with advanced analytics based on internal design and operational expertise can contribute to increase the main engine availability while reducing the workload for the onboard crew compared to traditional monitoring systems. The paper further describes the continuous product improvements WinGD is applying based on the experience gathered from the deployment on many vessels with engines of various sizes. In particular, the paper will describe how WiDE is unique positioned to contribute to optimize the maintenance activities on the main engine based on real stress of the main components. This result can be achieved only by combining engine's specific digital twins with direct design and operation experience gained over the years with millions of operating hours. The paper also describes the further development and extension of WiDE to encompass vessel performance. In this innovative application, the propulsion engine is used as a "virtual sensor" for vessel performance assessment process. The vessel's data are verified first by WiDE, which also ensures that any engine underperformance is accounted for. WiDE then supplies these validated data to the vessel performance module, where machine learning is used for linking the engine performance, instantaneous torque supplied and fuel consumed, to the detailed data on vessel journeys, events and geographical location, leading to deduction of profiles for vessel operation under various conditions. This innovative approach has been shown to provide very accurate performance assessment and prognostics, which are valuable for vessel comprehensive management. The results of a full-scale long-term pilot installation of this integrated application on a vessel are presented, demonstrating how this innovative combination can cover both the vessel and the engine performance evaluation requirements of a shipping company.

1 INTRODUCTION

Ship owners and operators strive to maximize vessel availability and profitability. Continuous monitoring of main propulsion engine behaviour plays an important role, ensuring components are in good condition and keeping track of wear in order to plan overhauls or reconditioning.

Traditionally engine monitoring has been performed by crews manually checking and recording the condition of the engine. With the introduction of new environmental regulations, more technologies and parts need to be taken care of, requiring continuous crew training. Manual recording implies high effort both onboard and from the onshore crews that analyse the data.

The availability of engine and ship sensors, and the ability to send data from the vessel to onshore servers at low costs presents an opportunity for operators to harness digital intelligence. This can improve vessel efficiency, release crew members from monitoring tasks and provide automated analysis of engine condition.

This is the background for the development of WiDE (WinGD integrated Digital Expert) [1]. Since its introduction as standard specification on WinGD branded engines and subsequent installation on all new delivered engines from 2020, both the hardware and software elements of WiDE have been further developed for greater functionality.

The original digital-only system has also been extended by a remote monitoring service, allowing engine experts to aid onboard crews with problem solving. This approach provides the operator with the fastest and most competent advice on optimizing engine operation, while ensuring that new findings can be integrated in the software system.

As well as improvements to existing software, WiDE has been extended to include an approach for condition-based maintenance, overall vessel (hull and propeller) performance monitoring and optimisation.

This paper describes the features and capabilities available through WiDE today, the processes introduced to validate and continuously improve the system and the latest support functions under development.

2 CUSTOMER EXPERIENCE

WiDE is a comprehensive digital tool providing ship operators with a full picture of their engine's operating condition and enabling actions to control and optimise ship and fleet operations. WiDE consists of hardware and software that collects data and analyses it based on core WinGD knowledge. By analysing engine performance and health status in real-time, WiDE enables early detection of anomalies and empowers crew to resolve issues significantly faster (Figure 1).

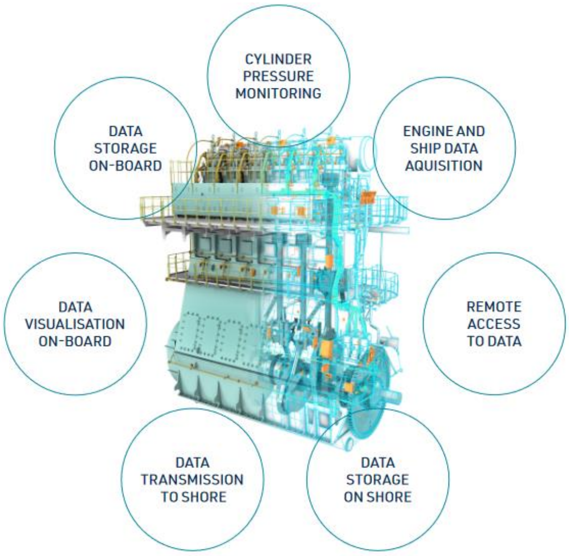

Figure 1: WiDE provides access to and visualisation of engine and ship data

2.1 Data collection

The vessel hardware component of WiDE is the Data Collection and Monitoring (DCM) system, which is a standard component delivered with new WinGD engines. Installation and cabling are performed during engine commissioning to enable the collection and transfer of engine data from the sea trial onwards. DCM collects two categories of data:

- 'Slow' data with a sampling frequency of 1-10s, consisting of engine and main ship data.
- 'Fast' data with a sampling frequency of milliseconds, consisting mainly of cylinder data (e.g. cylinder combustion pressure, exhaust valve movement, gas admission valve operation)

2.2 Data analysis

The software component of WiDE is the Engine Diagnostic System (EDS), comprising rule-based, advanced machine learning algorithms and an engine 'digital twin' – a thermodynamic model calibrated using shop test (as-new) engine data combined with actual, in service measurements.

The EDS software is installed on the DCM computer and uses this measured data to perform the engine diagnostic analyses. WiDE constantly monitors the status of the engine's main components, identifying potential anomalies that enable early detection and information for crews. If an anomaly is detected, WiDE alerts crews and provides interactive troubleshooting support. WinGD operation experts are also notified to provide proactive remote support.

The EDS software package includes the following modules:

- Engine performance monitoring
- Component diagnostics
- Troubleshooting support

The performance monitoring module detects and analyses actual engine performance, evaluating any divergence from optimal reference conditions.

The component diagnostics application collects and monitors signals from several engine sub-systems., including:

- Servo oil system
- Fuel injection system
- Piston running behaviour
- Scavenge air and exhaust gas system
- Engine control system
- Gas admission system (for dual fuel engines)

The received data is analysed using advanced analytics techniques and defined correlations between the signals to predict engine component malfunctions, and to generate actionable insights.

Component diagnostics draw on know-how-based analysis to confirm operation within target boundaries or predict malfunctions and failures. The module uses the measured data already processed by the DCM to monitor the performance of the sub-systems in real time.

The troubleshooting support module provides customers with instructions on how to solve engine problems in case of a detected fault or warning. It reports the problem, lists relevant alarms, identifies the part involved and provides basic instructions on how to solve the problem.

2.3 Data visualisation

The data collected is available and displayable both on board and on shore, the latter by sending and storing it on a WinGD server via encrypted communication channels. Ship operators can access data through a protected web portal user account which meets the latest cyber security requirements [2].

WiDE offers two basic options to visualize the data.

2.3.1 Data trend visualisation

The engineer on board can see deviations in trends across time, giving them an initial indication of the health of the engine.

Figure 2 shows an example of data trend visualisation. Vessel speed and engine power over time are compared with engine data including cylinder pressure, liner wall temperatures and injection system parameters. This enables crew to easily compare for example the behaviour of individual cylinders (combustion, injection system, etc.) or sudden deviations over time at stable engine operating conditions.

Figure 2: Data trend analysis

2.3.2 Engine and engine systems health overview

The next level of insight is provided by visualizing the condition of components and systems of the engine, which support the onboard engineer in the interpretation of the data.

The engine diagnostic system with the digital twin allows crew to compare expected component parameter values at the same engine load, power and speed with the actual measured value, taking into account actual environmental conditions and engine settings. Instead of looking at individual data, the difference between actual and expected values can be visualized.

Figure 3 shows a general overview, displaying health of all systems by green (all in order) or red (system deviation detected). With this visualisation the ship engineer gets a very fast overview on the overall engine condition.

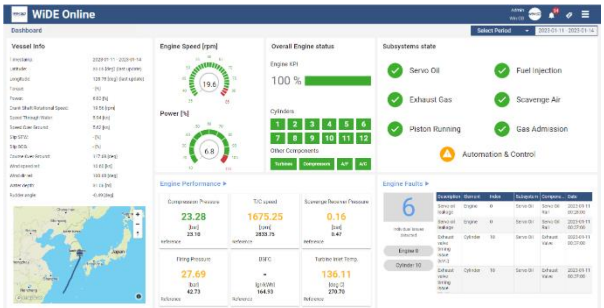

Figure 3: WiDE online display giving an overall picture of engine health

Moving forward, the analysis result of each individual engine system can be shown. As example, Figure 4 shows the overview of the fuel injection system condition, with the performance degree indicated simply in green, yellow or red, either confirming proper operating conditions or indicating the urgency for checking and remedying deviations from target levels.

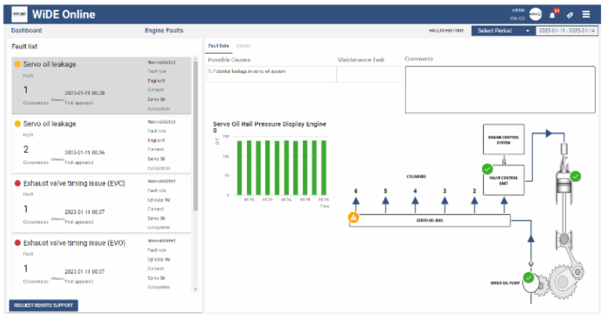

Figure 4: Example of engine system condition display (here, the fuel injection system)

Through the onboard user interface, crew have access to all necessary charts and tables for easier data visualisation and analysis, such as trends, dashboards, reports and logs. All engine specific signals can be accessed in one place.

2.4 Engine performance reports

Ship engineers and vessel superintendents need to report regularly on the operating condition of engines. Observations made during a specified time range are documented as part of quality monitoring processes. This reporting also ensures that deviations from normal operating conditions are detected and opportunities for performance improvements captured.

WiDE enables crews and superintendents to generate an automatic report including the following information:

- An overall picture displaying health of all engine systems
- Review of behaviour of key engine data like power, turbocharging data, performance data, injections system parameters, etc. over time in comparison to reference data

As an optional service, the engine designer's experts can review the recorded information on the cloud, providing an extended report with additional data and a more in-depth interpretation. This service includes expert recommendations to improve engine performance or check engines systems that may require attention.

2.5 Support for ship operators from remote experts

Engine technology is subject to continuous improvement. These improvements are needed to optimize fuel consumption, reduce overall operational life cycle costs, meet new emission regulation requirements or allow combustion of new more environmental friendly fuels. This evolution requires crews to continuously update their knowledge of engine behaviour and new engine features and controls.

The WiDE system is similarly under continuous improvement and the actual installed digital support may not cover all events experienced on board.

To deliver even greater support, customers are being offered a remote monitoring service staffed by engine designer experts.

These engineers have continuous access to the engine data and can support the crew in real time, helping to identify new issues, possibly dispensing with the time and cost associated with sending service engineers to a vessel, and eventually increasing engine availability by fast and competent solution finding.

An added benefit of this remote support is that learnings can lead to new analysis algorithms being implemented into the monitoring system. Remote monitoring is therefore part of a closed loop improvement process for the WiDE system, while also delivering continuous improvement of onboard troubleshooting processes.

As well as supporting troubleshooting for a sudden issue, remote WinGD engineers are also able to prevent costly and time-consuming damage. By monitoring the performance of vessels at all times, potential problems can be identified at in an early stage and action taken to ensure uninterrupted operation and optimal engine performance.

WiDE remote support centres are established in Switzerland and South Korea (Figure 5), enabling around-the-clock support, wherever the vessel is located.

Figure 5: WinGD WiDE room in Switzerland.

To explain the remote support process and value, two examples of troubleshooting support are described below.

2.5.1 Remote support case: Piston running

Piston ring scuffing on internal combustion engines is a type of excessive wear that occurs when the piston rings rub against the cylinder walls. Scuffing can be identified by visual inspection of the cylinder walls and piston rings for signs of discoloration, scoring, or material transfer. Such an example can be seen in Figure 6.

Figure 6: Local scoring/scuffing of ‘A’ ring gap ends.

Piston running systems usually optimized during more stable shop-trial conditions experience new boundary conditions during vessel voyages. In some cases this can move the piston running system out of balance. With the help of the WiDE monitoring system, such situations could be analyzed by remote engine design experts to help the crew to secure engine operation. As a first step the history of engine operating condition and the liner temperatures was analyzed identifying unfavourable operating ranges, mainly related to transient operation outside the normal reference conditions. Eventually a first direct feedback could be provided to crew on preventive measures to secure vessel safety and operability. In a second step, updates to the piston running system design and engine control were introduced to replace the first preventive measures and re-establish the full operating range.

Finally, the above analysis revealed new insight on the connection between selected engine parameter changes and scuffing events. The information was fed back to the EDS diagnostic system with new improved rules to identify these anomalies, enabling early pre-scuffing warning to the crew (see also chapter 3.1.3.3).

2.5.2 Remote support case: Exhaust valve

Another engine component subject to long-term wear is the exhaust valve. Exceptional situations may lead to damage of the sealing surface and the need to switch off the affected cylinder, with an impact on operational cost and reliability.

Exhaust valve damages often relate to combustion characteristics deviating from target level. This can be very challenging to troubleshoot by using only signals typically monitored by the Alarm Monitoring Systems (AMS), such as exhaust gas temperatures. These signals sometimes show abnormal behavior only after the exhaust valve damage has fully manifested, indicating the final effect rather than the root cause.

One such damage can be seen in Figure 7. This picture is taken from the sealing surface between the exhaust valve and the valve seat, where obvious damage and small pits were observed. The material investigation revealed a network of surface cracking and resulting pitting, caused by high levels of fatigue.

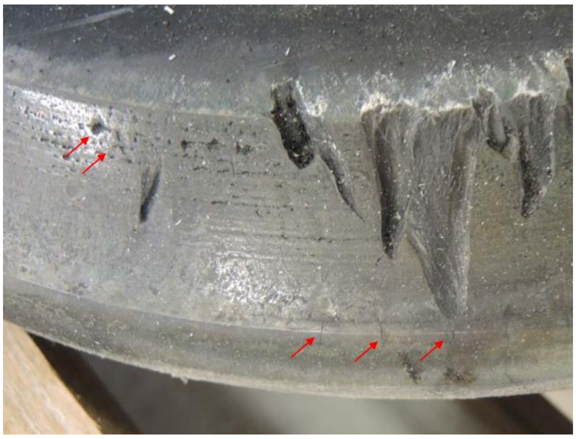

Figure 7: Exhaust valve sealing surface damage.

WiDE allows for the collection of fast signal data at a high sampling frequency (1 kHz), which has proven useful in identifying the cause of such issues in the field and developing appropriate remedies.

In the specific case on a X-DF engine, the in-cylinder pressure curves, exhaust valve stroke and gas admission valve opening signals were collected. The investigation revealed some abnormal combustion cycles with strong gas pre-ignition and in other cases misfiring/pre-ignition, as can be seen in Figure 8.

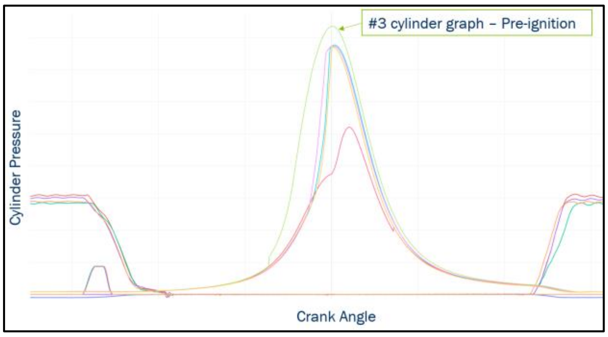

Figure 8: WiDE fast signal collection with pre-ignition on cylinder #3

The Root Cause Analysis (RCA) through the WiDE data revealed that the reason for the pre-ignition was a leaking fuel injector. This was later confirmed by the crew onboard the vessel when removing the fuel injectors from this cylinder.

In this case troubleshooting used analysis of historical WiDE data before the damage. The operator benefitted from an accelerated RCA process. Again, using this experience, new tools and algorithms to detect such abnormalities in real-time data were incorporated to the installed WiDE system.

3 SOLUTION IMPROVEMENTS

3.1 Improvement of User Interfaces

The user interfaces (UI) of DCM and EDS are developed based on web application technology and have been updated continuously for new features and enhanced based on cyber security requirements.

The on board UI for EDS was designed to be user-friendly, delivering information in a direct manner without forcing the user to take more steps to acquire it. The UI is intentionally lean and hides the complexity and technical depth of the underlying engineering, mathematical, logical, and statistical calculations taking place in the background. The UI comprises the main dashboard as well pages for each EDS module.

High resolution or fast data is a unique feature of WiDE, which can show important signals such as cylinder pressure curves, GAV positions, exhaust valve positions, injection quantity and lubrication pressures. These can be accessed without installing additional hardware.

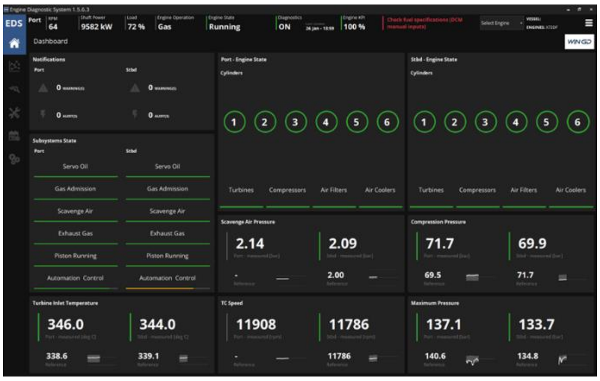

Figure 9. Example of EDS Dashboard from a X72-DF twin engine

The main view of the EDS dashboard (Figure 9), gives the user a quick overview of engine condition and operation as well as all key issues and core parameters analyzed within EDS. It also tracks the health of core elements/parts (cylinders, turbochargers, etc.) and the evolution of some key engine parameters. Most importantly, the dashboard presents the latest findings and events diagnosed by the system. Depending on the findings presented, the user can navigate deeper into the rest of the UI modules and generate reports.

As log viewer has been added, allowing users to see the real-time alarms and events from the control system. This is valuable information to be used for the engine monitoring and diagnostics activities on board.

3.2 Establishment of powerful hybrid edge-cloud system

Unlike most conventional IoT solutions, WiDE provides an optimized combination of local onboard capabilities and a strong cloud footprint.

Decisions on maintenance or corrective measures may need collaboration between crew on board, the superintendent and the fleet manager. Onshore fleet management have direct access to most of this data through the cloud-based advisory system.

The WiDE cloud system also allows the mobilization of WinGD's global experts network and service company.

Sometimes more data is needed to perform complex in-depth analysis cases with support from the onshore team. Therefore the WiDE cloud system has been designed with a secure channel to the onboard DCM system, allowing access to high-resolution data.

The hybrid edge-cloud solution also enables an efficient maintenance concept for the onboard system. Using the same secure connection, upgrades and new releases for the onboard software can be installed.

With the increasing number of installations connected to the cloud a continuous adaptation of the storage capacity has and is being pursued, which also secures fast data transfer and access by the different users.

To protect the vessel from external unallowed access, emphasis has been put on the cyber security of the communication between on board and cloud systems. Following compliance with the basic cyber security requirement as the SP0 rules defined by class DNV-GL [2] the system is continuously updated, and eventually will be also compliant with the UR26 rule imposed by IACS for all vessels ordered from 1st January 2024 onwards [3].

3.3 Improvement of the diagnostic system performance

The initially included rulesets were built using failure mode effects analysis (FMEA), thresholds, statistics and operational data available at the time of development. Each subsystem (e.g., fuel injection, piston running, servo oil, gas admission) has a specific ruleset. A matrix of fault symptoms and effects was constructed for the various engine components and subsystems.

3.3.1 Customer to expert feedback loop

With the extensive deployment of WiDE on vessels, there was and is opportunity to validate, correct and improve rulesets using actual operational data from running engines, feedback from WiDE users and input from the WinGD 24/7 service engineers.

In some cases, it was noticed that rulesets were too sensitive. In such instances, a deeper investigation and revision has taken place. In other cases, it was found that the process exhibited peculiarities which had to be accounted for through a deeper review of the specific ruleset.

Occasionally the quality of data coming from the sensors is poor and unnecessarily triggering rules. This was addressed by advanced filtering concepts of the data. The increasing operational experience with DF engines led to the creation of algorithms supporting new diagnostic rules for gas admission and pre-ignition detection.

Regular analysis of vessel operator experience and feedback has become an essential part of the EDS system improvement process.

3.3.2 Assessment of diagnostic fleet data

Beyond individual case feedback from customers, analysing diagnostic data provides valuable metrics related to the activation count of individual diagnostic rules. Holistic performance indicators across engine fleets, time dependencies, etc. can be extracted. Figure 10 below shows the number of individual diagnostic rule activations collected over a two-year period.

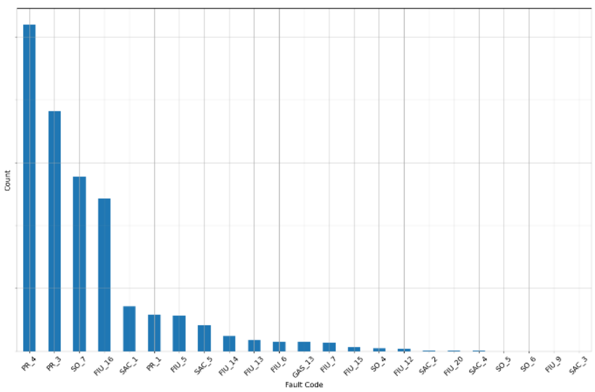

Figure 10: Comparison of diagnostic rule activations collected for different engine systems over same period of time.

These results eventually show differences in the number of rule activations across individual engines systems. With the support and added value of internal warranty data, combined with historic diagnostic data collected from the field, continuous steps are taken to ensure the engine diagnostics in WIDE are fine tuned to be in line with the latest requirements. This includes updating the parameterization of individual diagnostic rules as well as removing, consolidating, or adding new diagnostic rules as deemed necessary. In this way, the diagnostic set in WiDE always remains up to date and maximizes value for the vessel operator.

3.3.3 Development of new anomaly detection algorithms

By combining a ruleset based on expert knowledge with a digital twin engine model, WiDE can detect most of the major issues that are well known to engine experts, and can therefore be defined by clear rules.

However, not all relevant incidents that can occur on an engine are known precisely enough to be defined and detected by simple algorithms. Certain problems are so complex that they need a new analysis approach. There are also cases where the operating condition looks acceptable to an expert at first glance, but damaging behaviour is already taking place. Such problems will only be detected by an unambiguous rule when the behaviour exceeds a certain threshold and greater damage has already occurred.

To detect such behaviour at an early stage, a method is needed to detect even small deviations from the normal state (anomalies). However, such an anomaly detection can only use its pattern recognition capability to judge whether the current operating state deviates from the norm. A clear attribution to a specific fault is only possible in combination with additional algorithms. However, the pure early detection of a deviating behavior is already a great help for a continuous monitoring of the engine operation. If such a deviation is detected, then the crew can receive a warning so that they can then use their knowledge to check whether a larger issue is possibly brewing.

The development of such an Anomaly Detection system has been started, with the target to integrate it into WiDE. A machine learning method is applied with a so-called unsupervised approach [4]. The data used for the training of the algorithm is engine operation data which has been labeled by domain experts to show normal behaviour. When the Anomaly Detection method is used, data from the engine being monitored is compared with the learned normal operating condition. An Anomaly Score (AS) is applied as a measure of how far the current condition deviates from the normal operation.

The Anomaly Score is calibrated by engine experts: an anomaly value below 1 confirms the operating condition is within the target range. An AS above 1 means, that the current operating condition is starting to be abnormal. The higher the AS, the higher the degree of the anomaly.

In Figure 11 the results of WinGDs' Anomaly Detection method is shown for the analysis of cylinder liner wall temperatures. The lower part of the chart shows the temperature sensors for one specific cylinder, while the Anomaly Score is plotted in the upper part. A horizontal line shows the anomaly threshold value of 1. If the red curve is above this threshold, the liner wall temperatures are anomalous. The signal stays below the threshold for several weeks. But when it exceeds the anomaly threshold, it does so significantly. This is a clear indication that the liner wall temperature is in an anomalous state.

This case is from a real liner scuffing incident on that cylinder. When the crew detected the scuffing themselves, the liner was so heavily damaged that it had to replaced. But the Anomaly Score had already exceeded the threshold days before the crew detected the issue. This early detection could have enabled the crew to identify the issue much earlier and take actions to protect the material.

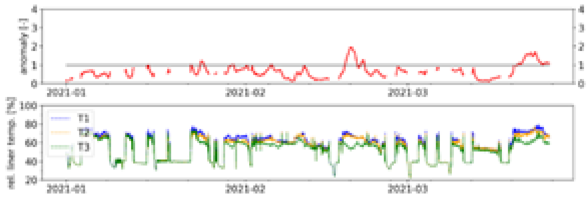

Figure 11: Example result of the anomaly detection for scuffing detection

Such anomaly detecting algorithms are and will be continuously improved and implemented to the benefit of the vessel operator.

3.4 Transitioning to Condition Based Maintenance (CBM)

3.4.1 Introduction

Traditionally, engine maintenance has been based on planned time intervals set by the engine designer based on risk assessments made against a set of characteristics specific to each component. This landscape is now changing towards condition-based maintenance, which will eventually evolve into Predictive Maintenance [5]. This section will describe how WinGD as an engine designer is uniquely positioned to contribute to optimize the maintenance activities of the main engine by combining operational experience with the data collected from the engine and analysed by advanced methodologies.

The use of vessel data in combination with design experience provides the opportunity to assess operational severity and thus facilitates the transition to a condition-based maintenance (CBM) scheme. Classification societies have also been consulted to support the development and to ensure that the necessary requirements for the CBM maintenance scheme can be fulfilled for the pilot.

A visual example of a condition based proposed overhauling timing is shown in Figure 12 below for extending the overhauling interval (green dot).

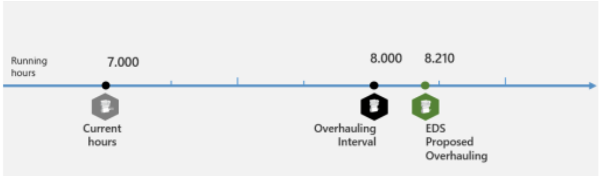

Figure 12: Extension of overhaul interval (green dot)

3.4.2 Pilot

To facilitate the development of CBM methodologies, a pilot vessel has been defined. This will allow the operational behaviour and performance of the methods to be monitored over extended periods of time and revised if necessary.

3.4.3 Concepts

The applied CBM methodology aims to estimate the remaining useful life (RUL) of components based on the estimation of 'usage-based' operating hours. The concept is based on characterising component usage as light, average or heavy based on a set of mathematically defined criteria, comparing continuous signal readings related to current component operation against a set of predefined criteria and thresholds at each time step. The logic outputs a so-called usage score, which can further be applied to map the usage characterization and derive a usage hour multiplier. An overview can be seen in Figure 13 below.

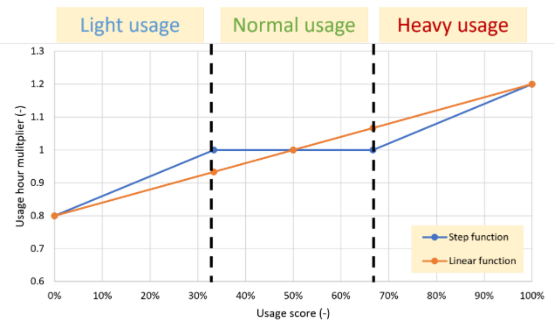

Figure 13. Usage characterization and usage hour multiplier as function of usage score.

The usage multiplier is applied to the standard running hours in the following step to compensate for the severity of usage exerted on the component, resulting in so-called 'usage-based' running hours. This calculation follows the simple formula below and is performed at each time step. Here, h represents the operation hours and C the usage hour multiplier (obtained in via figure X above).

$$h_{usage}(t) = C(t) \cdot h_{actual}(t)$$

The maximum usage hours multiplier which currently can be assigned is set at 1.2, while the minimum value is set to 0.8. Thus, in the case a component being defined as operating under 'heavy usage', the usage-based running hours can in the most extreme case be 1.2 and 0.8 in the case of 'light usage'. Thus, an example of how standard and usage-based running hours can evolve over time is shown in Figure 14 below, where the x-axis represents the actual time trace.

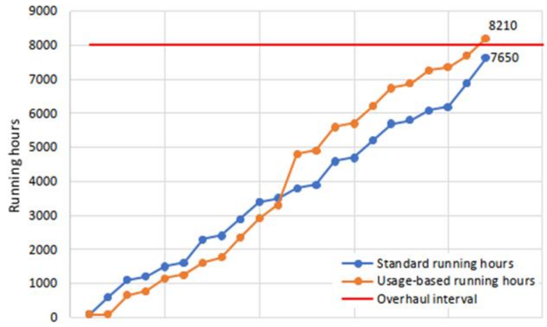

Figure 14. Component 'standard running hours' (orange), 'usage-based running hours' (blue) as well the 'overhaul interval' (red) as function of actual time trace

3.4.4 Component Selection

For the pilot installation, the following systems have been selected evaluating the following parameters: ship operator benefit, availability of operational customer data, model development complexity and data/signal availability. The components shortlisted are: Fuel injectors, fuel pump, exhaust valve, piston ring and cylinder liner.

3.4.5 Component Methodologies

Based on concept outline, each of the five selected components has been assigned a logic from detailed expert reviews to define which factors and characteristics determine operational severity.

3.4.6 CBM EDS Event Workflow

The workflow of the condition based maintenance scheme can be seen in the holistic overview in Figure 15 below.

The EDS maintenance event (CBM Task) starts its life cycle on board the vessel and is initially created by the EDS Maintenance module. The event, along with the necessary related information, is transmitted via the cloud to the WinGD user cockpit, where it awaits approval/rejection. Once approved, EDS tasks and maintenance events are available to shipping company personnel through WiDE Online and the shipping company`s maintenance page, accompanied by a notification and an email report communicated to the customer. Additionally, the WiDE Online platform automatically transfers the maintenance tasks and events to the customer's PMS (Planned Maintenance System) via an API, custom-made for each individual PMS. Finally, all reviewed (approved and rejected) tasks are communicated back to the vessel to update its maintenance tasks table.

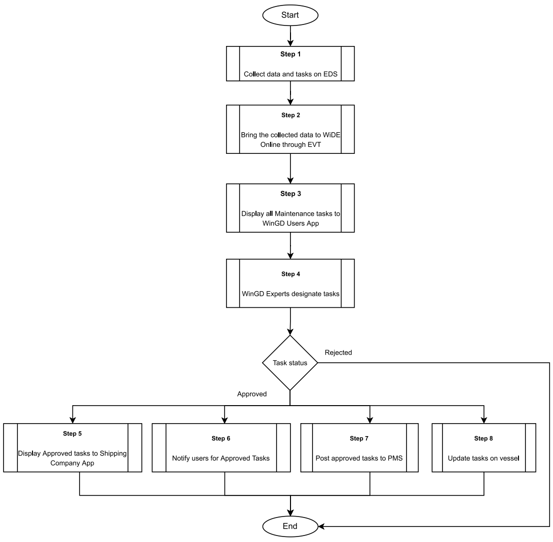

Figure 15: Holistic overview of data exchange and workflow for CM evaluation and approval or rejection of maintenance tasks

3.4.7 CBM EDS User Interface

The webapp cockpit for reviewing and validating the received EDS events triggered on the vessel side by the installed CBM software is shown in Figure 16 below.

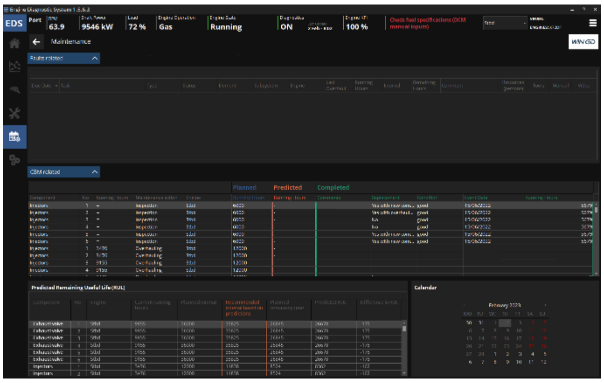

Figure 16: CBM User Interface

The main features consist of charting the evolution of running hours for the components maintained under the schema per the chart in Figure 16 above. Moreover, based on the EDS data received, calculate key performance indicators to better monitor the operational behaviour. Further, following each maintenance event, the actual condition of the components and any remarks made by the crew are included in the table, providing feedback to assess/validate the CBM recommendations. Finally, the interface also enables periodic report generation, compiling charts and calculations in a structured document format.

3.5 Extension of WiDE towards vessel performance optimization

Accuracy of evaluation is important in vessel performance, since the fouling penalty grows slowly over a long period, but its implications are substantial. A change of fuel oil consumption by 1% is difficult to detect, but can result in additional fuel costs from several 10,000 USD per year for small vessels to several 100,000 USD per year for large container vessels.

With the software module named QUAD, a novel methodology is introduced where the fundamental process in ship operation of the successive conversion of fuel into engine power, propeller thrust, and vessel speed is considered in two interlinked parts. (Figure 17)

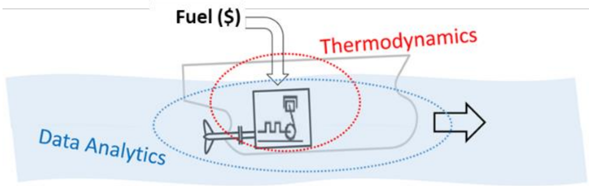

Figure 17: Combination of data from different sources used to improve vessel performance prediction accuracy

The first part uses the ‘engine as a sensor’ and through a thermodynamic model calculates the engine instantaneous power supply. This links to the second part which uses continuous vessel telemetry data, fed into analytics algorithms for hull power demand estimation, for each operating condition (Figure 18).

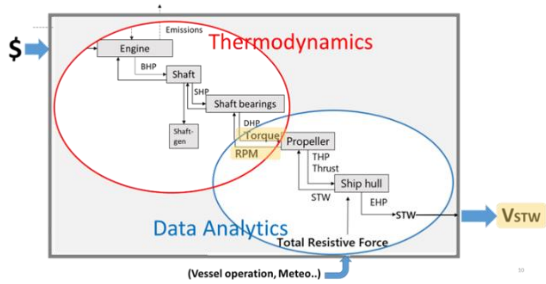

Figure 18: Connecting Engine Thermodynamic and vessel perfomance data

QUAD uses the continuous vessel and engine operation and navigation data available through WiDE, removing the need for any additional hardware installation onboard. Within QUAD, telemetry recordings of vessel and engine data allow vessel profiling and performance evaluation (Figure 19).

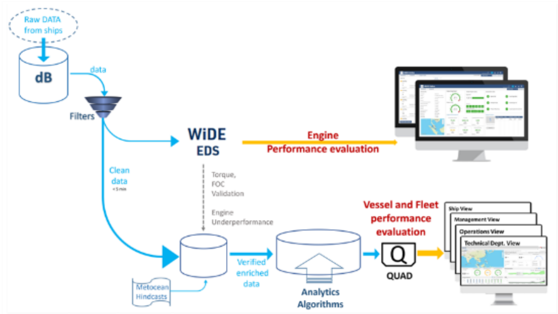

Figure 19: Data and analysis flow of QUAD software to evaluate vessel performance.

QUAD uses analytics/machine learning applied to continuous vessel data, combined with metocean hindcasts, to create vessel performance models used for analysis of past performance and performance predictions. The engine thermodynamics-based calculations in the EDS engine 'digital-twin' provide increased accuracy in the analysis by validating measurements of torque and fuel consumption. This ensures that the analytics algorithms in QUAD for vessel performance are fed with highest quality data, enabling the dissection between increased fuel oil consumption due to any engine under-performance and any extra fueling from increased power demand due to fouling.

The QUAD application within WiDE provides:

- Detailed analysis of current and past hull and propeller fouling: this provides an accurate estimation of current overconsumption due to fouling to aid with optimal cleaning event planning, as well as quantification of the improvement from past cleaning events.
- Current vessel performance: accurate outputs of speed/fuel oil consumption relationship for the current state of the vessel for any sailing condition (draught, trim, weather) to inform chartering. This 'vessel profile' is also accessible via API for use with vessel routing systems.
- Main engine related CII (Carbon Intensity Indicator [6]) analysis:
    - Past CII analysis: Detailed analysis of the evolution of CII and the effect of different factors (vessel speed, currents, weather, fouling, operational profile, etc.) on the current CII grade.
    - Future CII projections: Accurate projections of CII based on the current vessel performance and inputs of vessel operating conditions and profile.
- Sister vessel or period comparison: direct comparison of sister vessel performance, or differences in performance between different periods. This functionality can provide accurate ex-post evaluation of any effected measures for emissions reduction, such as engine power limitations, operational changes or hull and propeller efficiency improvements.

The combination of WiDE and QUAD systems was tested for a period of several months in a pilot installation on M/T Energy Triumph, which is equipped with a WinGD X72 engine using WiDE. The major objective of the pilot was system integration, which involved testing data exchange between applications, resolving interface issues and evaluating the interaction of models.

Legacy data prior to the pilot were used to train the QUAD machine learning models for vessel profiling on M/T Energy Triumph. The vessel was relatively new (<2 years) with original hull paint from the yard, so hull fouling was quite low, as reflected in QUAD estimates.

Figure 20 shows the linear average of extra power demand due to fouling over 18 months. The upper curve was based only on torque meter raw data. Torque meter operational issues were occasionally faced, so the lower curve is based on EDS calculations of true thermodynamic engine output and is deemed more accurate. Visual hull propeller and hull condition reports were available for M/T Energy Triumph and the hull visuals matched with the QUAD fouling estimates.

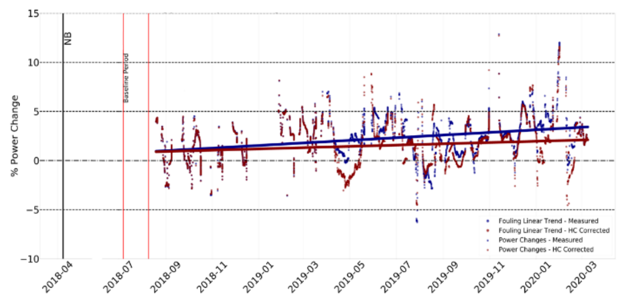

Figure 20. Calculated fouling effect on propulsion power demand based on torquemeter (blue) and Engine diagnostic data (red)

4 CONCLUSIONS

The original WiDE system, combining data and collection monitoring system (DCM) with Engine Diagnostic System (EDS) to provide advice and troubleshooting support to crew for engine operation outside of the expected parameters, has been developed extensively from its initial incarnation. The system is being explicitly improved with new advanced anomaly detection algorithms and has been complemented with remote 24/7 expert support. Forthcoming solutions for condition based monitoring and vessel performance optimisation will continue to increase the value WiDE delivers to onboard crews, fleet managers and superintendents.

Offering a shared interface between vessel operator and engine designer, WiDE enables closer collaboration, helping to make engine operation more reliable and efficient. In the longer term, the insights delivered by WiDE monitoring and diagnostics support developments towards more autonomous and reliable propulsion systems.

5 ACKNOWLEDGEMENTS

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6 DEFINITIONS, ACRONYMS, ABBREVIATIONS

API: Application programming interface

CBM: Condition based maintenance

CII: Carbon intensity indicator defined by IMO

WiDE: WinGD Integrated Digital Expert

DCM: Data Collection and Monitoring System

EDS: Engine Diagnostic System

PMS: Planned Maintenance System

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