WinGD's trial of its diagnostics and predictive maintenance platform was performed on Energy Triumph

AI engine data system trialled on Suezmax

31 Jul 2019 by Craig Jallal

The trial of an engine data collection system on the Suezmax tanker *Energy Triumph* has proved successful in optimising engine behaviour

At the 29th CIMAC World Congress in Vancouver, Canada, Winterthur Gas & Diesel's (WinGD) general manager of business development, Carmelo Cartalemi* presented a paper on how the group formulated and conducted a trial of its WinGD's Integrated Digital Expert (WiDE) predictive maintenance technology on board Enterprises Shipping & Trading's Suezmax tanker *Energy Triumph*.

Energy Triumph is powered by a WinGD 6X72 engine but WiDE is not exclusive to that engine design, and was developed for two-stroke, gas and diesel engines. WinGD developed WiDE in conjunction with Propulsion Analytics of Piraeus, Greece, which produced the analytics software.

WiDE consists of three main elements: the collection of data; analysis of the data; and reaction to the analysis.

The raw data is fed from the engineroom control panel and the engine alarm system into a module referred to as Data Collection & Monitoring (DCM). The DCM cleans the data by synching slow and fast time signals, smoothing outliers, providing a time stamp and averaging input over one minute. The DCM also receives and logs one-off event data and manual inputs from the crew, such as fuel used, or particular actions undertaken by the crew.

The DCM feeds the cleaned data to the advanced real-time Engine Diagnostic System (EDS) software, developed by Propulsion Analytics in

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collaboration with WinGD. The EDS contains a 'digital twin' of the engine from the design, shop test, and sea trial, laying out the parameters of rotational speeds, pressures and temperatures. Together with values for fuel consumption, torque, emissions and internal values, such as friction and heat transfer, this creates the thermodynamic model of the individual engine.

Propulsion Analytics provided the thermodynamics-based analysis methodology and technology from its Engine Hyper Cube engine management suite. This is applicable to all WinGD engines and is used to produce the reference thermodynamic model; it also provides the starting point to optimise the particular engine. After calibration of the model, it is run through simulations of all the possible combinations of operating conditions and settings to produce a 'hyper-map' which is embedded in the EDS for that engine.

The DCM feeds the clean data into the EDS, which runs the real-time DCM data through the digital twin and its hyper-map. The differences between the real-time DCM data and EDS digital twin contributes to the assessment of the engine's behaviour. The EDS tests for faulty readings, which may be due to damaged sensors or mis-calibrations, and also produces the required diagnostic testing and actions to correct the fault.

Once the self-test faults have been eliminated or accounted for, the EDS is able to produce specific assessments of the variations between the physical engine performance and the digital twin. This may indicate specific issues, such as fuel injector problems, turbocharger fouling, or a leaking exhaust valve.

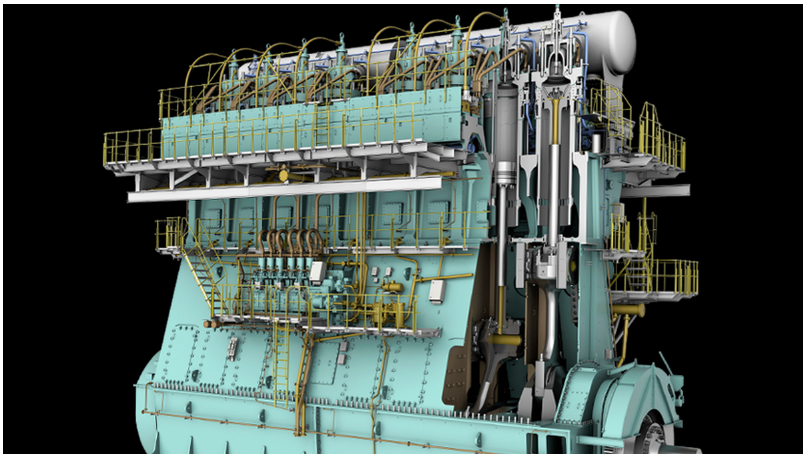
The thermodynamic model in the EDS provides a higher level of analysis. The heat release rate (HRR) is calculated in the EDS from the high-resolution pressure trace for each cylinder. With an accurate and timely HRR the EDS can provide diagnostics on in-cylinder behaviour and faults.

From the WinGD design database the algorithms for the sub-sets in the engine provide a reference point for the behaviour of:

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

Together with the operational manuals and WinGD's experience, these form the specific rulesets for each component in the system. This mass of knowledge is translated into a range of sub-sets in the EDS to:

- Identify various component potential failure modes (FMEA analysis)
- Connect potential failure modes with effects on component (faults)
- Identify possible causes for effects on component
- Trace faults
- Define reference values for traced influenced parameters
- Define tolerance limits for the parameter deviation from reference values
- For each fault, rulesets are defined based on the influenced parameters and their tolerance limit
- These fault rulesets are not used individually but in combination to provide a more stable conclusion



WiDE was trialled on a WinGD 6X72 engine

The third major component after the digital twin and fault-finding ruleset is the artificial intelligence (AI) learning engine. The AI in the EDS identifies patterns of engine behaviour and compares them to the WinGD database of known outcomes. For instance, there is a known correlation between cylinder liner wall heat patterns and high friction. The AI had to be trained to recognise different friction states. The outcome is the AI can label friction states:

- Normal operation: smooth liner temperatures in line with engine speed and load
- Pre-friction operation: specific deviations of temperature and patterns that correlate to approaching high-friction operation
- High-friction operation: high and frequent temperature deviations

The training of the AI and its subsequent operation showed that normal operation was identified and, more importantly, pre-friction and high-friction operation was identified 60% of the time; high friction scuffing was detected 98% of the time. These instances would not otherwise have been detected without the removal and close observation of the cylinder liner.

The AI used for the temperature analysis is a Neural Network Classification Algorithm (NNCA). The NNCA is embedded in the EDS and takes a 25-minute observation of the temperature input from the EDS to recognise the above friction states.

The above is an example of one of the functions taking place in the EDS. These functions need to be co-ordinated and consolidated to provide meaningful information. This is done in the Consolidation and Orchestration modules within EDS.

Consolidation brings together the thermodynamic analysis, the knowledge base and the AI machine learning modules and produces a score for fault severity and fault analysis. The consolidation module notifies the user when the relevant parameters are predicted to exceed tolerance levels. The consolidation module also filters reactions by analysing fault detection over time.

The Orchestration module takes a detected fault that has been confirmed by the Consolidation module as non-momentary to the next level – alerting the crew. There are several levels; in the case of a severe fault, the alert is issued immediately. Otherwise, a sequential process is started:

- Troubleshooting: reports all possible causes and actions. No maintenance intervention proposed at this level

- Maintenance: provides the recommended maintenance procedure. It also connects to the Planned Maintenance System to provide a list of available or interchangeable spare parts
- External: this raises the action to access external sources of expertise online

The EDS catalogues and archives faults and resolutions and links to the preventative maintenance system. Within the maintenance programme is the condition-based maintenance module, which predicts the remaining useful life of components. This was created using an AI machine learning programme and takes in the wear measurements from the EDS. The spare part module provides the ability to identify, display and share spare part data.

The development of WiDE won the coveted Intelligent Monitoring & Maintenance Award at the 2019 *Marine Propulsion & Auxiliary Power* Awards.

*Also named in the paper was the co-development team of:

- Michel Meier, Winterthur Gas and Diesel
- Gregory Sudwoj, Winterthur Gas and Diesel
- Panos Theodossopoulos, Propulsion Analytics
- Efstratios Tzanos, Propulsion Analytics
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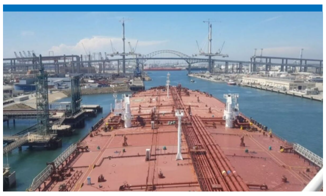

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