Engine Performance Optimization by Permanent Use of Holistic Expert Condition Monitoring System

Hinrich Mohr, Rüdiger Teichmann
AVL List GmbH, Austria

Vegard Hansen
Kongsberg Maritime AS, Norway

Worldwide the shipping branch is facing strong demands to reduce operational costs and fuel consumption. In addition to that new emission legislations are affecting this business already and will have an increased impact in the near future. This leads to the demand for a continuous holistic ship operation optimization. Norwegian-based Kongsberg Maritime has built up a vessel performance monitoring system as information and decision support for the crew on board and the fleet management ashore. For delivering the user the full picture of the vessel's operational status including engine performance and energy management Kongsberg Maritime has built an expert triumvirate with AVL List from Austria and Marorka from Iceland. The outcome is the Kongsberg K-Chief 600 VPS with AVL EPOS^{TM} and Marorka MAREN inside.
This presentation concentrates on engine performance optimization by using the expert condition monitoring system AVL EPOS^{TM} with regard to system setup, integration into Kongsberg K-Chief 600 VPS and achieved field experiences from various installations.
The goal of engine performance monitoring have to be an optimum thermodynamical and mechanical behavior of the main and auxiliary engines leading to low operating costs and high life cycle quality. So the view has to be set onto monitoring the combustion, of course, but also onto monitoring the fuel supply and injection, the turbocharging, the cooling, the lubrication and all related auxiliary systems.
Developing such an engine condition monitoring system requires an extensive knowledge about engine operation, but also about measurement technology and data evaluation, which are both key business fields of AVL. In this respect robust hardware components have to be introduced which are suitable for long life times under rough operating conditions. For receiving as much as possible input a broad interface to the alarm and monitoring system is evident. The user should retrieve the evaluation results via a simple graphical user interface (GUI). The data storage must be effective and configurable according to each application. Existing measurement systems have to integrable. A connection ashore to the fleet management is required for regular data submission.
As result of these requirements the AVL EPOS^{TM} is built as an open diagnosis platform fully integrable into Kongsberg's automation system. The basic concept is:

- a plausibility check of the input signals including a modeling of the sensor
- the AVL IndiCom combustion analysis
- an extended concept of an field experience based fault-symptom-pattern
- various subsequent algorithms based on upstream data analysis, fuzzy logic and different physical models
- the signatures of the input signals are compared with reference values
- a sophisticated consideration of fault probabilities and symptom importance

The final result gives a status classification of the monitoring engine, the cylinders and the related subsystems. For simple user access and information transfer a GUI with a traffic light display was chosen. Of course, in case of need or increased interest the user is lead into more detailed engine information by the system itself.
The currently available version 1.1 of AVL EPOS^{TM} includes already

- a continuous evaluation and permanent analysis of the fuel injection process and the combustion process (with AVL $GaPO_4$ cylinder pressure sensors)
- a failure detection by expert algorithms of the fuel injection system and the combustion chamber area
- a trend analysis (chronological, characteristic plot vs. engine load or speed) and a trend prediction

– an integration possibility of external monitoring devices

The basis of Kongsberg's vessel performance system, in which AVL EPOS^{TM} is fully integrated, is the K-Chief 600 automation system, using standard modules communicating by dual redundant process network. This system is configurable for all vessel types. In the background a seamless data flow between both tools. It is ensured that there is no interference with the integrity of the automation system itself.
Up to now various installations of AVL's condition monitoring system are in operation, two of them starting more than three years ago already. Beside several ship installations (car carrier, container vessel, VLCCs and ferry) the system is installed on a stationary engine as well as on a locomotive engine. Currently a series of VLCCs is equipped with the system as part of Kongsberg's vessel performance system, whereas the 'Sifa', the first vessel of this series, was assigned with the Norshipping Clean Ship Award 2011.
One heart piece of the system, the AVL cylinder pressure sensor, has proven it's suitability for this application on various engine types (2-stroke and 4-stroke) and different fuel types (HFO, gas, biooil) for more than 15,000 hours until now.
The software - as another heart piece of the system - is operating very stable and reliable in the field. On several installations failures were firmly detected by the system and were proven by the following maintenance works (e. g. reduced compression by burned piston crown, fuel injection pump failure, fuel injection timing and amount, …).
The field experience is showing additional system advantages beside the early detection of upcoming faults and the avoidance of damages. In most cases unplanned repair works on the monitored engine components or systems can be changed to planned maintenance works due to the early delivered system information. Further on experience show an operation optimization potential of up to 3 % engine efficiency (relates to 4 … 6 g/kWh fuel consumption reduction) on usual maintained engine and even higher potentials on poor maintained engines. These figures are confirmed by a publication of MAN Diesel on last CIMAC 2010 as well. So a consequent use of the delivered information for optimizing the engine tuning could enable operational savings of up to 100.000 US-$ per year.
For further improvement of the AVL EPOS^{TM} several development activities are ongoing. Exemplare main topics are a thermodynamic turbocharger monitoring, an online NO_x emission modeling in combination with SO_x and CO_2 calculation, a prediction of engine component behaviours and an improved hardware diagnosis ensuring a high signal reliability. Of course, further topics are in the pipeline.

Hinrich Mohr *is working since 2004* ***at AVL List GmbH****, Graz, Austria as Key Account Manager and Product Manager for Systemintegration of Large Engines. After graduating from the Technical University, Braunschweig with a master's degree in mechanical engineering he continued at the university as a scientific researcher, finishing with a doctor's degree in 1993. Then he joined the division "Engine Plants" at Blohm + Voss, Hamburg were he finally acted as R&D Manager, before he changed to AVL List.*

Vegard Hansen *is acting as Product Adviser at* ***Kongsberg Maritime AS****. He graduated from university as communication engineer in 2001. He then served the Norwegian Army and Navy as Technical Officer before he joined Kongsberg in 2009 as Product Manager.*