Monitoring & Diagnosis
Expertensystem
AVL EPOS™ für Haupt- und Hilfsmotoren
MCN Workshop Seevetal, 25.04.18
We all know:
Engines operate fine in the field ...
... until wear & tear happens.

Therefore – and to avoid incidents as shown left - AVL developed an expert system allowing

- permanent engine monitoring and early fault detection
- direct root cause information
- detailed knowledge on engine reliability and performance
- optimized engine balancing
- data-stock for condition-based maintenance
- NO\textsubscript{x}, SO\textsubscript{x} and CO\textsubscript{2} emission tracking

Let’s see ...
Agenda

- Introduction
  - AVL as company
  - AVL EPOS™ Expert Condition Monitoring
- Field Experiences
  - 2-Stroke Engines
  - 4-Stroke Engines
  - Multi-Engine Application
- Outlook
- Conclusion
Our Experience for your Success

- AVL achieves unique results in regards to the development and improvement of all types of powertrains as well as in the field of measurement and test technology.
- AVL – over 65 years’ experience
- Involved in more than 1,500 engine development projects
- More than 4,000 engine testbed installations
Solutions for all Customer Segments

- Passenger Cars
- 2-Wheelers
- Racing
- Construction
- Agriculture
- Commercial Vehicle
- Locomotive
- Marine
- Power Plants

Powertrain Engineering

Development Platform

Simulation & Testing
Enterprise Development

**RESEARCH 10%**
of turnover in-house R&D

**INNOVATION 1500**
granted patents

**STAFF**
9,500 employees
65% engineers and scientists

**GLOBAL FOOTPRINT**
30 engineering locations
• >220 testbeds
• Global customer support network

**GROWTH**

**SALES**
1995: 0.15 billion €
2017: 1.55 billion €
Plan 2018: 1.71 billion €

**EXPERIENCE**
70 years!

**STAFF**

9,500 employees
65% engineers and scientists

**GROWTH**

**SALES**
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**GLOBAL FOOTPRINT**
30 engineering locations
• >220 testbeds
• Global customer support network

**ONE PARTNER**

**5 powertrain elements**
Large Engines Designed by AVL

Total Number of Engines: 147
Diesel Engines: 99
Gas / DF Engines: 48

Status June 2017

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Gas / DF Engines  Diesel Engines
CAT 3618 DF-Conversion for High-Speed Craft Application for

- reducing fuel consumption costs
- improving 'green' image

Project Tasks:
- DF-conversion concept incl. BOOST engine modelling
- detail and layout design
- CRUISE M modelling for early demonstration of operational behavior for customer and class
- preparation, supervision and evaluation of prototype engine testing at 3rd party test bed provider
- participation in engine commissioning on board
Field Application Services

**Examples**
- Excessive Liner Wear Survey
- Root-Cause Investigation for Piston Crown Rupture
- FIE Quality Improvement Potential Evaluation
- Bearing Seizure Analysis
- TC Retrofit Layout Check
- Liner Cracking at High Load — Specification & Production Evaluation

**Tasks**
- Inspection on Board/at Site by dedicated & OEM independent Experts
- Data & Information Collection
- Internal Root-Cause Investigations
- Use of Simulation Tools
- Elaboration of Improvement Tasks
- Report Generation, Presentation & Discussion @ Customer
- Follow-up & Evaluation of Improvement
Expert Condition Monitoring System

AVL EPOS™
PREDICTABLY POWERFUL
AVL EPOS™ in a Nutshell

**Expert Condition Monitoring System**
- for all Large-Bore Engines (2-/4-strokes)
- for all Fuels (HFO, MDO, Gas, ...)
- for all Applications
- for Newbuilds and Retrofits

**Permanent evaluation** of engine behavior with regard to reliability, performance and emissions

**Operators benefit** from early fault detection, avoidance of severe engine damages & fuel savings (up to 3 %)

**More than 125 installations on**
- Car Carriers
- Container Vessels
- Crude Oil Carriers
- RoPAX Ferries
- Cruise Liners
- Locomotive
- Power Plants

**Very flexible system concept** allow integration of other components and integration into other systems.
AVL EPOS™ Work Environment

ENGINE STATUS via simple TRAFFIC LIGHT indicator

CYLINDER STATUS via TRAFFIC LIGHT colours

EMISSION MONITOR (optional)

FAILURE MATRIX – evaluation of measurement data regarding predefined engine faults

KEY CONDITION INDEX (KCI) – tracking engine condition via one parameter – how 'healthy' is the engine?

KEY PERFORMANCE INDEX (KPI) – tracking engine performance via one parameter – how 'efficient' is the engine?

Further screens show data, trends and diagnosis in different detail and depth.
AVL EPOS™ Work Environment

Plant / Fleet Graphical User Interface
AVL EPOS™ System Configurations

Full Diagnosis Functionality
Field Experience 2-Stroke Engine

Engine Performance Analysis & Evaluation

M/T Vessel

Measured Cylinder Pressure Traces

Cylinder Pressure Traces → No significant deviations between cylinders are detected
AVL EPOS™ indicated that cylinder no. 3 has lower fuel quantity which causes the lower mean indicated pressure (~10% lower compared to mean value of all cylinders)

- Fuel pump & fuel rack has been checked → excessive wear of fuel pump detected!!
Field Experience 2-Stroke Engine

Engine Performance Optimization – BSFC Improvement

Slow-speed Diesel Engine

VIT Variation

VIT Variations

- Cylinder 1
- Cylinder 2
- Cylinder 3
- Cylinder 4
- Cylinder 5
- Cylinder 6
- Cylinder 7
- Cylinder 8

Engine VIT Settings (l) vs VIT Setpoint (bar)
Field Experience 2-Stroke Engine

Engine Performance Optimization – BSFC Improvement

- $p_{\text{max}}$-Variation vs. VIT
- BSFC-Variation vs. VIT

✓ HFO Consumption: ~90 tons/day
✓ BSFC improvement $\rightarrow$ ~2-3 g/kWh
✓ Fuel Savings $\rightarrow$ ~60 tons/month !!!
Field Experience 4-stroke Marine Engine

Engine Performance Optimization – Cylinder Balancing

- Optimized Engine tuning based on AVL EPOS™ Indications & Analysis

- Maximum pressures well balanced
- Cylinder IMEP show significant deviations
- Improper Engine cylinder balancing

- Optimized cylinder balancing
- ~1.5% improved fuel efficiency
- Lower mechanical stress on crankshaft
Field Experience Multi Engine Application

- Linhares Geracao Power Plant in Brazil (207 MW$_{el}$)
- 24 medium-speed 20V gas engines, all equipped with AVL EPOS™
- Cylinder pressure sensors achieved more than 16,000 h meanwhile
- 16,500 measurements with corresponding expert engine diagnosis available
- 107 events detected (cylinder misfire & balancing, gas admission valve malfunction, inlet/exhaust valve leakages, knocking behavior, …)

Operator saved approx. 1.5 Mio € in first year of operation due to optimized operation, early fault detection and avoidance of unplanned stops
AVL EPOS™ Fleet asshore
@ Owner/Operator
or
@ AVL Service

... as precondition for further use of BIG data to support ...

AVL EPOS™ on Ships
Local fast diagnosis
Goal: full engine room expert monitoring

Outlook

Cloud Services

Data Transfer

Fleet Operation Centers

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Potentials NO\textsubscript{x}-Monitoring & Optimization

Monitoring of NO\textsubscript{x}, SO\textsubscript{x} and CO\textsubscript{2} emissions of your fleet based on thermodynamic calculation (no analyzer required)

**Direct link** of engine emission to engine condition (cylinder specific emission values available)

Input to **fleet wide emission** tracking and **reporting** (MRV)

**Certified** compliance of system for NO\textsubscript{x} monitoring method

Exemplary calculation...

**Main engine** 40 MW
NO\textsubscript{x} Base (of limit) 85 %
NO\textsubscript{x} Tuned (of limit) 95 %

Fuel consumption 15,000 t/year
Fuel savings (1.5%) 225 t/year

**Savings** \(~80,000\) $/year
Potentials $\text{NO}_x$-Monitoring & Optimization

**Technical Approach**
- Based on AVL’s widely utilized combustion analysis software
- Two zone thermodynamical model based on cylinder pressure data
- Computation of combustion related properties from measured data
- Reaction-kinetic algorithm combines these cylinder individual parameters together with the corresponding engine and fuel data
- Accumulates $\text{NO}_x$-emission results
- For complete emission report, $\text{CO}_2$ and $\text{SO}_x$ computed out of adjusted fuel mass balance

No permanently installed emission analyzer necessary!

**Required Input Data:**
- Cyl. pressure curve
- Engine torque & speed
- Fuel consumption
- Bunker report
- Ambient conditions

Data accuracy is key for exact emission data, especially for cyl. pressure and fuel consumption.
• **Permanent monitoring** of main and auxiliary engines respectively the complete engine room enables optimized operation with regard to fuel consumption and maintenance

• Given reference examples show benefits clearly, in most cases **ROI figures of less than 2 years** are achieved

• Combination of **local intelligence for fast reaction/crew support and onshore fleet performance data evaluation** enable optimum ship management

• **Cloud services and big data technology** combined with ship/engine expertise & real-time ship simulation open further improvement potential

• **Additional detailed analysis technologies** require more and exact sensors, e. g. for fuel metering (AVL product in preparation)

• **Business models need to be flexible** – change from pure product offer to service agreement
Thank You

www.avl.com

Contact:

Prof. Dr. Hinrich Mohr
hinrich.mohr@avl.com

Dr. Vasilios Lamaris
vasilios.lamaris@avl.com

Dr. Rüdiger Teichmann
ruediger.teichmann@avl.com

www.avl.com