AVL List GmbH (Headquarters)

Monitoring & Diagnosis Expertensystem AVL EPOS™ für Haupt- und Hilfsmotoren

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Public

Introduction

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_x, SO_x and CO_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 !

5 powertrain elements

ONE
PARTNER

Large Engines Designed by AVL

User Reference:
Fred. Olsen Express DF-Conversion

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™ 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 Newbuilts and Retrofits

More than 125 installations on

- Car Carriers
- Container Vessels
- Crude Oil Carriers
- RoPAX Ferries
- Cruise Liners
- Locomotive
- Power Plants

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

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

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

Engine Control Room

Measurement System
Industrial PC

LAN

Sensor
connectors

Trigger (CDM) –
fix installation

Sensors –
fix installation

$p_{Cyl\ (1\text{-}n)}$

CDM/TRIG

Portable System

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

Field Experience 2-Stroke Engine

Engine Performance Analysis & Evaluation

Cylinder Mean Indicated Pressures

AVL EPOS™ Diagnosis Results – Subsystems Overview

- 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

Field Experience 2-Stroke Engine

Engine Performance Optimization – BSFC Improvement

p_{max}-Variation vs. VIT

BSFC-Variation vs. VIT

- ✓ **HFO Consumption: ~90 tons/day**
- ✓ **BSFC improvement → ~2-3 g/kWh**
- ✓ **Fuel Savings → ~60 tons/month !!!**

Field Experience 4-stroke Marine Engine

Engine Performance Optimization – Cylinder Balancing

Optimized Engine tuning based on AVL EPOS™ Indications & Analysis

- ✓ **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**

Outlook

Cloud Services

Data Transfer

AVL EPOS™ Fleet ashore
@ 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

Fleet Operation Centers

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Potentials NO_x-Monitoring & Optimization

Monitoring of **NO_x, SO_x and CO_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_x monitoring method

Exemplary calculation…

Main engine	**40 MW**
NO_x Base (of limit)	85 %
NO_x Tuned (of limit)	95 %

Fuel consumption	15.000 t/year
Fuel savings (1.5%)	225 t/year
Savings	**~80.000** $/year

NO_x Emissions
Vessel 1

NO_x Emissions
Vessel 2

NO_x Emissions
FLEET

Potentials 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 NO_x-emission results
- For complete emission report, CO_2 and 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

Gas Exchange and Combustion Analysis

Conclusion

- **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

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