Real emissions of NRMM challenge and solutions

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Department of Intelligent Hydraulics and Automation
Established in 1965
Started as foundation in 2010
Four faculties
- Business and Built Environment
- Computing and electrical engineering
- Engineering Sciences
- Natural Sciences

TUT Facts 2015
Funding approx. 140 M€
1700 Employees,
124 Professors
8300 Students
Graduates
819 BSc. and 804 MSc.
88 Doctors
We develop technologies that reshape the competitive landscape of Finnish industry.

- Digital operating environment
- Energy- and eco-efficiency
- Health technology
- Light-based technologies

Forerunner in university-industry collaboration

Our research combines
- natural sciences
- technology and
- business.
Department of Intelligent Hydraulics and Automation, IHA

Research areas

- Intelligence of mobile machines
- Energy efficient drives and systems for mobile machines
Intelligence of mobile machines

- Motion control, automation
- Autonomous operation
- Sensor systems
  - mobile machines, ships
- Navigation
- Perception, sensor fusion
- Multi-machine operation
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Energy efficient drives and systems

- Holistic optimization of powertrain
  - Diesel engine, transmission, hydraulics, system
  - Control and power management
- Digital hydraulics
  - Digital hydraulic power management system
- Combination of electric and hydraulic drives
- Efficiency vs. Emissions
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Facts and Facilities
6 Professors, 50 employees

Testground at TUT campus
- Asphalt and gravel, different slopes, excavation and loading area

Test machines
- Excavator, forwarder, 2 multipurpose loaders, 2 miniloaders, tractor

Control and measurement systems
- Matlab, dSpace, BODAS-systems
- AVL fuel measurement and AVL PEMS for HD use
TUT, Aerosol Physics Laboratory

Real world emission studies focusing on particles emissions
- PEMS
- Chasing vehicles on road
- Roadside / on-road in traffic
- Mobile measurement vehicle
- Chamber studies

Spin-off companies
- Dekati, Pegasor
Non Road Mobile Machines

NRMM vs. cars

- More versatility than in cars
  - Powertrains, manufacturers, users, environment, ...
- Emission regulations are for engines only
- There are no official test cycles for NRMM
  - Each test is one of a kind
  - Same is valid for fuel consumption
Emissions of NRMM

Current situation

- Lot of effort have been done for Stage 4 and Tier 4F
  - Development of engines, after treatment system, packaging
- In Bauma 2016 *Stage 5 - ready solution* was shown
  - Increased integration of after treatment systems
- Real emissions are still open question for many players
  - Stage 5 in-use-regulations are open
- Some studies have been done around the world
  - Focus on emission modeling
Emissions of NRMM

We are interest on the real emissions of machine

Our approach is on machine level not on engine or after treatment systems

Research question:
How much real emissions can be reduced by decreasing load variation, peaks etc. i.e. stabilizing the load

- System control (machine), Hybridization
- Autonomous operation vs. human operated
Measurement of real emissions

Variables in measurements

Machine
- Variants, wear,…

Operator
- They are individuals

Work task
- One or various, depends on machine

Load or material to process
- Variation great

Weather and environment
- Tropic – arctic
- Friction conditions

Measurement system
- Complexity

Measurement occasion
- Random errors etc.

Analysis
Our test machine

**Wille 655C loader (5.5 tn)**

- Used in widely in cities for street cleaning and maintenance work
- CAT 4.4 Tier 3 engine
  - 97 kW, 516 Nm
- Hydrostatic transmission
- Various tools and equipment available
Our test machine

Our loader is equipped with

- Model based control system development environment (Matlab/Simulink and Rexroth BQDAS control system)
- Various sensors for autonomous operation
- Hydraulic system with energy recovery feature
- AVL KMA fuel consumption measurement system
- AVL GAS PEMS
- AVL PM PEMS
Our machine with PEMS
Our machine with PEMS
Experiences of PEMS

Installation

Installation requires considerably amount of work

- Space requirement - BIG machines has no space
- Hoses and cables
- Power supply
- Burn gas for FID
- System weight is considerable for smaller machines
- Weather cover – rain and below zero conditions
Experiences of PEMS

Calibration every day
  • Requires gases with correct ppm level
Measurements
  • Many parameters, variables and aspects to consider
  • Success rate low at the beginning – learning takes time
Particle mass – weighting
  • Accuracy requirement – process, scale, room
Measurement analysis using AVL concerto
  • The easiest part – Results available quickly
Analysis

Experiences
Analysis

Experiences
NRMM real emissions

There is still work to do in this field
Measurements of real emissions are complicated
Good, reliable measurements require experience on the measurement system and application
Representativeness of the measurements
Small machines are problematic to measure