AGENDA

- Introduction
- Development
- Application on engine test bed
- Results
- Summary
The Company:

AVL is the world's largest privately owned company for development, simulation and testing technology of powertrains (hybrid, combustion engines, transmission, electric drive, batteries and software) for passenger cars, trucks and large engines.

Scope of business:

- Development of Powertrain Systems: AVL develops and improves all kinds of powertrain systems and is a competent partner to the engine and automotive industry.

- Simulation: In addition AVL develops and markets the simulation methods which are necessary for the development work.

- Engine Instrumentation and Test Systems: The products of this business area comprise all the instruments and systems required for engine and vehicle testing.
INTRODUCTION
CHALLENGES IN ENGINE CALIBRATION

Problems:

- Increasing number of sensors, actuators, control algorithms
  - \( \rightarrow \) increase of parameters
- Find optimal combination of parameters
  - for emission, fuel consumption, performance
- Manual variation of parameters is very time consuming
- Manual variation could lead to critical operating states or damage of engine

Solution:

- Development of Combustion Controller
  - to reduce variation parameters on the engine test bed
  - to protect engine even in unsafe operation points
- Model-based design in development
  - Short development time
  - flexibility
INTRODUCTION

COMBUSTION CONTROLLER ON TEST BED

AVL testbed automation system (AVL PUMA Open)

Combustion Controller
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DEVELOPMENT OF COMBUSTION CONTROLLER

- Controller design
  - MATLAB
  - Simulink
  - Stateflow

- Offline Simulation & Verification
  - MATLAB
  - Simulink
  - Stateflow

- Compilation for Real-time target
  - Real-Time Workshop
  - AVL ARTE.Lab™
  - (MATLAB Compiler)

- Execution and final tests on engine test bed
COMBUSTION CONTROLLER
SPARK ADVANCE (1)

MFB 50% Control

Knock Control

Knock Level 1
Knock Level 2

Knock Control State Machine

ECU Delta Spark Advance

MFB ... Mass Fraction Burned

Combustion Controller Development and Application using Model-Based Design
MFB 50% Control

Knock Control

ECU Delta Spark Advance

MFB ... Mass Fraction Burned
Component Protection

- max. Temperature Demand Value 1
- max. Temperature Demand Value n
- Critical Temperature Actual Value 1
- Critical Temperature Actual Value n

Function Block

A/F Ratio Control

- ECU A/F Ratio Demand
- ECU Fueling Factor Demand
- A/F Ratio Actual Value

PI-Controller
Simulation in Simulink

Simulink Simulation Environment
(engine, test bed, ...)

DEVELOPMENT OF COMBUSTION CONTROLLER SIMULATION AND VERIFICATION
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APPLICATION OF COMBUSTION CONTROLLER ON ENGINE TESTBED

Development PC

- Compile

ComCon.rta

Test Bed PC

- MATLAB
- Simulink
- Stateflow
- Real-Time Workshop
- AVL ARTE.Lab™
COMBUSTION CONTROLLER - OVERVIEW

Fuel Consumption
to be optimized

Emissions

Injection amount
Spark advance
to be calibrated

Indicating
Temperature Sensor
Lambda Sensor

AVL testbed automation system
(AVL PUMA Open)

Combustion Controller

AVL ECU
APPLICATION IN TEST FIELD

- Same controller on different test beds
- Administration of parameters with engine parameters
- Parameters stored in .MAT file

TB1  TB2  TB3

ComCon
parameters
PARAMETERIZATION

- Parameters in .MAT file
- Changeable at run-time
- Stored with parameters of automation system

ComCon.mat
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RESULTS (1)
2000 rpm / 4 bar
3000 rpm / 18 bar

Knock Control

KC on
KC off

MFB 50% [deg CRA aTDC]

Safe OP

Operating Point

Spark Advance [deg CRA bTDC]

Full Load

Delta Spark Advance [deg CRA bTDC]
RESULTS (2)

- **Benefits for controller development**
  - Reduction in development time by approx. 50% compared to standard programming languages
  - MiL testing in Simulink
    - Reliable failure free behavior due to offline simulation
    - Reduction of expensive test bed time for development by 80%
  - Model-based design eases enhancements

- **Benefits for engine testing**
  - Manual variation of spark advance and injected fuel amount not needed anymore
    - Speed up of engine development time
    - Decrease of testing time on engine test bed
      - Decrease of approx. 50%
      - In special test bed setups a decrease from 1 day to 30 min has been encountered
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Combustion controller development and application using model-based design

- Use of MATLAB and Simulink for faster and more effective engine calibration resolution
- Seamlessly integrated in AVL’s automation system PUMA Open
Ongoing improvement of gasoline engine controller

Testing of Diesel-controllers on engine test beds
- Controller for adjustment of injected fuel amount
- Controllers to support base emission calibration
- Controllers to support the DPF-temperature management calibration:

Diesel-controller under development
- Online-optimizer to support the smoke limitation-calibration