SIMULATION REQUIREMENTS ON PARAMETERS LIKE ALTITUDE WITH FOCUS ON RDE

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RDE – Vehicle Model

Simulation

Correlation with mapping

Modelling
RDE relevant Parameters

**Real Parameters**
- **Temperature**
  - moderate 0°C bis 30°C
  - extended (-7°C bis 35°C)
- **Height**
  - moderate < 700 m
  - extended < 1300 m

**Virtual Parameters**
- **Route / Driver**
  - City (34%) / Urban (33%) / Highway (33%), up to 160 km/h, 90-120 min
  - Driveability
- **Load / Road Load**
  - Realistic Vehicle Mass, Heating or Air Conditioning in Use
Influence on Altitude
Virtual Parameters

Model Based Testing with CarMaker

Real System | Virtual Environment - Real Driving Simulation

- Engine
- Road
- Vehicle
- Driver

Real Road

Virtual Road

Up/Down Hill Scenario

Driving resistances, air temperature and pressure

Engine-in-the-Loop Test Bench with Altitude Simulation

1. Fuel Consumption
2. Emissions
3. Thermal Behavior
Virtual Parameters

Engine-in-the-Loop Test Bench with Altitude Simulation

Features
- Real Parameter Simulation of pressure, temperature and humidity
- Dynamic and steady state performance

Use Cases
- R&D in respect of optimization on altitude influences like EGR, Turbo, canister loading, blow-by, …
- Correlation of global R&D locations on different altitudes
- RDE correlated driving cycles with variation of altitudes / road gradients
Load and Speed Transient Tests

Engine compressor map and tested points

Engine behavior depending on installation
Altitude Simulation (MEDAS)

External Units
Or
Central Air Conditioning

Simple Heat Exchanger

Humidity Conditioning

Altitude up to 6,000m
Intake air mass flow 1.200kg
Dynamic and accurate
Energy efficient
NEDC Cycle

- Pressure and altitude oscillations in vacuum (to reproduce an altitude of 1949 meters in a test bench at sea level)

- Altitude peaks < ±100 meters

- Pressure peaks < ±10 mbar
Start & Stop Tests

- Pressure and altitude oscillations in overpressure (to reproduce sea level conditions in a test bench at 532 meters).

- Altitude peaks < ±100 meters

- Pressure peaks < ±10 mbar
MEDAS 5012 VO Performance

- Altitude vs mass flow
  - Maximum mass flow at 2000 meters: 1200 kg/h
  - Maximum mass flow at 5000 meters: 720 kg/h
  - Test bench altitude: 0 ÷ 2000 meters
Engine Tests

NEDC tests. **Procedure**

- Day 1: 3 consecutive tests @ 150 m
- Day 2: 3 consecutive tests @ 1000 m, 2000 m and 3000 m
- Each test of day 2 can be compared with corresponding at 150 m of day 1

**Variables will be shown differences with respect to 150 m for each altitude**

- Last two hot tests at 150 m has been compared between them to check repetitiveness
- Emissions measured with HORIBA MEXA 7100 DEGR between DOC and DPF
Engine Tests

NEDC tests

- **EGR:**
  - Fully closed for any speed at 2000 m and 3000 m
  - At 1000 m, EGR valve is closer than at sea level for any speed
  - **A:** @ EUDC EGR is more open at 150 m and closer at 1000 m than @ UDC

- **VGT:**
  - **B:** @ UDC VGT shows open loop control with dynamic corrections at every tested altitude
    - At 1000 m is closer the first 8 min → Cold start effect
  - **C:** @ EUDC VGT controls $p_2$ and is closer with altitude
NEDC Tests Conclusions

- Same trends in emissions & consumption if analyzed g/km

Control strategies @ altitude has to be re-oriented from just engine & turbo protection to emissions abatement
WLTC Tests Conclusions

- Same trends in emissions & consumption than NEDC
- Lower increment of CO, THC & Soot emissions since higher engine loading in WLTC increases use of p2 control in closed loop
- Anyway control strategies at altitude must be re-oriented from just engine & turbo protection to emissions abatement (at least up to 2000 m)
Extension of MEDAS to HD application

MEDAS 5009V
900kg/h, 5000m
Dimensions: 2 x 1,4 x 1 m

MEDAS 5009V
900kg/h, 5000m

MEDAS 5012VO
1200kg/h, 5000m
Dimensions: 2,8 x 1,4 x 1,2 m
Possible Test Cell Design

Drivetrain Concepts

Environmental Conditions

Different Loads
Summary

- **Motivation**
  - Influence of altitude on engine components and combustion process are emission and performance relevant
  - Requirement to simulate virtual and real parameters for correlation on test bed level and front loading processes as well as global R&D correlation

- **Virtual Parameter simulation**
  - Model based Testing with CarMaker (Hybrid)
  - Real driving simulation via road load simulation

- **Real Parameter simulation**
  - Simulation of combustion relevant parameters like P, T & H are essential for CE development (for example EGR, Turbo, …)
Thank you

감사합니다

ありがとうございます

Dziękuję

धन्यवाद

Merci

谢谢

Gracias

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Obrigado

Danke

شكرا

Τέσσερις

Большое спасибо