Case Study on 6 Cylinder HDD Application GT-POWER Model Build using FRM Builder and Running on HiL Platform

by

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Contents

• Objective
• Virtual Test Bed (VTB) Overview
• FRM Builder Approach for Plant Model Development
• RT Plant Model Setup on VTB
• Results & Comparison
• Summary
Objective

- Assessment of FRM builder approach for engine calibration
- To achieve reasonable accuracy with minimum efforts using FRM builder, when limited test data is available
- Converting to Real Time model and run on Virtual Test Bed (VTB)
- Run steady state and transient cycle
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Virtual Testing

Simulation

Road Testing

Lab

Front load activities to simulation environment from calibration engineer perspective

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Virtual Test Bed (VTB) Workflow

FRM builder approach
RT Plant Model

- Refined model setup
  - Engine Cylinder
  - Engine Air Path

- Thermodynamic NOx-Emission
- EMPIRICAL STATIC GLOBAL
  - HC, CO, Soot, PN ...
- COMBINED MODEL
  - Increased number of engine specific outputs

Model refinement

Virtual

- Plant Model Development
  - Concept investigations
    - Model with limited measurement data

- Refined model setup

- Base engine testbed development

- DoE Measurements

- MiL Setup

- VTB Setup

- Calibration of Various variants
  - Robustness analysis
  - OBD calibration
  - Vehicular expedition trials

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## Model Accuracy Level

<table>
<thead>
<tr>
<th>Model Maturity Level</th>
<th>Description</th>
<th>Usage</th>
</tr>
</thead>
</table>
| **Level 1** (concept model) | Geometrical data is used for model setup | • H/W concept investigations  
• EAS configuration  
• ECU functionality |
| **Level 2** (refined model) | Steady state and transient data is measured for model refinement | • Ambient correction  
• OBD calibration  
• Vehicular drivability |
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Approach: FRM Builder

- **Introduction**
  - Choose an Engine Type
    - Compression Ignition (CI)
    - Spark Ignition (SI)
  - Compression Ignition (CI) FRM Wizard
    - Diesel engines with a single stage twin-scroll turbocharger will be created.

- **Cylinder Geometry**
  - Please provide values for the following parameters:
    - Bore
    - Stroke
    - Compression Ratio

- **Control Logic Type**
  - Choose Control Logic Type:
    - Twin Scroll GT-SUITE Controller (Wastegate)
    - VGT GT-SUITE Controller
  - Coupled to Simulink
    - A Simulink and Matlab model which can be used for any engine version needed.

- **Engine Type**
  - Choose Engine Type:
    - 4 Cylinder Twin Scroll
    - 4 Cylinder VGT
    - 6 Cylinder Twin Scroll
    - 6 Cylinder VGT

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Following changes carried out on default FRM built

1) Removed EGR system
2) Turbocharger map changed
3) Waste gate controller removed
4) Speed range changed
5) Fuelling controller removed
6) Combustion and emission model tuned with limited test data

- Engine Inputs
- Geometrical data
- TC map
- Through flow
- Engine 6 cyl HD application
- FGT Turbocharger
- 1600 bar max injection pressure
FRM Builder Approach: Model Build

Intake

Exhaust

Main

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FRM Builder Approach : Model Build

FRM diesel

Intercooler

Conditions sensed from upstream parts

Actuates intercooler pipe wall temperature to impose intercooler outlet fluid temperature.

Moving Average calculates the average intercooler outlet fluid temperature.

MathEquation calculates the intercooler outlet fluid temperature using input intercooler effectiveness and coolant temperatures.

Lookup Table uses sensed upstream mass flow to forecast the effectiveness value and sends it to the MathEquation.

Signal/Generator sends coolant temperature to MathEquation.

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FRM Builder Approach: Parameter Acceptance Criteria

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tolerance Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD %</td>
<td>5</td>
</tr>
<tr>
<td>BSFC %</td>
<td>5</td>
</tr>
<tr>
<td>MF_AIR %</td>
<td>10</td>
</tr>
<tr>
<td>T_21°C</td>
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</tr>
<tr>
<td>T_31°C</td>
<td>25</td>
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<tr>
<td>T_41°C</td>
<td>25</td>
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<tr>
<td>P_21 %</td>
<td>10</td>
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<tr>
<td>P_31 %</td>
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</tr>
<tr>
<td>NOX_EQ_gph %</td>
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</tr>
<tr>
<td>NTURB %</td>
<td>15</td>
</tr>
<tr>
<td>MFB_50 %</td>
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</tr>
<tr>
<td>P_max %</td>
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</tr>
</tbody>
</table>

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Open Loop- ECU and Actuator Setup

- ECU functionality check
- Feedbacks to ECU - MAP, Crank, CAM, Rail pressure, Acc Pedal etc.
- Rail Pressure model
- Injector coordinator - Start of Injection, Pulse width, Pilot etc.
Closed Loop- ECU and Actuators with RT Plant Model

- ECU in loop with RT plant model
- Feedbacks to ECU from plant model
- Steady state and transient operation
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VTB Results - Steady State

- Torque
- Air flow rate
- BSFC
- Comp out temp

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VTB Results - Transient

• Very good correlation wrt Test Data
NO Emission Results- Transient

NO variation wrt Test +10.2 %
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Summary

- The FRM builder approach took very less efforts and time to reach required accuracy level

- The plant model built with limited test data has shown very good correlation with experimental data at steady state & transient level

- The FRM model showed real time compliance and therefore its usefulness for calibration using VTB approach
Acknowledgements

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VTB Approach for Calibration

- Calibration Not Dependent on Weather, Location & Prototype Availability
- Improved Calibration Quality with High Reproducibility & Good Extrapolation Capability
- Concept Definition, Calibration Robustness Investigation
- Minimized Usage of Expensive Test Facilities
- Reduces Number of Prototypes Resulting into Faster Time to Market

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• Calibration on real ECU with Real Time models
• Same ECU can be taken further for actual testing
• Once parent engine rating data is available, derivatives can be calibrated in very short time
Thank You!

Virtual Test Bed for BS VI, stage IV, V and RDE calibration challenges!

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