Virtual Engine Calibration: DPF Regeneration Example

Peter J Maloney
Senior Principal Development Engineer
Outline

▪ Market drivers increasing calibration workload

▪ Building blocks for virtual calibration
  – Surrogate controller and plant models
  – Calibration support tools
  – Calibration Automation

▪ Example:
  – Automatically calibrate a diesel engine controller and plant
  – Assess DPF regeneration impact on fuel economy
## Market Drivers Increasing Calibration Workload

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Euro 5 Light-Duty</th>
<th>Euro 6 Light-Duty</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gasoline</td>
<td>Diesel</td>
</tr>
<tr>
<td>CO</td>
<td>1.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>
| HC        | 0.1*
| HC+NO\textsubscript{x} | 0.23 | 0.17 |
| NO\textsubscript{x} | 0.06 | 0.18 | 0.06 | 0.08 |
| PM        | 0.005\textsuperscript{c} | 0.005 | 0.005\textsuperscript{c} | 0.005 |
| PN (#/km) | 6.0 \times 10^{11} | 6.0 \times 10^{11} | 6.0 \times 10^{11} | 6.0 \times 10^{11} |

### Calibration Parameters

![Calibration Parameters Graph](chart.png)

### Calibration Time

![Time on X-axis](chart.png)

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**DSF**

Dynamic Skip Fire (DSF) is the ultimate evolution of cylinder deactivation technology. Applied to engines using proton-cylinder deactivation technology, DSF boosts fuel efficiency.

**SKYACTIV-X**

SKYACTIV-VEHICLE ARCHITECTURE

**INFINITI VC-Turbo**
Virtual Calibration: Goal and Challenges

Need To Move Calibration Activities, Retain Measured Data Basis, Decrease Workload
Surrogate Controller and Plant Models

- Surrogate controller models
- Powertrain system models (aka plant models)
Calibration Support Tools: Model-Based Calibration Toolbox

- Design of Experiments (DoE)
- Response Surface Modeling (RSM)
- Calibration Optimization
Calibration Automation

- Calibration automation tool
- Supports each step along the virtual calibration workflow

Calling other tools and accelerators in the background depending on the task
- Parallel Computing
- Statistics and Machine Learning
- Integration With Off-Shelf Blocks
- Calibration Report Generation
Building Blocks for Virtual Calibration

- Integration with existing data collection tool and measurement data
- Measurement data is essential to achieving high model quality
Virtual Calibration Example

- **Problem statement:**
  Design diesel particulate filter (DPF) regeneration post-fueling logic and assess fuel economy impact of regeneration event.

- **Solution**
  - Use Powertrain Blockset as starting point for system model
  - Use calibration automation tool for plant and controller torque structure model
    - Model-Based Calibration Toolbox
  - Add DPF regeneration post-inject fueling logic and DPF plant
  - Assess fuel economy impact at vehicle level on US-FTP75 drive-cycle
Powertrain Blockset as a framework for the solution

DPF Regen Logic

22 coupled calibration tables

Torque Structure Used As Estimator and Plant

Exothermia Aftertreatment Plant
Powertrain Blockset as a framework for the solution

Controller Modification for DPF Regeneration
Powertrain Blockset as a framework for the solution

Controller Modification for DPF Regeneration
Calibration Automation Tool

Import Data
Base Calibration Model Fit
Base Calibration Map Generation
Torque Efficiency Model Fit
Torque Efficiency Map Generation
Update Lookup Table Maps in Simulink
Calibration Support: Model-Based Calibration Toolbox Template

- User provides spreadsheet data
  - Torque
  - Fuel
  - BSFC
  - Etc.

- MBC builds model automatically
  - Engines
  - Turbochargers

- MBC/CAGE writes calibrations to model
- User can open MBC to inspect and modify results
Calibration Support: Model-Based Calibration Toolbox Template

- Increase productivity
  - Less hands-on interaction
  - Uniform data

- Leverage the power of MBC
  - Statistics
  - Optimization
Result: Automated Filling of Calibration Tables in the Torque Structure
Result: Determined Active DPF Regen Fuel Economy Impact

8.7% Increase in fuel consumption due to DPF Regen on USFTP75
Summary

- Market drivers increasing calibration workload

- MathWorks provides building blocks for virtual calibration
  - Surrogate controller and plant models: open and useful for new and advanced users
  - Calibration support tools
  - Calibration Automation

- We look forward to supporting you and taking the tooling for virtual calibration to the next level
Questions?