Fuel Injector Design Optimization using GT-SUITE

GT Conference 2015
07/12/2015
Aurobbindo L
## GT Conference- Fuel Injector Design Optimization

### Agenda

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Motivation for simulation

Use of simulation in early development phase

- Enable evaluation of new concept before the hardware exists
- Identify the optimal design parameters with given constraints before the hardware development
- Reduce number of prototypes developed
- Reduce actual hardware testing time

Objective:

- To determine the optimal Fuel Injector design parameters to achieve the target fuel flow rate
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Modeling approach

Based on Fishbone analysis, the influencing parameters have been identified which would determine the flow rate.

Main requirements of Injector:
- Target Fuel Flow rate
- Spray atomization
- Penetration depth
- Spray shape
- Spray size - SMD

Fuel Flow rate depends on:
- Needle Lift
- Volume b/w Needle & Orifice plate
- Number of Holes
- Hole Size

Flow metering

3D Injector model
Modeling approach Contd.,

- Understand Injector construction from 3D & AutoCAD drawings & Build Injector Model using Hydraulics & Pneumatics Library in GT-SUITE
- Parameterization of model to achieve desired Injection profile
- Achieve pressurized injector flow rate as per injector specifications in the simulation
- Changes in the boundary conditions like supply pressure and observe if the model could capture the flow dynamics
- Match low pressure injection test bench data results with simulation results
- Conduct DoE to achieve the target Fuel flow rate with low pressure
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Injector model built in GT-SUITE and its output behavior for pressurized system

Simplification: The electromagnetic circuit is built as a force lookup table.
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Test bench and simulation results comparison

<table>
<thead>
<tr>
<th></th>
<th>Simulation</th>
<th>Test bench</th>
<th>Simulation</th>
<th>Test bench</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Pr</td>
<td>bar</td>
<td>2.7</td>
<td>2.7</td>
<td>3</td>
</tr>
<tr>
<td>Needle Lift</td>
<td>Microns</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>On time</td>
<td>ms</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Static Flow</td>
<td>g/min</td>
<td>109</td>
<td>110</td>
<td>116.9</td>
</tr>
<tr>
<td>Dynamic Flow</td>
<td>mg/Pulse</td>
<td>3.3</td>
<td>3.3</td>
<td>NA</td>
</tr>
</tbody>
</table>

Sensitivity Analysis of 1D Simulation model

Flow rate variation with different operating pressure

Dynamic Flow rate variation with varying On time

Static flow rate variation with varying lift
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Instantaneous mass & Pressure inside sac Volume for low pressure system

Note: As the duty cycle is increased more fuel flows into the sac volume and gaseous volume fraction decreases and density increases.
Test bench and simulation results comparison for low pressure system

**P1 pressure**

- Engine speed N1

**P2 pressure**

- Engine speed N1

- Engine speed N2
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DoE case set up

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<tr>
<th>Parameters</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Holes</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Hole Dia</td>
<td>mm</td>
<td>0.2</td>
</tr>
<tr>
<td>Sac Volume</td>
<td>mm$^3$</td>
<td>1.18</td>
</tr>
<tr>
<td>Lift</td>
<td>microns</td>
<td>60</td>
</tr>
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- The goal of DoE is to identify the most probable combination of the design parameters, which provide maximum flow
- The available maximum design parameter values are used as boundary condition
- A full factorial DoE type is used for DoE settings
DOE case setup results

Integral of Mass Flow Rate

On time 2.5ms
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Summary

- Sensitivity analysis shows that the model is able to capture the flow dynamics under varying operating conditions.
- The supply pressure is varied during static and dynamic conditions and compared with actual test bench measurements.
- The low pressure system operation is well captured in the simulation and test bench comparison results show a good match.
- DOE analysis provide the best possible combination of the design parameters with given constraints.
- GT 1D hydraulic simulation helps in reducing the number of prototype generated, testing time, cost and effort.
I would like to Thank the following people for their help during this work

- Pradeep R (GS/ESB11-IN) - RBIN
- Shawn Harnish – Gamma Technologies
- Bradford Lynch – Gamma Technologies
Thank You