Establishing a correlation for gas exchange dynamics between multi-cylinder and single cylinder test benches using GT-POWER

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Vinod Rane
Agenda

01  Background & Objective

02  Fluid Flow Volume Optimization

03  Concept Validation

04  BC’s Generation for Single Cylinder

05  Summary
Background & Objective

- Combustion is an essential element in optimizing the design of the entire engine.
- For combustion development using multi cylinder test bench is simply uneconomical and inefficient.
- One of the biggest challenge in using single cylinder (or 1 Cylinder) test bench is to replicate the full scale engine behavior in terms of gas dynamics.

Test Engine Specifications:

- Engine Application: Marine (V – type engine)
- Engine rated power: 9100 kW @ 1150rpm
- Power / Cyl: 455 kW
- No. of Cylinders: 20
- Per Cylinder Volume: 17.4 L

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Performance comparison:

Inference:

- In-order to achieve air flow rate similar to Multi cylinder, 1 Cylinder exhaust manifold pressure is **40% less than** Multi cylinder.

- It shows that fluid flow volume needs to optimize in-order to correlate gas dynamics.
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Cyclic plots – Comparison 1 Cylinder vs Multi Cylinder

**Observation:** Large deviation in exhaust manifold pressure magnitude is observed. Deviation in intake manifold pressure is acceptable
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02 Fluid Flow Volume Optimization
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1Cylinder - Calibration

<table>
<thead>
<tr>
<th>Parameters</th>
<th>(Measurement Vs GTP) Diff in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Speed</td>
<td>0.0</td>
</tr>
<tr>
<td>Power / Cyl</td>
<td>-1.0</td>
</tr>
<tr>
<td>Brake Mean Eff. Pr.</td>
<td>-1.0</td>
</tr>
<tr>
<td>Peak Cyl. Pr.</td>
<td>1.1</td>
</tr>
<tr>
<td>LambdaG</td>
<td>0.1</td>
</tr>
<tr>
<td>Air Flow Rate</td>
<td>0.1</td>
</tr>
<tr>
<td>Fuel Flow Rate</td>
<td>0.0</td>
</tr>
<tr>
<td>Intake Manifold Pr.</td>
<td>2.3</td>
</tr>
<tr>
<td>Intake Manifold Temp.</td>
<td>-0.8</td>
</tr>
<tr>
<td>Exhaust Manifold Pr.</td>
<td>-0.4</td>
</tr>
</tbody>
</table>

Inference:

- Engine performance parameter & Gas dynamics behavior is calibrated against steady state measurement data
- Overall model is offering reasonable result & trend against measured data

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## Multi Cylinder vs 1Cylinder Proposed

<table>
<thead>
<tr>
<th>Parameters</th>
<th>(Multi vs Proposed 1Cyl) Diff in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Speed</td>
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<tr>
<td>Power / Cyl</td>
<td>-0.7</td>
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<tr>
<td>Brake Mean Eff. Pr.</td>
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<tr>
<td>Peak Cyl. Pr.</td>
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<tr>
<td>LambdaG</td>
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<tr>
<td>Air Flow Rate</td>
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<tr>
<td>Fuel Flow Rate</td>
<td>-0.9</td>
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<tr>
<td>Intake Manifold Pr.</td>
<td>3.9</td>
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<tr>
<td>Intake Manifold Temp.</td>
<td>0.7</td>
</tr>
<tr>
<td>Exhaust Manifold Pr.</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Inference:** 1Cylinder proposed fluid flow volume variant exhaust gas dynamics correlating well against the Multi cylinder

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03 Concept Validation
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<table>
<thead>
<tr>
<th>Parameters</th>
<th>(Proposed_Measured vs Proposed 1Cyl) Diff in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Speed</td>
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</tr>
<tr>
<td>Power / Cyl</td>
<td>-0.1</td>
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<tr>
<td>Brake Mean Eff. Pr.</td>
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<td>LambdaG</td>
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<tr>
<td>Air Flow Rate</td>
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<tr>
<td>Fuel Flow Rate</td>
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<tr>
<td>Intake Manifold Pr.</td>
<td>4.1</td>
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<tr>
<td>Intake Manifold Temp.</td>
<td>0.2</td>
</tr>
<tr>
<td>Exhaust Manifold Pr.</td>
<td>-2.1</td>
</tr>
</tbody>
</table>

Inference:
GT Predicted result offers close agreement with measured data (1 Cyl test bed build with proposed flow volume)
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04  BC’s Generation for Single Cylinder
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### Why its required?
- Realistic BC’s to optimize combustion parameter in 1Cylinder (to overcome turbocharger effect)
- Reduce multi cylinder engine calibration time & operating cost

### Multi Cylinder GT Simulation
**Inputs:**
- Burn Rate
- Start of Combustion
- Rail Pressure
- Fuel flow rate

**Outputs:**
- Exhaust manifold pressure
- Intake manifold pressure
- Air flow rate
- LambdaG

**Iteration Criteria :**
- until reach the desired targets
- GT simulation (Multi Cyl.) air flow rate, fuel flow rate, exhaust manifold pr. equals to 1Cyl measurement

### 1 Cylinder Test Bench
**Inputs:**
- Exhaust manifold pressure
- Air flow rate
- LambdaG

**Outputs:**
- Burn Rate
- Start of combustion & Rail Pr.
- Intake manifold pressure
- Fuel flow rate
- Emissions

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Summary
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✓ Overall developed process shows a promising correlation for gas exchange dynamics between multi cylinder and single cylinder

✓ Suitable flow volume identified for single cylinder test bench with the help of GT simulation - reduced cost and time significantly

✓ Realistic boundary condition provided to single cylinder test bench to optimize the combustion parameters – acceleration in development program and operating cost
Acknowledgements

Mr. Sebastian Wustl – Combustion Development Engineer, Friedrichshafen

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Thank you