Introduction

- Market transition is towards smaller SI engines with turbocharging to comply with the emission standards and improved fuel economy.
- A 3-cylinder engine is suitable for pulse turbocharging due to the clearly separated exhaust pulses.

Problem Statement

- Small SI engine \(\rightarrow\) less torque margin at low rpm
- Downsized & turbocharged SI engine \(\rightarrow\) low speed torque deficit

Pulse turbocharging + 3-cylinder \(\rightarrow\) Better capturing high pulsating \(E\) (High enthalpy at turbine entry)

![Figure 1: Torque deficit](source)

![Figure 2: Pulsating energy in a 3-cylinder engine](source)

Objective

The aim of this research is to improve low speed torque of a 1000cc 3-cylinder SI engine through pulse turbocharging, without penalizing the overall fuel economy.

![Figure 3: Target performance curve](source)

Why Low End Torque?

- This is where passenger car engines will operate most of the time.
- On-the-road testing shows that most of the engine operating points are located in the low and mid load region and between 1000 to 2500 rpm, as shown in Figure 4.
- Thus, improvement of the low speed torque brings the following benefits,
  - Improved Drivability (Rapid Acceleration)
  - Enhanced Part Load Efficiency
  - Improved Transient Response

![Figure 4: Engine operating points during two driving cycles](source)

Engine Specifications

<table>
<thead>
<tr>
<th>Engine model</th>
<th>EJ-VE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine type</td>
<td>Naturally Aspirated Petrol, Water-cooled, 4-stroke</td>
</tr>
<tr>
<td>Cylinders</td>
<td>In-line 3 cylinders</td>
</tr>
<tr>
<td>Total displacement</td>
<td>989 cc</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>10 : 1</td>
</tr>
<tr>
<td>Bore x stroke</td>
<td>72 x 81 (mm)</td>
</tr>
<tr>
<td>Max output</td>
<td>43 KW @ 6000 RPM</td>
</tr>
<tr>
<td>Max torque</td>
<td>88 NM @ 3600 RPM</td>
</tr>
<tr>
<td>Fuel system</td>
<td>Electronic fuel injection (EFI)</td>
</tr>
</tbody>
</table>

Research Flow Chart

- 1-D Engine Modelling
- Base-line Engine Testing (NA Engine)
- 1-D Model Validation
- Turbo-Matching
- Turbo Selection & Integration
- Parametric Study
- Test-Rig Set up
- Conduct Experiment (Turbo Engine)
- Iterative Process
- Evaluation

![Research Flow Chart](source)

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