Boosted Gasoline engine concept for BS VI and beyond

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Agenda

Garrett introduction

CAFE road map & target vehicle segment

Baseline vs. BS6 technology engine

Miller introduction & impact on engine/ boosting

Miller & boosting benefit

Summary & next steps

Gasoline boosting portfolio
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Gasoline boosting portfolio
## Garrett introduction

<table>
<thead>
<tr>
<th><strong>$3.1B</strong></th>
<th><strong>5</strong></th>
<th><strong>13</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>2017 Revenue</td>
<td>R&amp;D Centers</td>
<td>state-of-the-art manufacturing facilities</td>
</tr>
<tr>
<td>~7,500</td>
<td>~1,200</td>
<td>50,000+</td>
</tr>
<tr>
<td>Employees</td>
<td>Engineers</td>
<td>Turbos / day</td>
</tr>
<tr>
<td>~1,200</td>
<td>100+</td>
<td>100M+</td>
</tr>
<tr>
<td>Engineers</td>
<td>New applications annually</td>
<td>Garrett turbos in use globally</td>
</tr>
<tr>
<td>40</td>
<td>1,400+</td>
<td></td>
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<tr>
<td>OEMs served globally</td>
<td>Patents issued or pending</td>
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</tbody>
</table>

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*Spun off on from Honeywell on 1st October 2018*
Garrett introduction

Vehicle Range
- Commercial Vehicle
- Light Vehicle

Supply All Major Channels
- Aftermarket
- OEM

Regions of Growth
- Americas
- Asia
- Europe

ALL SEGMENTS, ALL PLATFORMS, ALL FUEL, ALL CUSTOMERS

LIGHT VEHICLE: DIESEL  LIGHT VEHICLE: GASOLINE  ELECTRIC BOOSTING  SOFTWARE SOLUTIONS  ON-HIGHWAY VEHICLES  OFF-HIGHWAY VEHICLES

Proven foundation and strong performance
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Fuel consumption/ CO$_2$ emission norm becoming stringent
Most sold vehicle/engine segment selected for investigation

CAFE road map & target vehicle segment

- 1.2L Gasoline hatchback share ~18%

* 2017 SIAM data
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- Summary & next steps
- Gasoline boosting portfolio
## Baseline vs. BS6 technology engine

<table>
<thead>
<tr>
<th></th>
<th>Displacement (L)</th>
<th>Nos. of Cylinder</th>
<th>Boosting</th>
<th>Combustion</th>
<th>Injection</th>
<th>Max Torque (Nm)</th>
<th>Rated Power (kW)</th>
<th>Compression Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline (1)</td>
<td>1.5</td>
<td>4</td>
<td>Naturally aspirated</td>
<td>Otto</td>
<td>MPFI</td>
<td>140</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>Baseline (2)</td>
<td>1.2</td>
<td>3</td>
<td>Naturally aspirated</td>
<td>Otto</td>
<td>MPFI</td>
<td>110</td>
<td>65</td>
<td>10</td>
</tr>
<tr>
<td>BS6 Engine</td>
<td>1.2</td>
<td>3</td>
<td>Turbo VNT</td>
<td>Miller</td>
<td>GDI</td>
<td>230</td>
<td>95</td>
<td>11.5</td>
</tr>
</tbody>
</table>

- Downsizing, Boosting & new Combustion technology implemented on baseline Engine to study different scenarios
- 1.5L & 1.2L naturally aspirated FRM used for baseline Engine study

**GT POWER FRM Model used for comprehensive study**
Baseline vs. BS6 technology engine

Boosting in addition with Miller delivers improved performance & BSFC
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Miller introduction & impact on engine/boosting

- A combustion cycle with early or late intake valve closing
- Lower effective compression ratio compared to the expansion ratio
- Part of the compression outsourced to compressor of the turbocharger

Millerization achieved with EIVC, smaller valve lift & cam duration

Miller Ratio = \( \frac{V_{BDC} - V_{TDC}}{V_{IVC} - V_{TDC}} \)

\( = \frac{\text{Geometric displacement}}{\text{Effective displacement} + \epsilon} \)

**LEGEND:**
- 1.2L VNT
- 1.2L VNT + Miller
Miller introduction & impact on engine/boosting

- Reduces knock tendency
- Lower engine out temperatures
- BSFC improvement at full and part load

Miller advantage through out engine operating range

**Diagram:**
- BMEP - Brake Mean Effective Pressure
- Reduce knock probability
- Enable $\lambda = 1$ operation
- Lower Engine out Temperature
- BSFC improvement through out the map

**Legend:**
- 1.2L VNT
- 1.2L VNT + Miller
Miller introduction & impact on engine/boosting

- Lower flow requirement
- Higher boost requirement
- Increased discharge margin
- Lower exhaust Temperature
- Lower Turbine in Temperature

**LEGEND:**
- 1.2L VNT
- 1.2L VNT + Miller
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Miller & boosting benefit – Full load

Miller + boosting improves BSFC & performance at all speed

LEGEND:
1.5L NA
1.2L NA
1.2L VNT
1.2L VNT + Miller
Miller & boosting benefit – Engine map

**Reference vehicle**
Compact SUV
1.5L, Naturally aspirated
82 kW, 140 Nm
Vehicle mass = 1314 kg

**Reference vehicle**
Compact SUV
1.2L, Boosted Miller
92 kW, 170 Nm
Vehicle mass = 1337 kg

**1.5L Baseline NA Engine**

**1.2L Boosted Miller Engine**
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Summary & next steps

• Miller combustion & VNT boosting benefit on engine:
  • Significant fuel consumption/ CO2 reduction at full & part load
  • Smaller engine with better performance
  • Engine operating points in better BSFC zone
  • Lower temperature & pressure resulting in reduced knock tendency
  • Reduced knocking enabling higher geometric compression ratio & better combustion

• Miller combustion complementing boosting:
  • Reduced compressor flow & increase boost gives an opportunity for map optimization
  • Higher discharge margin resulting in lower base boost
  • Lower turbine inlet temperature could reduce material cost

• Next steps:
  • Transient response study in progress with dynamic vehicle model
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Gasoline boosting portfolio
Gasoline boosting portfolio

**Full portfolio of gasoline boosting with WG & VNT technology available**

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**Available**: MGT10 MS, MGT12 MS, MGT13 MS, MGT14 MS/TS, MGT15 MS/TS, MGT17 MS/TS, MGT20 MS/TS, MGT22 MS/TS, MGT25 MS/TS, MGT27 MS/TS

**In Prod.**: MGT10V, MGT12V, MGT13V, MGT15V

**Develop.**: MGT17V, MGT22V

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**Rated Power [kW]**

- 75
- 100
- 125
- 150
- 175
- 200
- 225
- 250
- 275

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**WG**

- MGT10 MS
- MGT12 MS
- MGT13 MS
- MGT14 MS/TS
- MGT15 MS/TS
- MGT17 MS/TS
- MGT20 MS/TS
- MGT22 MS/TS
- MGT25 MS/TS
- MGT27 MS/TS

**VNT**

- MGT10V
- MGT12V
- MGT13V
- MGT15V
- MGT17V
- MGT22V

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**Perf. Dem. Avail.**

- MGT10V
- MGT12V
- MGT13V
- MGT15V
- MGT17V
- MGT22V

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**Gasoline boosting portfolio**

- Full portfolio of gasoline boosting with WG & VNT technology available
Garrett is a cutting-edge technology provider that enables vehicles to become safer, more connected, efficient and environmentally friendly.

We lead the development of innovative and differentiated solutions which empower the transportation industry to redefine and further advance motion.