EGR-Diluted NG combustion simulation in a high-performance SI engine

Mirko Baratta, Daniela Misul, Prashant Goel

ICEs Advanced Lab. – Energy Department, Politecnico di Torino – Italy
The GasOn research project (H2020)

http://www.gason.eu/
The GasOn research project (H2020)

Technologies integration in WP4
(Charge Dilution and Exhaust-Gas Temperature Management for a CNG Direct Injection Engine)

Focus:
Studying the impact of charge dilution on NG combustion speed/efficiency

http://www.gason.eu/
GasOn engine

- High C.R., increased PFP
  - Diesel-based design
- Power target: 125 kW
- Revision of intake port geometry and intake/exhaust timing (VVT)
  - scavenging
  - increased tumble

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cylinders</td>
<td>4</td>
</tr>
<tr>
<td>Displacement</td>
<td>1.6 l</td>
</tr>
<tr>
<td>Number of valves / cylinders</td>
<td>4</td>
</tr>
<tr>
<td>Bore / stroke</td>
<td>80 mm / 80 mm</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>13.5:1</td>
</tr>
<tr>
<td>Peak pressure</td>
<td>180 bar</td>
</tr>
<tr>
<td>Direct injection / Injection pressure</td>
<td>20 bar</td>
</tr>
</tbody>
</table>

Computational mesh

Base size 4 mm

Total number of cells vs. crank angle

Fixed embedding (cylinder): 1 mm
Fixed embedding (boundary): 0.5 mm
Fixed embedding (spark plug): 0.5/0.125 mm
CFD engine model in CONVERGE

<table>
<thead>
<tr>
<th>Flow</th>
<th>Compressible Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Simulation</td>
<td>Redlich Kwong model</td>
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<tr>
<td>Numerical method</td>
<td>Implicit method</td>
</tr>
<tr>
<td>Turbulence model</td>
<td>RNG k-ε</td>
</tr>
<tr>
<td>Combustion model</td>
<td>ECFM</td>
</tr>
<tr>
<td>Heat transfer model</td>
<td>WF - Angelberger</td>
</tr>
</tbody>
</table>

LFS submodel from detailed chemistry developed and implemented via UDF

\[ S_L = S_L (p, T, \lambda, \text{EGR}) \]
Cycle-to-cycle variations of results

- In most of the operating points, with the present setup it was not possible to reach a ‘converged’ solution.
- A clear correlation of the peak pressure with the turbulent flow features at ST was found.
- Cycle-averaged results were considered from 2nd to 8th cycle.
- Correlation of the simulated CoV with the engine variables were also analyzed.
Combustion evolution – 2000x8, EGR=0

NG concentration contours

CA = 708 deg (4 deg AST)

CA = 713 deg (9 deg AST)

CA = 720 deg (16 deg AST)

CA = 735 deg (31 deg AST)
Combustion evolution – 2000x8, EGR=30%

NG concentration contours

CA = 690 deg (11 deg AST)

CA = 710 deg (31 deg AST)

CA = 735 deg

CA = 700 deg (21 deg AST)

CA = 720 deg (41 deg AST)

CA = 780 deg
EGR sweep @2000x3

Average pressure cycle

Normalized heat release
EGR sweep @2000x30

Average pressure cycle

Normalized heat release

Crank angle [cad]
EGR sweep - cycle-to-cycle variations

- The simulated CoV is nearly twice the experimental one
- The trend is respected
- However, the quite low number of simulated cycles represents a limit for this analysis
The thorough analysis of results shows that the EGR limit is reached when the MFB0-50 gets higher than 50 deg.

This also corresponds to an increase in the CoV imep up to 3-4 times the original value.

The exception is at full load where the CoV imep is mainly driven by the retarded ST and is nearly constant.
Thank you!