Optimization of a Jacket Water Circuit with GT-Suite at GE Gas Engines J624 Stationary Gas Engine

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Outline

- GE Gas Engines
  ... answering the Power Generation Challenges
- Engine Jacket Water Circuit
  - Requirements for BMEP 24bar+
  - Design & Simulation Methodology
- Modeling Details
- Results and Summary
GE Gas Engines

... answering the power generation challenge with fuel flexibility and tailor-made solutions
Fuel flexibility and tailor-made solutions

- Landfill gas
- Sewage gas
- Associated petroleum gas
- Special gases
- Biogas
- Greenhouse applications
- Cogeneration (Natural gas)
- Coal mine gas

Island mode
The new J624

...potential to power up to 10,000 households

2-stage turbocharged

<table>
<thead>
<tr>
<th>Engine speed</th>
<th>$P_{el}$</th>
<th>BMEP</th>
<th>$\eta_{el}$</th>
<th>$\eta_{tot}$</th>
<th>Lengths</th>
<th>Width</th>
<th>Height</th>
<th>Weight Genset</th>
</tr>
</thead>
<tbody>
<tr>
<td>50Hz 1500rpm</td>
<td>4.400kW</td>
<td>24bar</td>
<td>46.5%</td>
<td>90.0%</td>
<td>12m</td>
<td>2.5m</td>
<td>2.9m</td>
<td>44t</td>
</tr>
<tr>
<td>60Hz 1500rpm</td>
<td>4.360kW</td>
<td>24bar</td>
<td>46.0%</td>
<td>88.5%</td>
<td>14m</td>
<td>2.5m</td>
<td>2.9m</td>
<td>47t</td>
</tr>
</tbody>
</table>
Engine Jacket Water Circuit

… Ready for BMEP 24bar+

… Requirement for increased power density & efficiency
Requirement for increased power density & efficiency

Electrical efficiency [%]

Specific output

Jacket water circuit development required?
Engine Jacket Water Circuit

Simple layout (single pump with single feed- and return pipeline) can be further improved → definition of standard layout.

J624 ... simple layout in early design phase

Crankcase boundary

"minimum approach" driven by design and manufacturing
Simulation Results

**Design option**

**Jacket water flow**

**Cylinder number #**

**Imbalance front-to-rear**

**Imbalance A-to-B**

**Baseline**

**Remaining imbalance front-to-rear**

- Optimization with 2 feed lines (simulated)
- measured

Expectation for increased BMEP:
Imbalance and its consequences will get worse.
Design not sufficient for 24bar+
Engine Jacket Water Circuit

Simulation for J624 2-stage showed the need for further optimization of the jacket water circuit for BMEP 24bar+ operation…

… but how?

J624 jacket water circuit layout for 22bar was not sufficient as a carry-over for 24bar+
Design & Simulation Methodology

Improved Concept Design and Simulation Loops
Design Improvement Strategy

1) Failure Modes and Effects Analysis
2) Design Validation Plan

Baseline Analysis & Measurement

FMEA

DVP

Test Bench & Field Validation

1) ... Failure Modes and Effects Analysis
2) ... Design Validation Plan
Design & Simulation
Loops

Improvement by Analysis
Conceptual Design

Possible Water header modifications

Pressure drop

Zylinder Number
flow [l/s]

1 pump
2 pumps
2 p.+coll greater
2 p.+2. coll-p
DN80
2 p.+2. coll-p
DN100
2 p.+coll. g.+2 C-p
DN80
2 p.+coll. g.+2 C-p
DN100

Jacket water flow

-0,100
0,000
0,100
0,200
0,300
0,400
0,500
0,600
pipes to engines
end cover to A-side
distribution rail
liner and head
collector rail
end cover out
pipes to check valve
check valve
thermostat
pipes to heat exchanger
heat exchanger
pipes to pump
dp [bar]
3D view and GT Suite model

3D view

GT Suite model
Pressure loss

Use of template **PressureLossConn Connection**

→ with template use of following Pressure Drop Reference Objects:

- FlowPDropPowerLaw
- FlowPDropTable
Pressure loss
FlowPDropPowerLaw

Used if only 1 data point (flow and pressure loss) from supplier available

\[ \Delta p = A + B \cdot \dot{V}^C \]

\[ A = 0, C = 2 \]

\[ \Rightarrow B = \frac{\Delta p [\text{bar}]}{\dot{V} [m^3/s]^2} \]

Temperature influence can't be considered!
Pressure loss
FlowPDropPowerLaw

Used for:

- cylinder (liner and head)
- thermostat
- turbo chargers
- ball valves
- flow controller
- heat exchanger
- not running pre heat pump
Pressure loss
FlowPDropTable

Used if more data curves available
(more than one data point, supplier data or measurement data),
or if there is a different flow behavior in both flow directions.

Used for check valves
(to prevent wrong flow with pre-heat-pump)

Pre-heat pump

check valve DN100

![Graph showing pressure loss vs. flow for a check valve DN100. The graph indicates a non-linear increase in pressure loss as flow increases.]
Pumps

- Either driven mechanically or per e-motor
- Constant speed
- Only 1 data set necessary

Templates:

- Pump
- Pump Map
- SpeedBoundaryRot

Proposal for next release: new unit “m H2O” instead of “mm H2O”
Heat transfer

Use of template **HeatAddition**

(simulation of only 1 circuit, otherwise use of **MasterHx** and **SlaveHx**) → used for heat exchanger, cylinders and turbo chargers

\[
\dot{Q}_{\text{heat-exchanger}}(\text{e.g. measurement}) = \frac{1}{n} \ast \dot{Q}_{\text{heat-exchanger}} + \sum_{i=1}^{n} \text{cylinders}
\]

For temperature stability, e.g. 90°C at 100%
Advanced shapes in flow system

1. Use of FlowSplitGeneral (e.g. mitre bends)
2. Use of GEM3D
Solver selection for Flow Control

<table>
<thead>
<tr>
<th></th>
<th>Explicit</th>
<th>Implicit</th>
</tr>
</thead>
<tbody>
<tr>
<td>strong dynamics</td>
<td>usable</td>
<td>usable up to Ma = 0.3</td>
</tr>
<tr>
<td>time step size</td>
<td>very small</td>
<td>usually large</td>
</tr>
<tr>
<td>calculation time per time step</td>
<td>short</td>
<td>long</td>
</tr>
<tr>
<td>stability</td>
<td>depending on time step size (Courant relation)</td>
<td>not depending on time step size</td>
</tr>
</tbody>
</table>

→ **typical applications**

- engine performance
- combustion
- gas exchange
- non-engine simulations with long duration
- cooling circuits
- exhaust system warm up

→ for the simulation of a jacket water circuit the Implicit solver is chosen
Simulation Results and Summary
Results of Improvement

Favorite version for improved balancing & flow rate

Jacket water flow [m3/h]

Cylinder number #

Initial simple layout as Simulation Baseline

Miscellaneous pump and design variations
Summary

• This Thermal Management optimization was related to current as well as potential future power increases of Engine Platform Type6.

• Successful cylinder-to-cylinder jacket water balancing
  • bank A/B
  • front/rear-end of the engine

• Extensive loop of concept designs, continuously improved by supporting 1-D simulation and overall Genset Thermal Management.

• The simulation-based design optimization is an approach that leads straightforward to a first-time-right design state. Therefore, it enables the reduction of development time and costs very effectively.
Thanks for Your Attention!

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