Simulation of engine cooling components within the development process of Behr

STAR Global Conference 2012
Amsterdam, 2012-03-20
Simulation of engine cooling components at Behr

**CFD @ Behr Engine Cooling**
Heat Transfer & Flow Analysis

- **Modules**
  Interaction of heat exchangers, fan & blockage

- **Parts**
  Optimization of pressure loss & mass flow distribution

- **Components**
  Trade Off for heat transfer & pressure loss

**Underhood Simulation**
Prediction of available cooling air, flow and temperature distribution for components
Simulation of engine cooling components at Behr

**Winglet tubes**
Optimization of winglet geometry

gas flow

**Parametric model setup**
- Textfile with geometrical parameters (> 20) is input for automatic meshing
- CAD data is not needed!
- Hexdominant mesh
- High resolution of BL

```
winglet.exe
```

```
Mesh & BCs
```

```
STAR-CCM+
```

Dr.-Ing. Stauch, March 2012

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**Winglet tubes**
Analysis of boundary heat flux

Identification of areas of low and high heat flux at heat transfer boundary with respect to optimization of winglet design for increasing the heat transfer
Winglet tubes
Development of optimized design

Development of new winglet design with higher heat transfer at reduced pressure loss
Oil cooler plates
Optimization of plate geometry

- Variation of plate geometry for optimization of heat transfer and reduction of pressure loss
- Possibility for meshing complex geometries by using STAR-CCM+
Oil cooler plates
Analysis of boundary heat flux @ different operating points

- Identification of areas of low and high heat flux at heat transfer boundary
- Partially different behavior for different operating points
Simulation of engine cooling components at Behr

Oil cooler plates
Analysis of flow field @ different operating points

- Identification and optimization of flow pathes
- Universal behavior (only minor dependence on operating point)
Oil cooler plates
Development of new plate design

Development of new plate design with significantly reduced pressure loss and almost no reduction of heat performance
Radiator
Post Processing Parts for pressure loss and performance

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<th>Δp</th>
<th>Location</th>
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<tbody>
<tr>
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<td>p_2 - p_1</td>
<td>Inlet Hose</td>
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<td>-</td>
<td>p_3 - p_2</td>
<td>Inlet Tank</td>
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<td>p_4 - p_3</td>
<td>Core</td>
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<td>-</td>
<td>p_6 - p_5</td>
<td>Outlet Hose</td>
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Simulation of engine cooling components at Behr

Radiator
Total pressure drop distribution

- Particular radiator with tubes of very short length
- Visualization of inhomogenities of total pressure distribution within tanks and tubes
Simulation of engine cooling components at Behr

**Radiator**

Mass flow distribution of tubes

### Deviation from mean flux [%]

<table>
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<th>Deviation from mean flux [%]</th>
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**Uniformity Index**

| Base Design | 0.9750 |

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**Radiator**
Analysis of flow field in inlet tank for different meshes

- Trimmed mesh
- Poly mesh

⚠️ Significant deviations in flow field in inlet tank for different meshes with reasonable number of cells
Radiator
Different meshing approaches

Trimmed mesh  Manual Meshing: “Hexcore” mesh  Poly mesh

“Manual Hexcore Meshing” seems to combine advantages of Trimmed mesh and Poly mesh
**Indirect Charge Air Cooler**
Simulation of Thermo Cycle Test (TCT)

- CFD Simulation for obtaining transient temperature distribution in solid
- FEA Simulation of TCT for identification of critical areas for part failure
Indirect charge air cooler
Thermal shock and Thermography: Temperature sensors comparison with CFD

- Comparison of experimental and numerical results for one cycle (heat up + cool down)
Indirect Charge Air Cooler
Thermal shock and thermography: Comparison thermography – “Temperature only“
Simulation of engine cooling components at Behr

**Radiator / Indirect charge air cooler**

Workflow of numerical simulation of TCT (CFD → FEA)

- Transient CFD
  - Mapping of transient solid temperature on FEA mesh
  - FEA for thermal stress prediction

**Drawbacks (Potential):**
- Full CFD data required for mapping (not only solids)
- Reloading of transient CCM files not possible
- Proximity check does not work

- Turbulent flow for both fluids
- Conjugate heat transfer to and from all solids
- Heat conduction in solids

**Lifetime Prediction**

Wöhler Curve / Fatigue Software
Conclusions and Outlook

- Variety of CFD simulation methods using STAR-CCM+ are established within the product development process
- High potential of automation and standardization by Java macro programming
- Mapping process of post data in STAR-CCM+ not yet fully developed
- More meshing features are desired (e.g. partially structured meshes, “parallel wrapper”)
- Documentation of models and features has to be improved (e.g. Dual Stream HX - Actual flow)