Thermohydraulic Calcs of Cooling Systems for MAN Heavy Truck using COOL3D
Contents of Presentation

- Introduction to thermohydraulic modeling
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Aim and Motivation

- Mathematical description of cooling system
- Verification and validation of simulation model
- Thermohydraulic analysis and parametric study for cooling system
- Modeling of cooling air path
- Comparison between numerical and experimental results
Introduction to thermohydraulic modeling

- Reynolds transport theorem:

\[
\partial_t U + \text{div}(F^e + F^c) = \text{div} F^v + S
\]

„Changing“ „Exchange“ „Source terms“

- Mass balance equation:

\[
\frac{dm}{dt} = \frac{d\rho}{dt} V + \rho \frac{dV}{dt} \Rightarrow 0
\]

- Energy balance equation:

\[
\begin{align*}
\frac{dE}{dt} &= p \frac{dV}{dt} + \sum \dot{M}u + \alpha A (T_a - T_w) \\
\frac{dE}{dt} &= V \frac{dp}{dt} + \sum \dot{M}h + \alpha A (T_a - T_w)
\end{align*}
\]

Closed system

Open system

- Momentum equation:

\[
\frac{d\dot{M}}{dt} = \frac{dpA + \sum \dot{M}\\tilde{v} \frac{\rho v |v|}{2} dx A - C_p \left( \frac{1}{2} \rho v |v| \right) A}{dx}
\]
Model description - D2676 engine with cooling system

Figure 1: D2676 engine EURO VI with cooling system
Model description → GT - SUITE

**Figure 2:** D2676 engine with cooling system, HT- and LT- cycle with 2 pumps

- 2 separate cooling cycles with 2 pumps for HT- and LT- cooler and accumulator
- Engine map (fuel consumption and heat rejection matrix) → engine test stand
- HP- and LP- indirect charge air coolers (thermal mass matrix)
- Fan → operating data → OEM
Model description → GT - SUITE

Figure 3a: COOL3D Model of TGS MAN heavy truck

Figure 3b: CAD Model of TGS underhood

Figure 3c: D2676 engine with cooling package

Figure 3d: Cooling fan module with cooling package

Model description → GT - SUITE
Model description → GT-SUITE

Figure 4: Top view – CAD Model (left) and COOL3D Model (right)
Figure 5: Cooling air outlet – CAD Model without gear box (left) and COOL3D Model with cooling air openings (right)
Figure 6: Underhood with cooling package - top view → recirculation and preheating phenomena

AC - air conditioning condenser
LTC - low temperature cycle
HTC - high temperature cycle
Figure 7a: Front side of cabin (TGS) and bumper with cooling air openings → GT-SUITE (COOL3D)

Figure 7b: Front side of cabin (TGS) and bumper with cooling air openings → series-production truck

cooling air inlet
Selected results

*Figure 8*: Temperature differences between measured and calculated values for completely underhood model
Selected results

**Figure 9:** Temperature and velocity distribution in- and on- LT (U-flow)- and HT (1-flow)- Cooler
Figure 10: Simplified underhood - COOL3D → 1D simplification

Figure 11: Model validation with additional resistances
Summary → simplified COOL3D model

- Short computational time
- Very good agreement in validation process with results of completed underhood model
- Validation of cooling air mass flow using DOE parametric study and optimisation methods

Resistance model for cooling air mass flow

**Figure 12: Model validation with additional resistances**
Summary and discussion

- COOL3D makes possible a precise modelling of cooling air path
- Using COOL3D the modeling of air preheating and air recirculation can be considered
- „Quasi“ 3D - CFD mathematical description of underhood make possible a completely parametric study of cooling package positioning (influence of variable distances between coolers, fan and engine on the air path parameters)
- Very good agreement with experimental data in validation process
- Reduction of computational time due to use of simplified underhood COOL3D model
Thank you for your attention!