Truck Cooling Package Optimization

Reducing the size of a cooling package thanks to 1-D Transient simulations
VOLVO group presentation

- What we do

We employ almost 100,000 PEOPLE, have production facilities in 18 COUNTRIES and sell our products in more than 190 MARKETS

- Where we are

North America
15,882

Europe
47,561

Asia
16,526

South America
4,774

Africa & Oceania
2,361

- What are our brands?
RENAULT TRUCKS GTT presentation

(GTT = Group Trucks Technology)

• What we do
  – Vehicle engineering and validation for Medium Duty trucks Renault – Volvo (8/26 t)
  – Heavy Duty trucks engineering when it’s specific to Renault brand

• Where we are

4 SITES IN FRANCE

- Blainville/Orne (Caen)
  Cabs, distribution range, components

- Bourg-en-Bresse
  Heavy duty range

- Lyon
  Engines, axles, stamping and spare parts

- Limoges
  Remanufacturing plant for service exchange

9,000 PEOPLE dedicated to the brand
1,440 SALES and SERVICES points Worldwide
Presentation of the study context

**Our mission:**  
Dimension and develop a cooling system (radiator, charge air cooler, fan)  
Control coolant and air temperature

- **Condenser:**  
  To reject heat from the HVAC system

- **Charge air cooler:**  
  To cool down the temperature of air at engine inlet  
  A criteria must be respected

- **Radiator:**  
  To control the temperature of coolant at engine inlet and reject the engine heat loss  
  A criteria must be respected

- **Fan shroud:**  
  Used to duct air and avoid recirculation

**Hot compressed air:**  
Around 200°C

**Hot coolant from engine:**  
Around 100°C

**Cooled air:**  
Around 60°C

**Coolant to engine:**  
Around 95°C

**Fan:**  
Is electronically controlled, driven by the temperature of coolant at engine inlet
Reasoning – Origin of the study

- Competitor analysis showed lower weight on components (fan, radiator, charge air cooler)
- Data analysis from previous trucks
- Analysis of cooling performance test results
- Customer contact, with truck instrumentation

There is margin to decrease the size / cost / weight on fan, radiator, charge air cooler

Case study will be: RENAULT TRUCKS D MDE5 240
Study Workflow

Perform simulations and tests with current truck

Correlate coolant and air temperature (steady state and transient) with test data

Evaluate different concepts by simulation (radiator, charge air cooler and fan size)

Anchor the concept

Final verification on physical prototype
Construction of the model

- Pipe geometry is compiled through GEM3D (for complex pipes) or manually.
- Component internal heat exchange are calculated by GT-SUITE.
- External heat exchange coefficients are calculated in external software (except cooling package).
- Cooling package heat exchangers are compiled through COOL3D with supplier data and simulation with GT-SUITE (HeatExchangerSpecs).
- Pump and fan performances are mapped in GT-SUITE with supplier data.
Construction of the transient model

The model was built with data coming from different horizons

CFD inputs (air flow) for fine tuning

Test inputs (results for correlations)

Engine performance (heat balance)

Fan / cooling package geometry and performance (supplier data)

Volvo 3P EVALUATION OF PERFORMANCES

Customer Part Nr : P1551 MD EU6, AA553.55.520, C-sample (ETALON part)

Volvo Reference no. 21675258

Behr part no. CD398001

Supplier name : BEHR

Date : 12/04/2012

Core Depth

Tube material : Aluminum

Overall tube number: 56

Between Headers: 730

No of rows of tubes: 1

Core Width : 568

Tube cross-section (mm x mm) 52 x 1.8

Fin type : louvered

Glycol 40 %

Fin density : 55

Ambient temperature : 35°C

Turbulator type : N/A

Delta T = 62 ºC

P Qm-cool. (kW) (kg/s)

1 2 4 6 8 10

Qm-air D p cool. (kg/s) (Pa) (Pa)

4428 13051 41035 85569 146330 199900

D p Air

1 56 49.4 53.8 56.1 56.8 57.2 57.5

2 154 82.2 96.8 105.0 107.9 109.4 110.4

3 289 101.0 126.2 141.5 147.3 150.3 152.2

4 462 113.9 148.6 171.3 180.1 184.8 187.7

5 671 123.2 166.4 196.3 208.1 214.5 218.6

6 915 130.3 181.0 217.6 232.5 240.7 245.9

7 1195 135.9 193.1 236.2 254.1 264.0 270.3

Remark :

Coolant pressure drop @ 90°C (core & tanks, isothermal)

Cooling air pressure drop @ 35°C (isothermal)
Correlation of the simulations (1/2)

- Model must represent the inertia of the system
- Engine coolant temperature level must be representative
- Fan speed must be OK

![Correlation between tests and simulations](image)

- Coolant temperature level and amplitude are well simulated
- Fan control is well reproduced
- PID is integrated in the simulations
Correlations of the simulations (2/2)

- Simulated air temperature at engine inlet must be realistic
- It’s a little more difficult on this point; this is a topic worked in the group, with the help of Gamma Technologies

**Conclusions**

Good correlation and confidence on coolant
Good control of the fan
Quite good simulation of air at engine inlet

Satisfying to continue with the downsizing and investigate solutions
Investigation with GT-SUITE’s component scaling option

- Several parameters were investigated:
  - Radiator size
  - Charge air cooler size
  - Fan shroud
  - Fan

Which fan?
- NFM?
- NFX?
- DFMX?
- DFI?

Which fan shroud?
- Engine mounted ring?
- Extended fan shroud?

Smaller radiator?
-80 mm
-160 mm

Smaller charge air cooler?
-3 tubes

Radiator: 730 mm
Charge air cooler: 28 tubes
Investigation with GT-SUITE’s component scaling option

- Based on correlated original model, GT-SUITE’s component scaling option was used
- The final concept was chosen, based on the GT-SUITE simulation with scaling option
  - Smaller fan was selected (650 mm ➔ 590 mm)
  - Extended fan shroud
  - 120 mm were removed on radiator
  - 3 pipes were removed on charge air cooler

All potential solutions were simulated on steady state cases
Investigation with GT-SUITE’s component scaling option

- Additional data were also requested from the supplier (heat exchange tables with downsized system)
  - Slight differences in results (<1°C) on coolant and air temperature in steady state case
  - Negligible impact / difference on those temperatures in transient

- Additional CFD simulations were performed to check the performance (mainly recirculation and air mass flow repartition)

To correctly evaluate in-vehicle temperatures, it was necessary to obtain the right equilibrium between air flows at the top and at the bottom of the heat exchangers.
Simulations showed a **higher fan engagement**, **higher average coolant temperature**, but without any risk to the engine.
Results with downsized system (2/2)

- The downsized cooling system was prototyped and tested successfully after simulation.
- The new cooling system tests results were well correlated with new simulations.

- During severe tests in Spain, no risk on engine was observed even after a high reduction of the cooling package size.
Conclusions and outputs

- GT-SUITE model correlated well with tests in:
  - Steady state case
  - Transient road cycle
- Suppliers were solicited and proposals were simulated on steady state cases
- The best compromise was kept as a solution  transient simulations were undertaken
- The downsized solution was also tested  correlation was also satisfactory

Two main outputs:
- The new method with transient cycle simulation and investigation with GT-SUITE’s component scaling option is valid for future projects
- Potential benefit have been possible on the truck:
  - Up to 35 euros / truck and around 3 kg on cooling package
  - Around 3 kg on fan
Thanks for your attention

Do you have any question ?