Simulation of Radiator Performance Using Gt-Suite Software

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Abstract- *The work investigates the integration between tools for analysis and simulation of cooling system at Volvo Group Trucks Technology.This work simulates and analyses the engine cooling system of Volvo trucks. The variable used in analyses are temperature, pressure, mass flow rate of air, rpm of radiator, cooling fan .For this purpose software used is GT-SUITE. The effect of this variable on engine performance is investigated.This paper focuses on 1-D simulation tools. The work includes a detailed model of main coolant circuit. Coolant flow rate and fan speed are directly proportional to the heat dissipated out of radiator, whereas ambient temperature is inversely proportional to heat dissipated. This paper can be seen as a comprehensive manual to building and executing a simulation model.*

Keywords- 1-D cooling simulation, GT-SUITE, Engine models, Radiator.

I. INTRODUCTION

Since the advent of digital age, computers models and simulations have been used in engineering to recreate phenomenon in system in a comprehensive, accurate and cost efficient manner in order to obtain performance parameters of interest. Due to the fact that some models are prepared by using assumptions and specifications, so this often involves deciding which physical phenomenon in the system to capture to what extent and level of refinement (discretization).A wide range of physical phenomenon occur in the cooling system of a heavy duty vehicle. As far as results from cooling simulations are concerned, the main parameters of interest are temperatures, pressures, mass and energy flows in the system. GT-SUITE is a powerful tool for engine performance simulations. The process will begin with collecting all necessary control and functional blocks. Engine model, fan control, coolant pump control will be acquired and adapted to the specifics of the simulation. A model of the coolantcircuit will be made, including a functional model of the thermostatic valve. All the blocks will be integrated in a common software environment and the model of the coolant system will be calibrated according to test results.

II. THEORY

This paper introduces the theoretical foundation related to this project. It begins with a short account of the basic mechanisms of heat transfer and continues with a concise description of a truck's cooling system, where the basic components and their functions are summarized.

a) Heat Transfer: Heat transfer is the transition of thermal energy between bodies or fluids of different temperatures. There are several different mechanisms for the heat transfer: conduction, convection and radiation.

b) Conduction: Conduction is the heat transfer happening when there is a direct contact between particles of matter with different temperatures. Those particles exchange energy without any motion. Conduction acts to equalize temperature gradient, so the heat is transferred from the hotter region to the colder one. The amount of heat being transferred is proportional to the temperature difference, so if the temperature gradient tis higher the conduction heat flux will have a bigger value.

In terms of equations the conduction heat flux can be calculated in the following way:-

$$Qcond = -k*[(T2-T1)/L].$$

Where k is thermal conductivity in W/m-K, (T2-T1) is the local temperature gradient(K) and L is the material length (m). A good example of conduction in the cooling system is the heat being transferred through the material of the engine resulting in fastwarm up of its outer surface.

c) Convection: Convection is another heat transfer mechanism that requires a medium. It occurs by means of the molecules movement within fluids. It takes place in two different ways: diffusion and advection.

The convection can be classified to forced and natural. Forced convection occurs when a fluid flow is affected by external means. In case of coolant pipes it is affected by the pump, therefore the convection heat transfer here can be considered to be forced. On the other hand natural convection occurs when there is no outer influences on the heat transfer.

In terms of formulas one can find the following equation for the convection heat flux:

$$Q_{conv} = h*(T_s-T_\infty).$$

Where h is the convection heat transfer coefficient (W/m²-K), Ts is the surface temperature (K) and T∞ is the fluid temperature (K) outside the thermal boundary layer.

d) Radiation: Radiation is the third heat transfer mechanism. It is concerned with the exchange of thermal energy between two or more bodies and unlike conduction and convection it requires no medium. Heat transfer through radiation takes place in form of electromagnetic waves mainly in the infrared region. The intermediaries are photons which travel at the speed of light.

The total energy radiated per unit surface area of a black body in unit time, Eγ, can be found using Stefan-Boltzmann law:

$$E\gamma = \sigma Ts^4$$

Where σ is a Stefan Boltzmann constant (W/m^2-K4) and Ts is the surface absolutetemperature (K).

III. OVERVIEW OF A TRUCK COOLING SYSTEM

An internal combustion engine produces lots of energy and a huge part of it goes away with exhaust gases and in terms of heat being released. The main purpose of the cooling system is to handle the heat rejected by the engine and to keep the engine at its most efficient temperature. Here on the left side one can see a cooling package consisting of air conditioner condenser, charge air cooler, radiator and fan. There are two circuits shown: charge dare circuit and coolant one. In case of EGR engine used an EGR cooler could be added for cooling down temperatures of EGR gases.

a) SPECIFICATION OF RADIATOR:

COPPER ALLOY:

Sr.no	DESCRIPTION	VALUE	UNITS
1.	Elastic Modulus	1.10E+11	N/M^2
2.	Poisson ratio	0.37	-
3.	Shear Modulus	4E+10	N/M^2
4.	Mass Density	8900	Kg/M^3
5.	Tensile Strength	394380000	N/M^2
6.	Yield Strength	258646000	N/M^2
7.	Thermal Expansion Coefficient	2.4E-0.05	/kelvin
8.	Thermal Conductivity	390	W/(m.k)
9.	Specific Heat	390	J/(kg.k)
10.	No. of rows oftubes	5	-

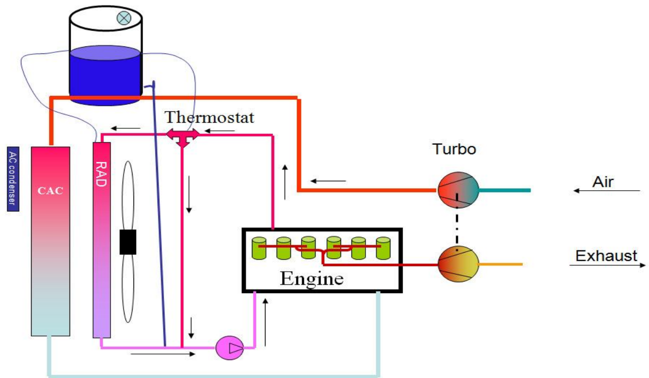


Fig.1 Simplified cooling system (Ref.no.4)

b) NEED FOR AUTOMATIVE COOLING SYSTEM:

Modern automotive internal combustion engines generate a huge amount of heat. This heat is created when the gasoline and air mixture is ignited in the combustion chamber. This explosion causes the piston to be forced down inside the engine, levering the connecting rods, and turning the crankshaft, creating power. Metal temperatures around the combustion chamber can exceed 1000° . In order to prevent the overheating of the engine oil, cylinder walls, pistons, valves, and other components by these extreme temperatures, it is necessary to effectively dispose of the heat. Approximately 1/3 of the heat in combustion is converted into power to drive the vehicle and its accessories. Another 1/3 of the heat is carried off into the atmosphere through the exhaust system. The remaining 1/3 must be removed from the engine by the cooling system.

IV.COMPONENETS OF AUTOMATIVE COOLING SYSTEM

1. COOLANT MIXTURE: To cool down the engine and other hot components the coolant is circulated around the coolant system by the pump. The engine is cooled by coolant passing in channels inside the engine block and head. Coolant mixture also absorbs the heat at the EGR-cooler and other

components that require cooling and then it releases the heat at the radiator part. The coolant usually consists of the water mixed with ethylene glycol with some additions.This is done to reduce freezing point temperature and improve corrosion resistance. It also raises the boiling point temperature that is important for the hot day conditions when the higher temperature difference between air and coolant is desirable as it imp
roves the heat transfer performance of the radiator.

2. PUMPS: The pump is used to force the coolant to circulate through all parts of the cooling system as all of them, even pipes, have pressure losses that need to be overcome. Themost commonly used pumps have mechanical connection to the engine shaft with a fixed pump speed / engine speed ratio.

Fig 2. Volvo FH centrifugal coolant pump (Ref no.4)

3. THERMOSTAT: The thermostat is a thermally controlled valve that regulates the amount of coolant that goes through the radiator. The valve is activated by temperature sensitive wax and usually starts to open at temperatures around 82 ^{O}C.

Fig.3 Thermostat (Ref no.4)

At high temperatures thermostat opens and directs coolant through the radiator decreasing its temperature and consequently keeping engine at optimal operating temperatures.

4. RADIATOR: Radiator is one of the main components of the cooling system. It acts as a heat exchanger in between the hot coolant side and the cold ambient air side. It has two tanks and a number of small tubes that connect those tanks to each other.

Fig.4 Automobile coolant radiator (Ref no.4)

5. FAN: The radiator performance is highly affected by the amount of air passing through it. A fan is used for sucking the air in and therefore for increasing this amount. A shroud is added to guide the air and to force it to go through the cooling package.As a cooling pump the fan is usually mechanically connected to the engine shaft and its speed is directly dependant on the engine RPM, on the other hand it usually has a viscous clutch that allows decreasing the rotational speed when extra air flow is not needed.

V. GT-SUITE

GT-Suite is a software tool produced and distributed by Gamma Technologies (GT) that allows modeling and simulation of different systems in automotive and transportation engineering.GT-Suite can be used for modeling each system independently or for coupling several systems together to make them interact with each other, so more complex systems can be analyzed. The GT-SUITE software contains three software in all:

GT-COOL, COOL-3D, GT-POST.

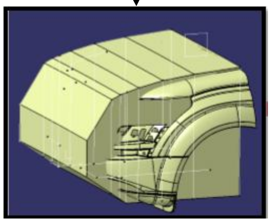
COOL-3D: There is a special subprogram included in GT-Suite called Cool-3D. This is apreprocessing tool that allows building 3D underhood thermal management models of vehicles, constructing it component by component and therefore allowing includingmuch more details than a usual 1D simulation model made in GT-ISE may have.

VI. FLOW OF MODELLING IN GT-COOL

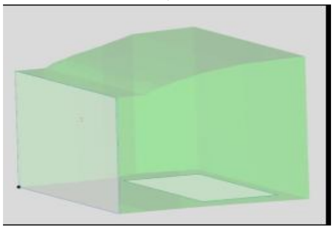
All the standard parameters (specifications) of the radiator and cooling system need to be inputted to the software. After inputting the parameters actually modeling starts in COOL-3D. The flow of creation is creating the domain and the components. Domain is the entire region of the under hood cooling system, or the total space in which the air is present from inlet to outlet.

After this the components radiator, fan, grill, engine block was created.

Vehicle level engine component



Extraction of under hood extraction



Cool 3D approximate model

Fig.5 Actual 3D Model Created

Assumptions made for analysis-

- All the grills are assumed in same plane.
- Grille mesh not considered.
- Components above engine are not considered.
- Engine block and transmission simplified & approximated.

Now the components were linked in the sequential manner as shown in fig.no.6. After linking the model, the model gets discretized in COOL-3D.

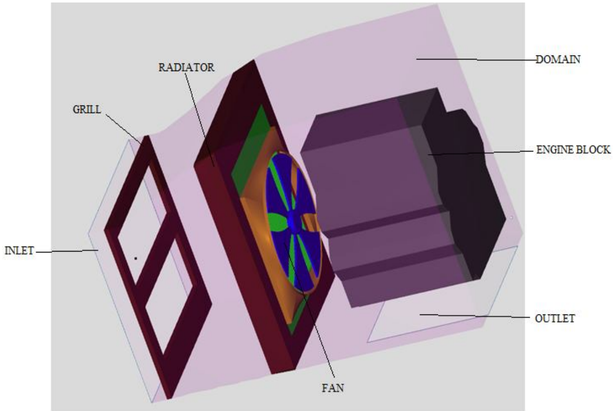


Fig.6 Cool 3D Model

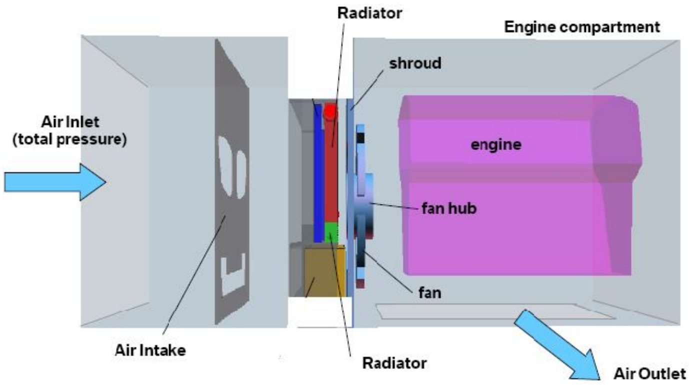


Fig.7. Simplified Under hood simulation in COOL-3D

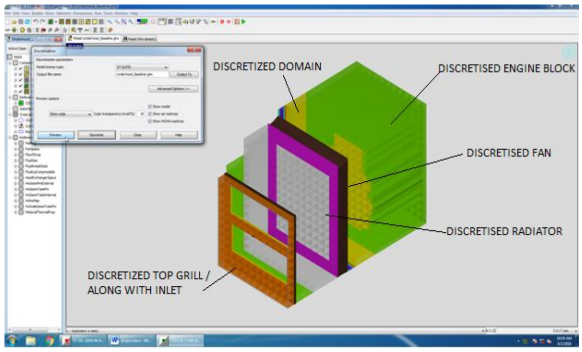


Fig.8Discretized Cool 3D Model

Discretization of every component is done automatically depending on the length of discretization that we specify as shown in above fig no.7.

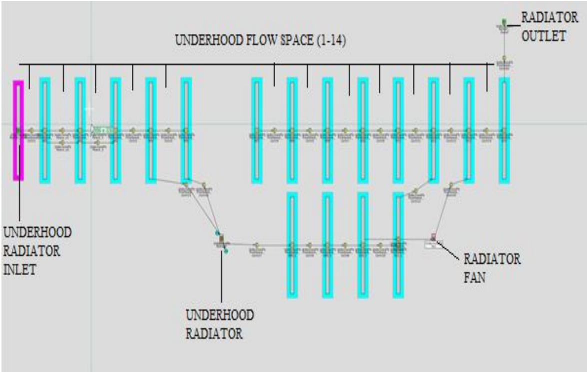


Fig.9 Subassembly after discretization

VII. CONCLUSION

As a result of the project a simulation model was created. For this model the main three parameters were considered as these parameters have a critical impact on the performance of the radiator. These parameters are COOLANT FLOW RATE, FAN SPEED and AMBIENT TEMPERATURE. The impact of these parameters was seen by simulation results:

1. COOLANT FLOW RATE increases the heat dissipation also increases simultaneously the outlet temperature of the coolant decreases.
2. As the FAN SPEED increases the heat dissipation also increases.
3. As the AMBIENT TEMPERATURE increases the heat dissipated decreases and outlet temperature increases.

As the software used is highly accurate and fully predictive the results can be used for the actual modeling of the radiator. But we should be precise in giving input to the software.

VIII. ACKNOWLEDGMENT

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