

Influence of Advanced Technology for Thermal Management on SUV

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ABSTRACT

Reducing fuel consumption is a major challenge for vehicle, especially for SUV. Cooling loss is about 30% in total energy loss under NEDC (New European Driving Cycle) cycle. It is necessary to optimize vehicle thermal management system to improve fuel economy. Otherwise, rapid warm-up is beneficial for friction reduction and passenger comfort in cold-start. Vehicle thermal behavior is influenced by cooling system layout, new technology and control strategy.

Thermal management simulation is effective to show the energy flow and fuel consumption under the influence of new technology under NEDC cycle. So 1D thermal management simulation model is created, including vehicle, cooling system, lubrication system and detailed engine model with all friction components. And the interrelations between all the components are considered in the model. For model calibration, large amount of data is obtained from vehicle tests such as transient fuel consumption and transient coolant temperature. Base on the accurate model, electric water pump, split cooling, controlled oil pump and other technology are applied to show the influence of fuel consumption and warm-up behavior during drive cycles of NEDC under 20°C and -20°C ambient temperature. And all the modifications are verified for reliability under the worst cycle. And the most effective technology will be applied for new generation engine of GWM (Great Wall Motor company Limited).

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INTRODUCTION

Reducing fuel consumption is a major challenge for vehicle, especially for SUV. The highest thermal efficiency of gasoline is about 40% on engine test bed, while on vehicle the thermal efficiency is about 20% under NEDC cycle. Most of energy is used to heat cylinder block, cylinder head and coolant. It is useful for reducing fuel consumption to study the vehicle thermal behavior. Otherwise, the friction is influenced by the oil temperature and water temperature. Rapid warm-up is beneficial for low friction, low fuel consumption, and passenger comfort in cold condition. The reliability under worst cycle should be verified. Simulation is an efficient method to study the vehicle behavior under drive cycle as the test cost is high. Several advanced technology are used in the model to show the influence of fuel consumption. From the results, the choice of the technology would be adopted for next generation engine.

Recent studies focus on the simulation model including the detailed methods and parameter. Several studies considered the under hood underbody analysis for heat protection. This paper focus on the

influence of technology in engine for SUV, as SUV becomes more and more popular in China. And the interrelations between all the components are studied.

In the paper, 1D thermal management simulation model is created, including vehicle, cooling system, lubrication system and detailed engine model with all friction components. For model calibration, large amount of data is obtained from vehicle tests such as transient fuel consumption and transient coolant temperature. Base on the accurate model, electric water pump, split cooling, controlled oil pump and other technology are applied to show the influence of fuel consumption and warm-up behavior during drive cycles of NEDC under 20°C and -20°C ambient temperature. And all the modifications are verified for reliability under the worst cycle.

MODEL SETUP

Table 1 lists the vehicle specifications for the study.

Figure 1 shows the energy flow of powertrain model. The model consists of the following components: three fluid circuits (engine coolant, engine oil and transmission oil), two metal masses (engine



and transmission), and two heat exchangers (radiator and transmission oil cooler)[1]. Especially, engine structure was setup in detail including meshed 3D components of linear, flame deck and exhaust ports. For setting up the model, the components should be considered.

Table 1. Specifications of vehicle and powertrain

Vehicle	Type	SUV
	Weight	2200kg
Engine	Displacement	2.0L
	Fuel type	Gasoline
	Power	155kw
	Oil type	5w40
Transmission	Number of Gears	6AT

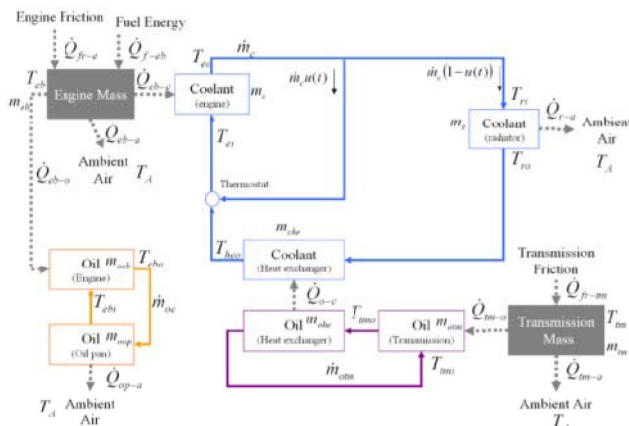


Figure 1. Schematic diagram of powertrain model[1]

Figure 2 shows the thermal management model of the SUV supported by FEV. The model was built by GT-SUITE. There is no technology for thermal management. Wax thermostat, fixed oil pump, mechanical water pump and non-split cooling were applied in the vehicle. There were two important roles in the model. The heat transfer from solid to fluid system and solid to solid is considered. All the temperature including components and fluid temperature are the most important results, so the detailed heat transfer should be defined exactly to show the interaction. The exhaust ports, linear and combustion chamber were meshed to get the exact heat transfer and temperature distribution from gas to cylinder block and cylinder head. The complex cooling jacket of engine was discretized to small pipes to consider difference flow rate and heat transfer in different position. To ensure 1d cooling system exactly, cooling jacket 3d cfd analysis were made. The results including cooling jacket volume, flow rate and system pressure were confirmed the same as 3d cfd analysis results. Moreover, the main factor for fuel consumption is friction including piston, valve train, crank shaft and mass balancing system. The friction maps were set up based on oil temperature and liner temperature. So the friction improvement would be evaluated due to the rapid oil temperature change. For the transmission, shift strategy was implemented, and efficiencies were also considered for different temperatures.

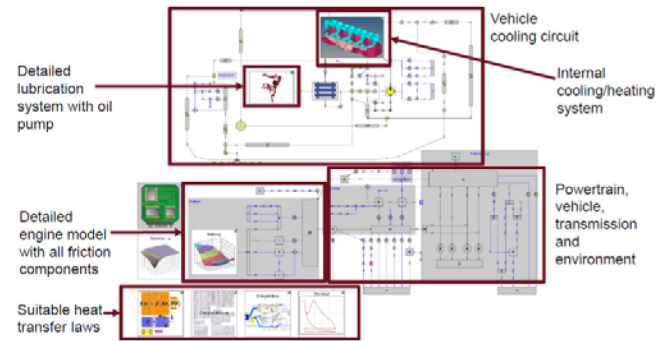


Figure 2. Model of the VTMS simulation for SUV supported by FEV

MODEL CALIBRATION

To calibrate the simulation model, two tests were done under NEDC while the environment temperature were 8°C and 25°C. The vehicle was tested in wind tunnel to get the exact measured data under 8°C and 25°C shown in Figure 3. The transient measurement data were used for model calibration.



Figure 3. Test vehicle in wind tunnel

Figure 4 shows the comparison of engine speed in test and simulation while the environment temperature was 25°C. In whole period of the cycle, the simulation curve met the test curve except the beginning. The surge came out unreasonably due to the measurement error. Because when the vehicle starts under NEDC, the engine speed would be a little higher than idle speed for rapid warm-up, not a surge.

The measured and simulated water temperature are shown in Figure 5. Simulation and measurement results show good compliance under 8°C and 25°C.

Figure 6 shows the comparison of transit fuel consumption. The fuel consumption in test was obtained from amount of CO₂ in emission.

As mentioned, the friction is one of the most factors for fuel consumption. The friction should be influenced by different temperature. The friction in different components and under different

temperatures should be used to calibrate friction map. The components include crank shaft, piston, valve train and balance system.

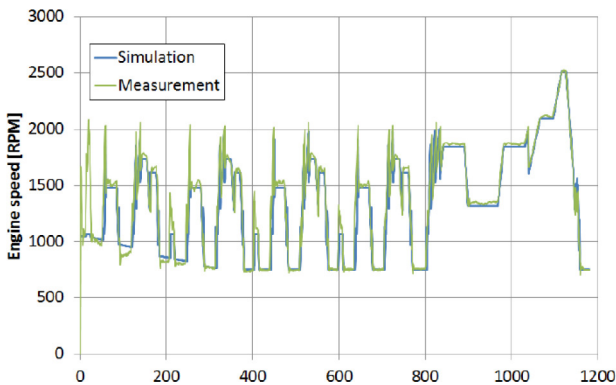


Figure 4. Comparison of measured and simulated engine speed under 25°C

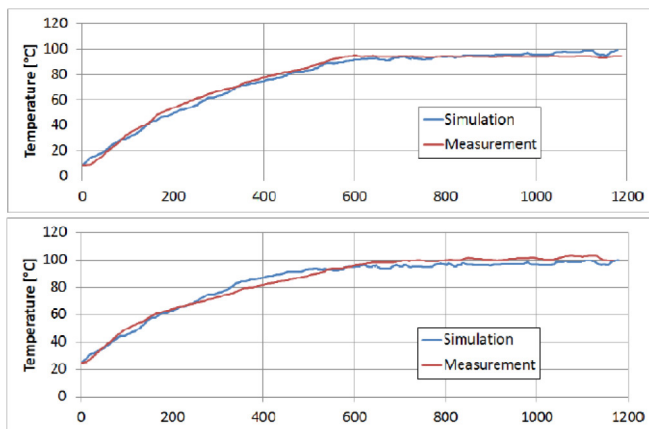


Figure 5. Comparison of measured and simulated water temperature under 8°C and 25°C

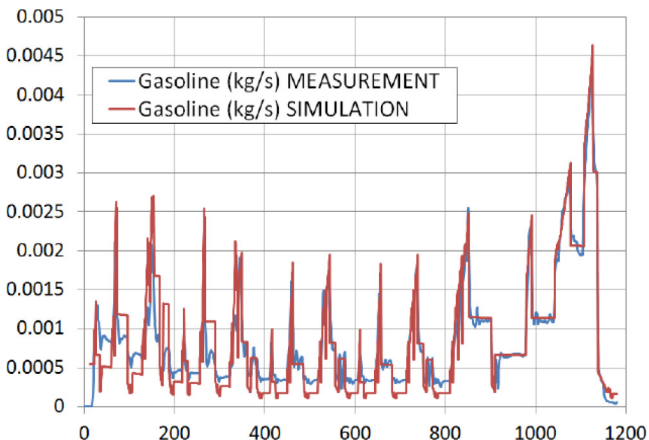


Figure 6. Comparison of measured and simulated fuel consumption under 25°C

SIMULATION RESULTS

Based on the calibrated model, several technologies were applied in the model to show the influence for fuel consumption and water temperature change. The technologies included map controlled thermostat, electric water pump, variable oil pump, split cooling and split cooling with electric water pump. The results were shown as below.

Map controlled thermostat

Compared to wax thermostat, map controlled thermostat had a higher opening temperature as shown in Figure 7, due to the additional heater can heat the wax body to enable a lower opening temperature.

Control strategy was more complex using map controlled thermostat. The control strategy need the inputs as shown in Figure 8. Based on the input, ECU decided to heat or not to heat the wax body to control thermostat. In general, the open temperature of map controlled thermostat could be set higher than wax thermostat, which could lower the engine friction.

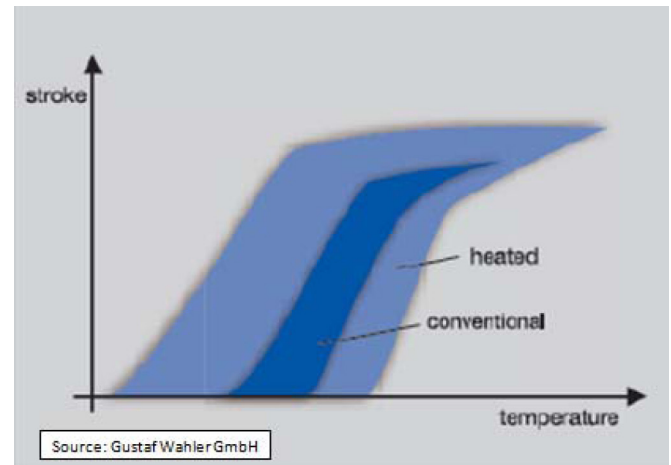


Figure 7. Comparison of wax thermostat and map controlled thermostat

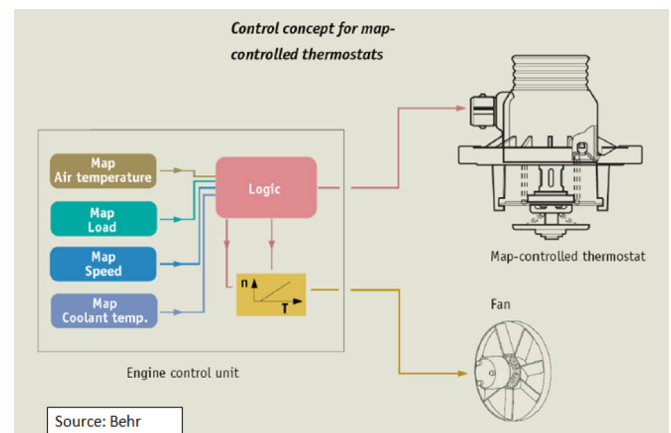


Figure 8. Control concept for map controlled thermostat

Figure 9 shows the curves of water temperature and valve lifts of wax thermostat and map controlled thermostat. Applying the map controlled thermostat, the opening temperature was set from 85°C to 95°C. After the warm up, higher water temperature was attained due to the higher opening temperature of map controlled thermostat, while the valve lift of map controlled thermostat was lower compared to the wax thermostat. The results were shown in Figure 10. Map controlled thermostat took effect after the engine warm up. Due to the higher water temperature, the friction reduced obviously. But the benefit of map controlled thermostat during the NEDC was not very high. For fuel consumption, the benefit of map controlled thermostat was just 0.312% under NEDC warm and 0.25% under NEDC cold compared to wax thermostat.