Environmental impact of planned introduction of electrically driven water pump in passenger car engines

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Abstract - **In spite some fuel and ignition systems are very complicated recently, cooling systems remain traditional. Water pump rotational speed is linear function of crankshaft speed not depending on engine temperature or vehicle speed. The possibilities of introduction electronic control for cooling systems has been presented in the paper. In first part of the paper used methods of electronic control of cooling systems has been described.**

Then the structure of new generation cooling system was proposed. Additional power has influence for toxic components emissions in exhaust gases. To learn how big influence has this load some tests on chassis dynamometer have been performed. The results of investigations has been described.

1. Introduction

Due to the trend towards an increase in traffic, especially in the growing European market and as a result of the increase of private and public traffic in urban centres, vehicles are increasingly becoming trendsetters with regard to environmental pollution. Overall emission regulations such as EURO IV claim to take all kinds of energy-saving potentials into account in order to minimize the increase in fuel consumption associated with these emission regulations.

With regard to engine optimisation, it is necessary to minimize the power consumption of the auxiliary units. Some units serve the engine and are necessary for propulsion system to work, some are switched on by a driver and are for special purposes of a car for comfort or safety.

In table 1 some powers of additional energy consumers of a typical passenger car are listed.

Table 1: Power consumed by additional units from engine shaft of a passenger car

Consumer	Power [W]
In cabin light	30
Power window	132
Short beams	177
Long beams	269
Rear window heating	252
Air condition	1740
Electrically driven water pump	max 100

Comparing very complex control systems of injection and ignition of some nowadays combustion engine to cooling system control one must notice its extreme simplicity. In low load condition by cool start the pump quantity is high. On the other pole while driving uphill is low because of low crankshaft speed. The only intelligent element is in the circuit thermostatic valve.

The cooling system has a great influence on the design of an engine; it is indispensable because metallurgical constraints imply that the engine is limited to maximum operating temperature level. However from a thermodynamic point of view, cooling the engine tends to reduce the ratio of power over fuel consumption, which is not desirable. For this reason, the aim of the engine cooling system is to provide during cold start or low ambient temperature conditions, an increase in temperature of coolant, the oil and the engine metal masses. Under uphill and full load conditions, it must provide sufficient cooling of the oil and the engine metal masses. By improving these aspects, it is possible to achieve an optimum compromise between important engine requirements (low fuel consumption, extended engine life and reduced gas emissions) and high performance.

2. The new generation cooling systems

New generation cooling systems tends to be rather complicated, compared to this presented above. They contain:

- electric water pump in place of the belt-driven pump,
- air shutters,
- variable speed electric fun,
- electronically controlled tree way valve,
- algorithm in ECU for coolant circuit control.

The only introduced by some car manufactures element from listed above is electronically controlled tree way valve. The valve is equipped in heating element (fig. 1) which is able to cheat thermal-expanding element that water is hotter than really is.

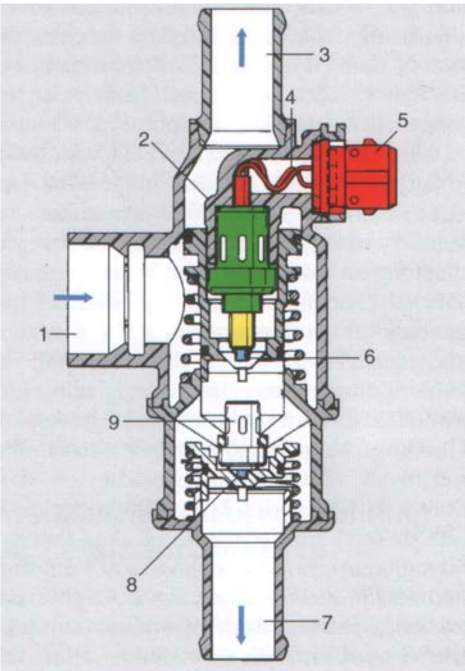

Fig. 1 Tree way valve with heater [3] 1 – inlet, 2 – case of thermal-expanding element, 3 – outlet to bypass, 4 – wiring of heater, 5 - heater socket, 6 – control piston, 7 - outlet to cooler, 8 and 9 – emergency valve

Then the flow throw the radiator is setting greater. It caused lower level of coolant temperature, which is desirable by higher load of an engine. By part load, coolant temperature is regulated at higher level for greater engine efficiency (fig.2.).

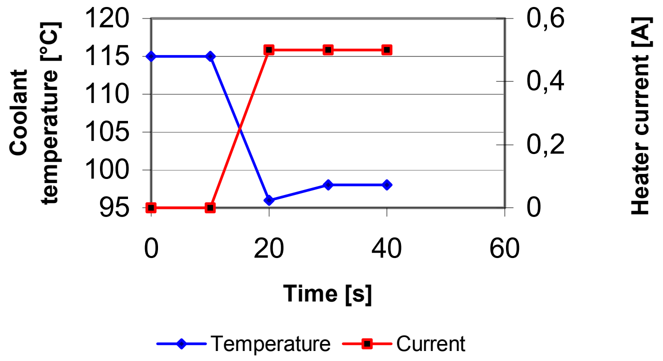

Fig. 2. Coolant temperature changes using the mechanical thermostatic valve and the electronically controlled tree way valve.

Schematic scratch of a new generation cooling system is presented on fig. 3.

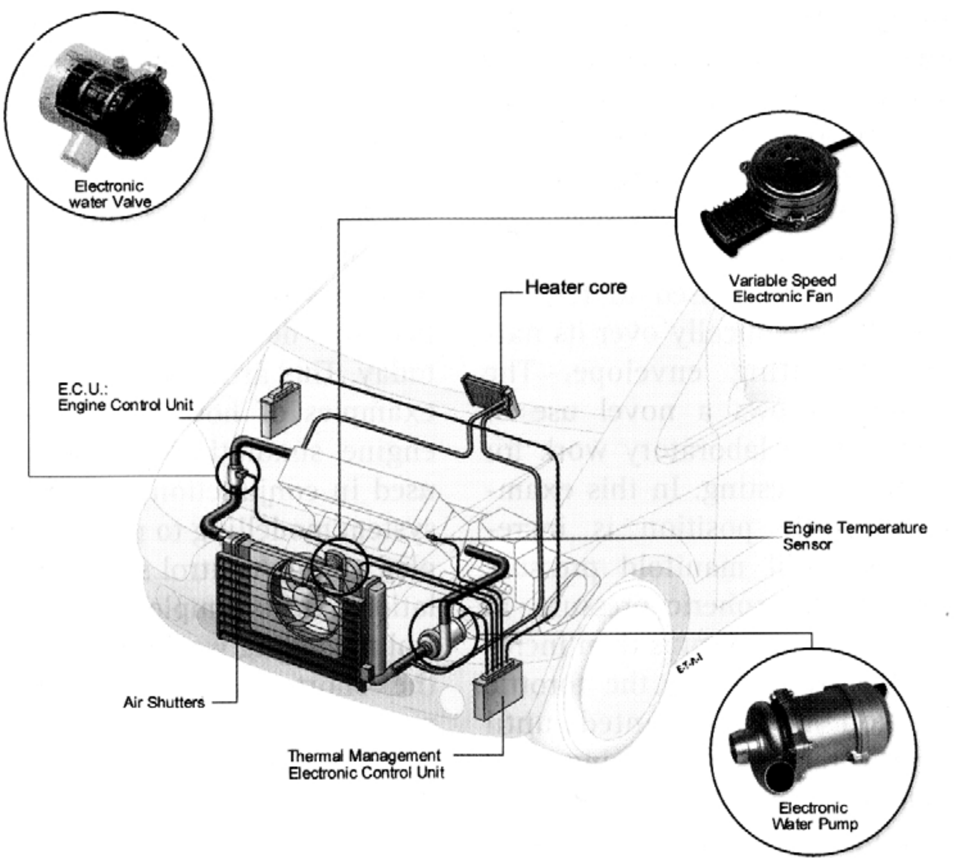

Fig. 3. The new generation cooling system by Valeo [2]

3. Benefits of using new generation cooling with electrically driven pump

The new system due to precisely active cooling enabled to reduce the coolant weight. It is usually connected with flow reduction. The main advantage, which is achieved is warm-up cutting connected with low toxic emissions and better cabin comfort. The Valeo introduced system called THEMIS [2], which was tested on various European and US cars from 1,4-litre to 3,6-litre V6 engines. Fuel consumption and emissions have been tested according to the European MVEG and the US FTP cycles in national laboratories, while system behaviour was field tested in Northern Europe at very low temperatures and in Southern Europe in the hottest temperatures. Results and conclusions were as follows:

During warm-up, a zero-flow pump strategy allows the engine to heat up with reduced thermal losses, thus halving warm-up time. Remember that some designers accept nucleate boiling recently. Typically, 200 seconds warm-up time is needed in a car equipped with THEMIS, whereas a normal car requires 400 seconds to warm up (fig. 4.).

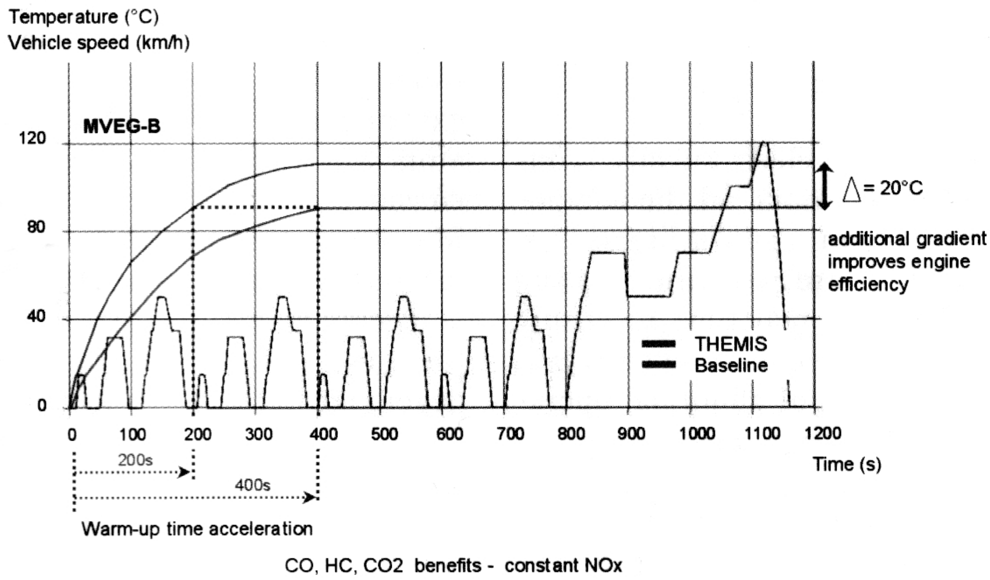

Fig. 4. Warm-up car engine difference in two cooling systems – with traditional and new generation cooling systems while performing NEDC [2].

At low and medium loads coolant temperature reaches much higher levels than those currently observed (basically 110/115 °C versus 95 °C), which enables the engine to operate at more beneficial internal temperatures, resulting in more efficient combustion. By the same token, the power consumption of the electric water pump falls below that of a belt-driven pump. The result is a 2% to 5% improvement in fuel economy with a proportionate reduction in CO_2 emissions depending on the driving conditions. This represents a tremendous improvement for a car, since no real change is being made to the hardware and it is all achieved by regulating coolant temperature. As far as emissions are concerned , the result on both NEDC and FTP cycles showed a significant mean decrease of 10% HC and 10 to 20% CO, while NOx emissions remained unchanged (fig. 5).

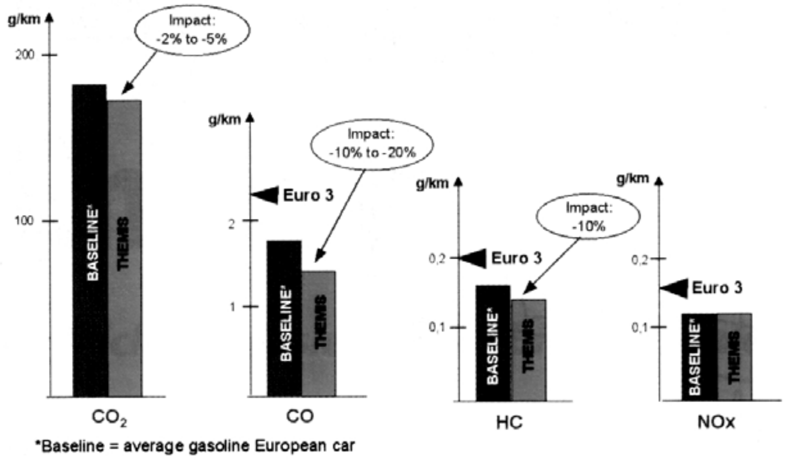

Fig. 5. Emissions comparison [2].

Use electronically controlled cooling system improves engine reliability. The thermal shocks are possible in two situations when:

- the engine is stopped after having reached very high temperatures,
- the temperature were to rise quickly for some reason.

Electrically driven water pump and fan help to avoid the thermal shocks. They can work when engine is stopped and also during hart outside conditions and rapidly increase their capacity.

The next advantages of the new generation cooling system is the improvement of cabin comfort. Some cabin heating systems remain very primitive. The only control is change of the air flow throw the cabin heater. It causes to warm air in cabin at Summer conditions. Low heater water flow is accountable for poor heater efficiency at idle or in urban traffic in Winter.

The result of the Winter test (-20◦C is presented on fig. 6.

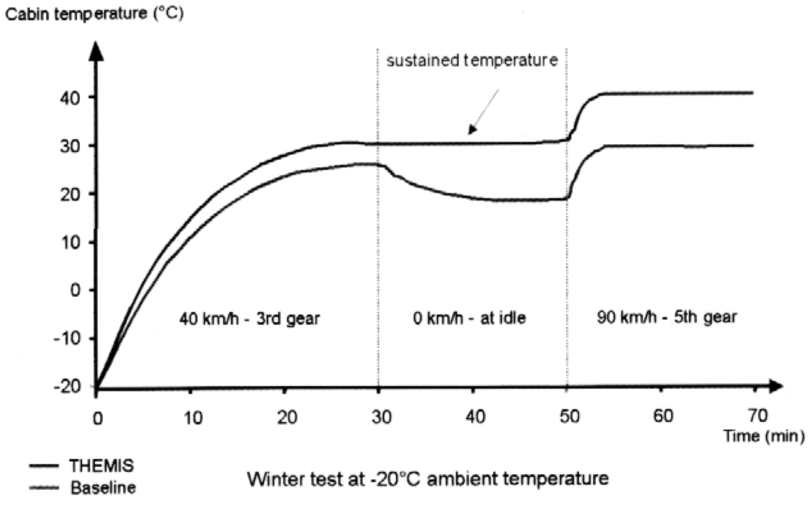

Fig. 6 Winter test of the cabin heating system [2].

Lower line on the chart is for traditional cooling system while upper for new generation. During urban traffic we can obtain average 5º more in new system to the old one.

More possibilities of boosting the water flow gives the opportunity of fail-safe mode. Some of the system elements malfunctions, the system can compensate by over-boosting another component. For instance, should the fan system fail, the water pump would be boosted and the valve opened wide to enhance heat exchange in the radiator. The only needed component is the water pump. If it would be out of operation fail-safe mode is impossible. Similar to the many other car systems also new cooling system is scanned and analysed in real time to ensure that it is operating correctly. In the event of abnormal operation, detection and countermeasures are immediate, and the driver is duly informed of a potential problem prior to failure. A specific service warning can be set in the instrument cluster to provide appropriate information to the driver. In the service workshop, the whole system can be analysed by specific routines, and information is than provided on its status.

4. Conclusions

The main goal which is a complex intelligent thermal system is on his way to series production. New generation of components, heat exchangers and electronic actuators are highly requested. New generation cooling systems can: lower emissions and fuel consumption, improved thermal cabin comfort, improved reliability of an engine. The larger number of components used in cooling systems increases the effort required to find the optimum. It is to perform this optimisation on hardware prototypes because the number of possible variants rises exponentially with the number of components. The simulation tool like AMESim [1] or KULI [4] are powerful tools for designing the cooling system including the controls. If necessary, this simulation model can be extended with existing or user defined MATLAB/SIMULINK controls for the cooling components and the engine.

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