Number 4, Volume X, December 2015

# ANALYSIS OF THE INFLUENCE OF OPERATING MEDIA TEMPERATURE ON FUEL CONSUMPTION DURING THE STAGE AFTER STARTING THE ENGINE

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*Summary: In Current increase in the automobile traffic results in the global increase in fuel consumption and thus the growing volume of pollutants produced during the combustion. Today's internal combustion engines are optimized for economical and environmental friendly operation with a steady temperature of all operating media, but the heating process still remains a critical phase. The designers of powertrains should therefore focus on the efforts to make this heating phase as short as possible. The paper deals with the analysis of the influence that the operating media temperature has on the consumption in the heating phase.*

*Key words: mechanical losses, fuel consumption, operating media, influence of temperature.*

## INTRODUCTION

The increase in the ecological burden and environmental pollution are the essential issues in the current trend of increasing automobile traffic. For these reasons, the development of the internal combustion engine concentrates today on the reduction of harmful substances in exhaust gases. One of the ways to reduce the production of harmful substances in exhaust gases is to reduce fuel consumption by means of increasing energy efficiency and reducing mechanical loss of engines. Mechanical loss and the energy efficiency in the internal combustion engine are greatly affected by the influence of temperature of the engine operating media.

Mechanical loss or power dissipation in the internal combustion engine take about 5-8% of the power from the indicated power at full load, and 100% at the idling speed. Depending on the load and the engine speed, the mechanical efficiency ranges from 40 to 95%.

When the mechanical loss is reduced, the energy released by the fuel is better utilized, and therefore the performance parameters increase, the specific fuel consumption is reduced, and, as a result, the environmental parameters improve too. Some studies show that by reducing of mechanical loss in a common vehicle engine by approximately 5% the fuel consumption can be reduced by 1%.

Other possibilities for further reducing of fuel consumption can be found in very specific operating modes of the engine, such as the stage after cold start. Here, the low temperature of operating media results in a significant increase in mechanical loss and a reduction in the energy efficiency of the internal combustion engine. Trying to compensate

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the given facts, there are new issues in the area of storage and effective re-use of waste heat for further preheating of operating media during engine warm-up stage.

## 1. DEFINITION OF MECHANICAL LOSSES

Mechanical losses of the internal combustion engine can be defined as the difference between the used energy produced by combustion of fuel in the combustion process building up working pressure in the cylinder and the work output on the crankshaft (2,3). Mechanical losses are dependent on loading forces, coefficient of friction, the friction surface, and on the relative speed. The friction loss is also dependant on the ratio of the maximum and the mean effective pressure. The smaller the difference, the better efficiency can be achieved.

In this paper, mechanical losses are all losses that reduce the indicated power of the engine to the effective power absorbed by the crankshaft. Mechanical efficiency is an expression of their share.

$$A_{loss} = A_{ind} - A_e \ , \tag{1}$$
$$P_{loss} = P_{ind} - P_e \ , \tag{2}$$
$$\eta_m = \frac{A_e}{A_{ind}} = \frac{P_e}{P_{ind}} \ , \tag{3}$$

where $A_{loss}$, loss of engine work [$J$], $A_{ind}$, indicated engine work [$J$], $A_e$, efficient engine operation [$J$], $P_{loss}$, engine power dissipation [$W$], $P_{ind}$, indicated engine power [$W$], $P_{ind}$, efficient engine power [$W$], $\eta_m$, mechanical efficiency of the engine[-] (1).

The overall power dissipation of the engine is therefore given by the sum of the power dissipation in each component.

$$P_{loss} = P_f + P_{vlv} + P_{aux} + P_{vent} + P_{crkp} \ , \tag{4}$$

where $P_{loss}$, engine power dissipation, $P_f$ power required to overcome the loss caused by friction of the piston, piston rings, and friction in bearings, $P_{vlv}$, power required to drive the valve train, $P_{aux}$, power required to drive all the auxiliary equipment associated with the engine operation, $P_{vent}$, power required to overcome the ventilation losses caused by oil swirling in the crankcase from the rotating engine components, $P_{crkp}$, for the two stroke engine – power required to compress the filling in the crankcase and air intake, for the four stroke engine – power consumed by work required to overcome the pressure or to exhaust gases from the crankcase (in the case of the vacuum created by the engine intake is included in the indicated work).

# 2. ANALYSIS OF THE INFLUENCE OF ENGINE OPERATING MEDIA TEMPERATURE ON CONSUMPTION REDUCTION

## 2.1 Engine oil

Influence of the oil temperature on the fuel consumption is due to an increase of mechanical losses at low temperatures for all related friction pairs. Furthermore, it is also due to an increase in power demand on driving the oil pump caused by higher oil viscosity at low temperatures (4,5). As an example for the operating temperature of an internal combustion engine, Fig.1 illustrates the distribution of power dissipation in each engine group with full throttle performance characteristics.

## 2.2 Coolant

As far as the mechanical losses are concerned, coolant temperature affects mainly the friction pairs in the piston group, namely secondarily by the running clearance between the piston and cylinder (4,5). The biggest impact on the fuel consumption, however, can be found in heat removal during the combustion phase through walls. The change in viscosity when the coolant is heated in respect to the power dissipation to drive the water pump is negligible unlike the oil pump.

## 2.3 Fuel

In fuel temperature, lower temperature has a positive effect.

## 2.4 Other

Not considered.

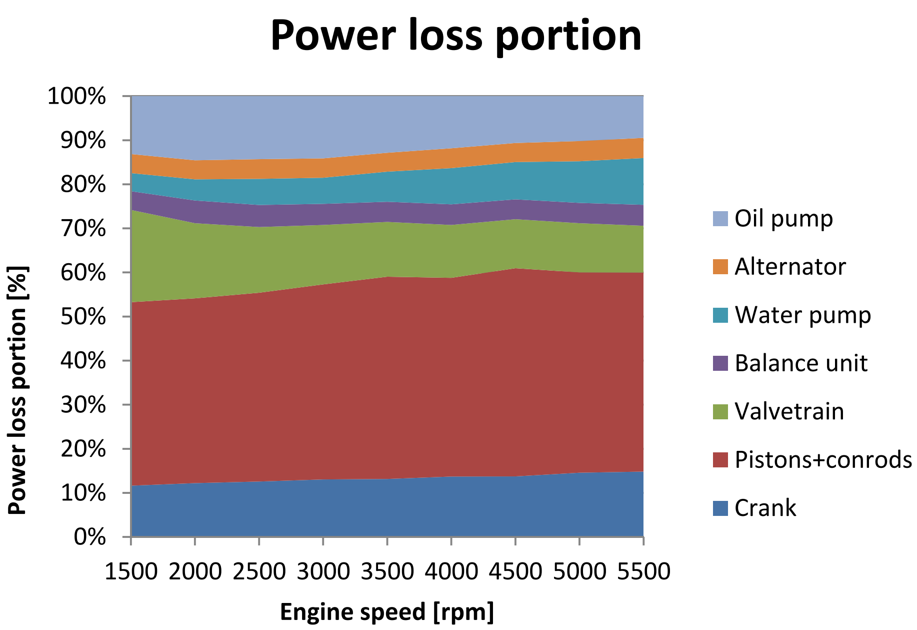


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Fig. 1 - Distribution of power loss of engine groups with full throttle performance characteristics in the engine warmed up to operating temperature.

## 3. EXPERIMENT

The main aim of the experiment carried out in the laboratories at the Institute of Automotive Engineering, Brno University of Technology, was to determine the influence of the temperature of the coolant and engine oil on the fuel consumption during the engine warm-up phase. The taken measurements were aimed to determine the potential benefit of the equipment for recovery of thermal energy to reduce the fuel consumption.

As an experimental power unit we selected a small-vehicle engine VW 1.2HTP. A test cycle, see Fig.2 was designed for primary purpose of the experiment. It reflects the required low load and idling speed. All results are shown for the given cycle. A simulation study NEDC is currently carried out at the author's workplace.

The designed test cycle includes three parts. The first one is the starting phase, the second part is the phase of stabilized idling speed immediately after the start, and the third part is the phase of steady speed with active lambda-regulation. The first two parts are not graphically represented due to the considerable instability in repeated measurements of current consumption when the engine is started.

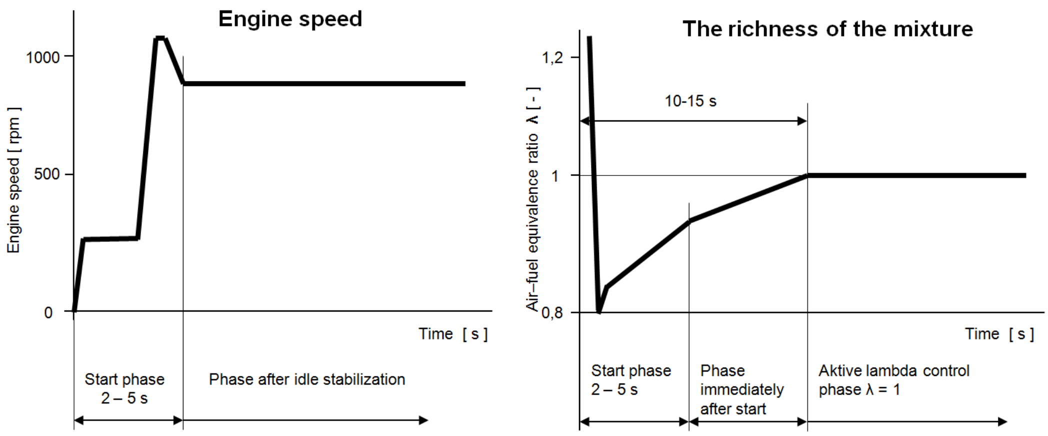


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Fig. 2 – Test cycle

Fig. 3 shows the circuit diagram of the heater system with the coolant and engine oil reservoir. Where appropriate, both media were forcibly circulated for a few seconds before the starting up (in case of oil just in the oil reservoir – oil sump).

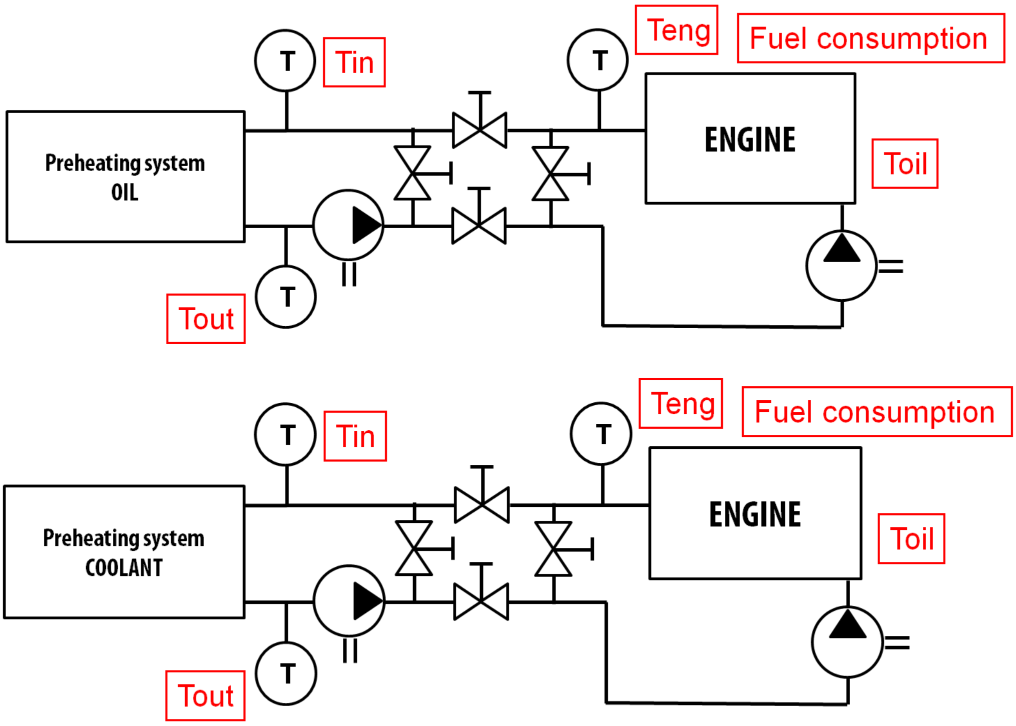


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Fig. 3 – Circuit diagram of the cooling system and engine oil

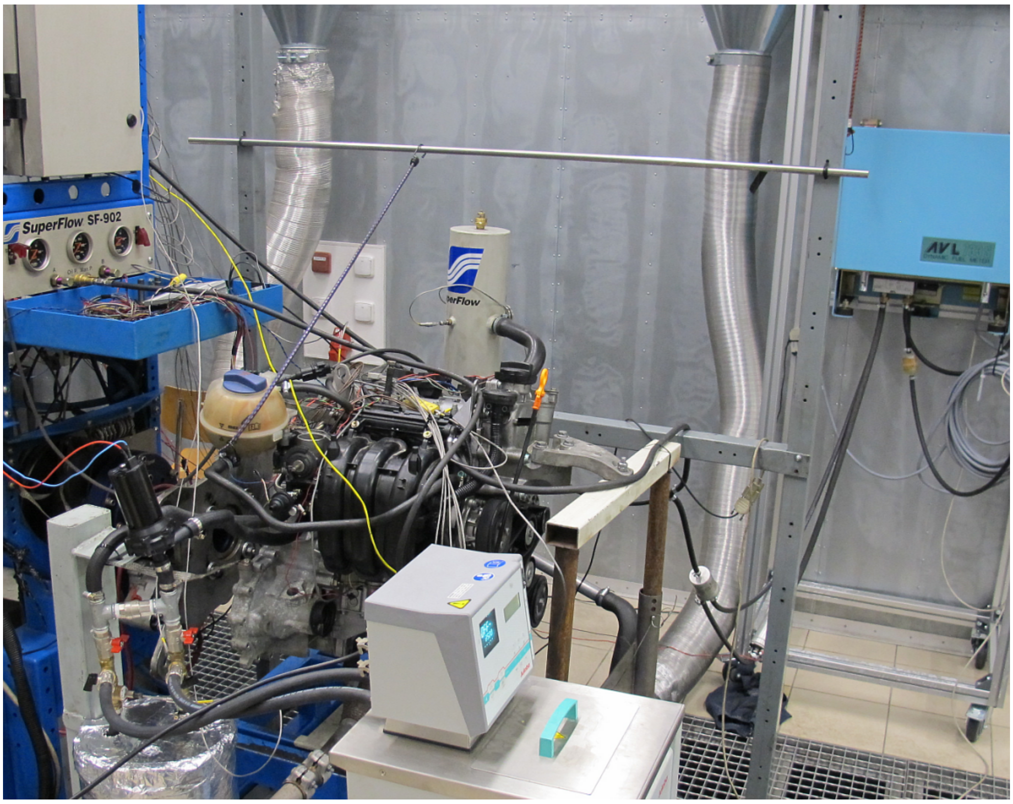


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Fig. 4 – Engine test stand with preheating circuit

## 4. RESULTS

Fig. 7 presents the timing of fuel consumption depending on the selected conditions of operating media. The initial temperatures of pre-heated media are deliberately chosen by the possibilities of current technologies available for heat energy recovery (Fig. 5, 6).

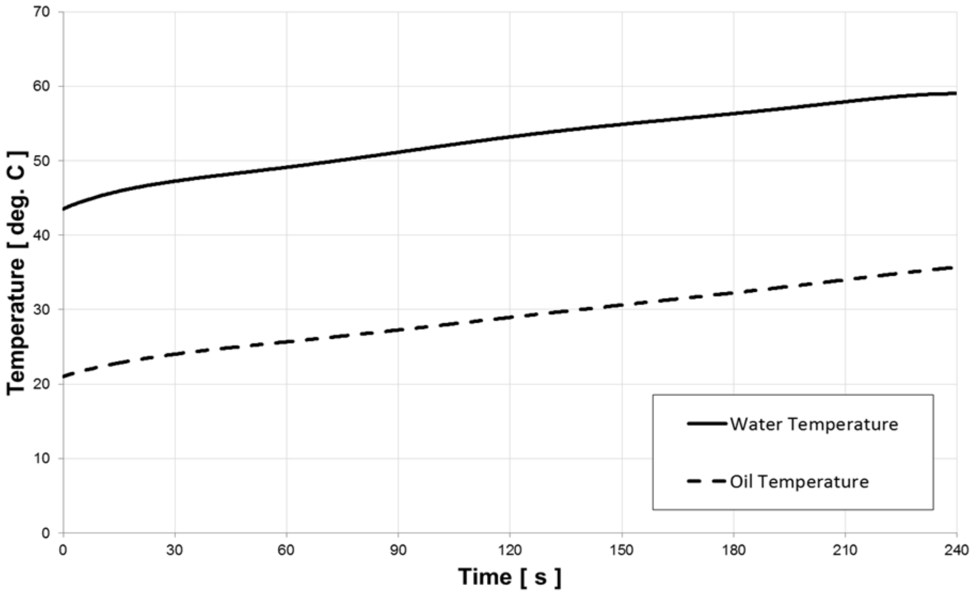


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Fig. 5 – Oil and water temperature during starting (preheating of the engine cooling water)

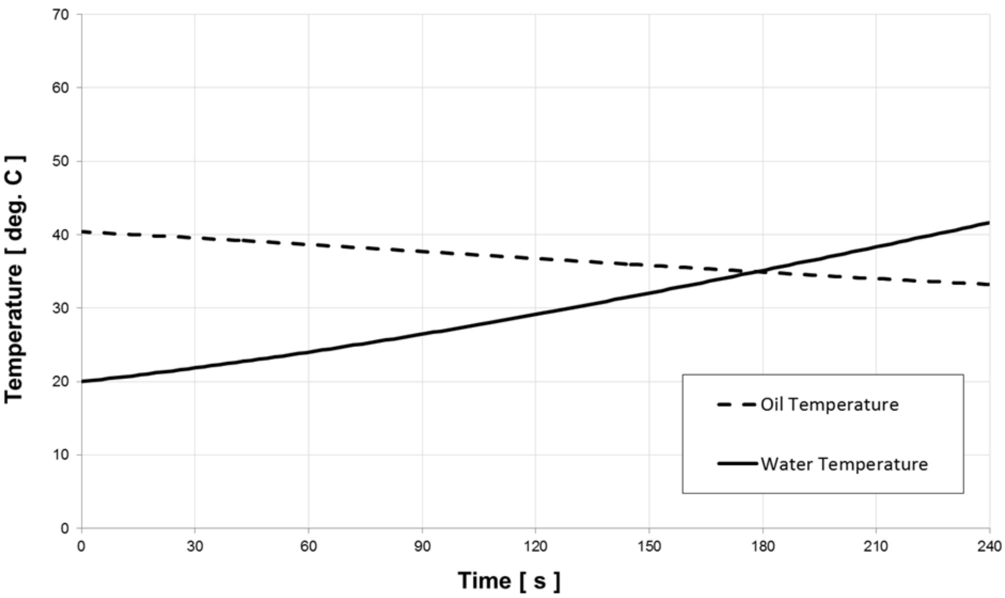


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Fig. 6 – Oil and water temperature during starting (preheating of the engine oil)

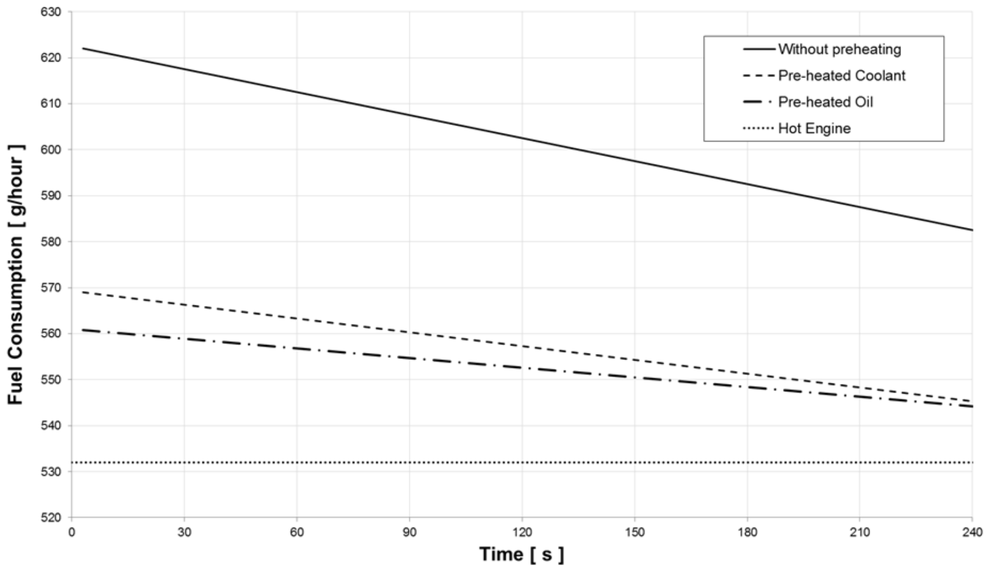


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Fig. 7 – Timing of fuel consumption
depending on the selected conditions of operating media

## CONCLUSION

Based on the graphical dependences, the raise in the temperature of engine oil before starting of the engine has the greatest potential to reduce consumption by means of preheating of the operating media.

In order to use the recovery technology in practice, time needed for heat energy transfer from the reservoir to the operating media before starting the engine will have to be taken into account. Here, the benefits of preheating of oil in contrast to the coolant can then partially erase.

## ACKNOWLEDGEMENT

This work is an output of an internal Brno University of Technology research project Reg. No. FSI-S-14-2334.

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