INFLUENCE THE HIGHER TEMPERATURE OF THE COOLING LIQUID ON OPERATIONAL PARAMETER OF THE PISTON COMBUSTION ENGINE

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Abstract

The results of selected research of the results of the combustion engine cooling system which works with higher coolant temperatures are presented in this paper. The temperature of this liquid was increased to a higher level than the temperature of boiling water in normal conditions, by decreasing of heat transfer intensity. This presented system was designed for the four cylinder 4CT90 diesel engine with indirect fuel injection. Research was done on the engine dynamometer stand which was equipped with standard measure devices (for measuring: speed, torque, temperatures, and flow) and exhaust gas analyzers. By applying a pressure cooling system it was possible to maintain a stable, increased ca. 20°C, coolant temperature for a standard engine cooling system at low overpressure 0.2 MPa. The results of increasing the cooler temperature were lower friction of unburned products during the combustion process (CO and HC) in the exhaust gas (up to 50%) at low torque and engine speed. This is the area where the catalytic reactor does not work because the exhaust gas temperature is too low. It was found that engine efficiency was increased up to 7% at maximum load and high engine speed. It is possible to achieve a temperature between 130 – 140^{o}C for an overpressure of 0.3 MPa in the cooling system. It needs a special cooler, however, and leak proof pipes.

***Keywords**: combustion engines, cooling systems, mathematical modelling, computer simulation*

1. Introduction

The effective management of energy, low levels of toxic emission and energy conversion are the most important challenges of today's civilization. The continued development of civilization, as well as the conditions of humanity, depends on energy sources and their effective exploitation. This includes energy used for the propulsion of wheeled vehicles, which are the fundamental means of transport in urban areas. These vehicles are still propelled by internal combustion engines. Combustion engines are also the most common form of engine as a prime mover. New models of the internal combustion engines are being improved to increase their efficiency as well as decrease toxic emission and noise. This is being achieved mainly by more precise control systems.

Increasing efficiency is possible by decreasing energy losses to engine cooling, convection, and exhaust gas. Energy released during the combustion process is converted to engine work and lost to exhaust gas and heat transfer by radiation (Figure 1).

Part of exhaust gas energy could be regained either by a turbocharger or by propulsion to an additional turbine joined to the engine crankshaft, which would increase total engine efficiency. Reducing the heat losses is also possible by applying a ceramic coating to the combustion chamber walls. The technology, which can be used for turbine engines, is costly. In the case of piston engines, however, which have reciprocate elements moving under inertial forces, the technology is unreliable and gives comparatively little effective elements. Moreover, the high temperature inside the inlet channels causes the reduction mixture (air in the engine cylinders) to be less useful to the engine power.

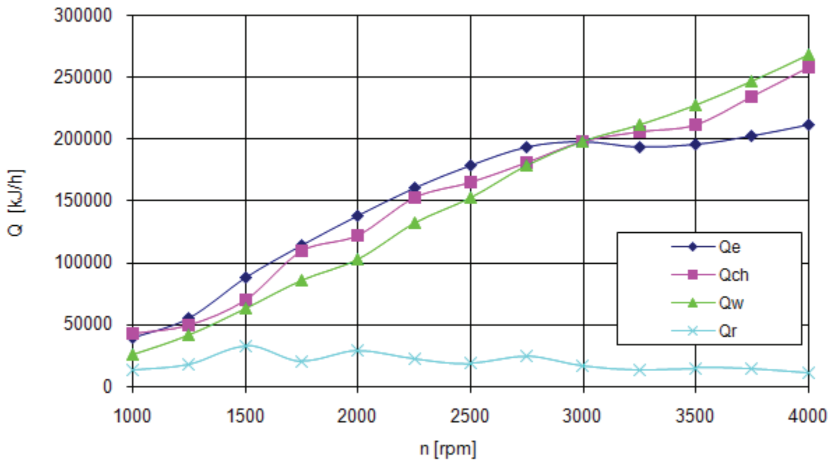

Fig. 1. Energy transformed from the working engine: Qe - effective work; Qch - losses by cooling, Qw - losses to exhaust gases, Qr – radiation

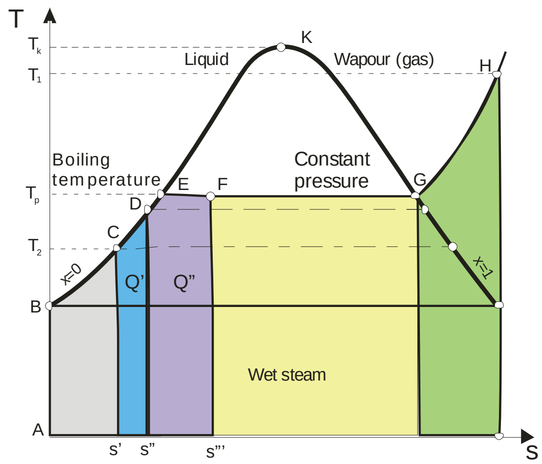

Fig. 2. Transition of the water phases

The next method in reducing heat loss could be to increase the temperature of the coolant. The implementation barrier of this method is the boiling temperature of the coolant, which contains water about 100^{o}C in normal environmental conditions (Figure 2). Steam formed while the water is boiling causes an increase in total coolant volume or pressure at a constant volume system. In this case, the cooling system should be resistant to higher pressure, e.g. by using a special open connection to the environment [4].

The results of the properties analysis of materials and lubricants show that the coolant temperature could be increased up to 140 – 160^{o}C. The result of a higher temperature will be higher engine efficiency and lower emission of unburned toxic compounds. An estimation of the possibilities and results of increasing temperature in the cooling system compared to water boiling temperatures were the main goal of this presented work.

2. Dynamometer test stands

The turbocharged four cylinder 4CT90 diesel engine with indirect fuel injection and RICARDO swirl combustion chamber was the object of the research works (Fig. 3). The main engine parameters were:

- a cubic capacity of 2,417 dm^3,
- power rating/speed 66 kW/4100 rpm,
- compression ratio ε = 21.1.

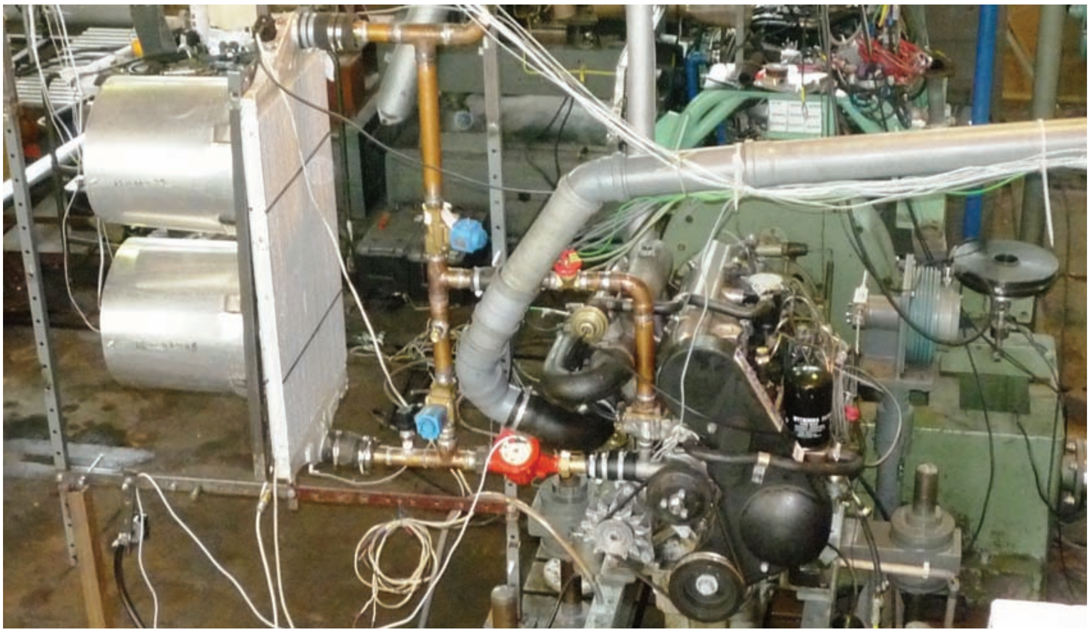

Fig. 3. Engine test stand with experimental cooling system

Engine work parameters were measured on the engine test stand as well as coolant temperature and pressure, temperature in the air inlet and outlet systems, air and fuel flown, and toxic compound volume concentration from gas exhaust versus the engine speed and load. An AVL CEB II was used to measure the exhaust gas volume components fraction (carbon monoxide, carbon dioxide, hydrocarbons and nitric oxides).

Engine work parameters needing to compare speed and engine load were measured using a pressure cooling system (standard cooling system with elevated pressure). The control of the system was performed with two stages. When the liquid overpressure in the cooling system exceeded 0.05 MPa, the main cooling circulation was switched on. When the pressure exceeded 0.07 MPa, then the fans were successively switched on. The same process was done at higher pressures between 0.25-0.35 MPa. Lower overpressure was limited by the integrity of the cooling system and mechanical strength of the standard cooler. The higher pressure range was limited by the durability of rubber connections whereas cooler was used from the intercooler system.

3. Research on the engine test stand

Keeping with the allowance for the already presented restrictions, it was possible to keep the coolant temperature higher 20°C than the temperature of the coolant for the engine with a standard cooling system in full range of the engine rotational speed. In the range of speed from n=1500 rpm up to maximum speed, the temperature of the liquid was kept in a range of 110-115°C (Figure 4a). Air temperature T_5 in the engine suction manifold increased 3 to 4°C. An increase in air consumption was visible when the engine speed exceeds 2000 rpm (Figure 4b). The air consumption was ca. 8% higher when compared to a standard cooling system at maximum engine speed. This can be explained as a result of the higher turbo compressor efficiency in these conditions.

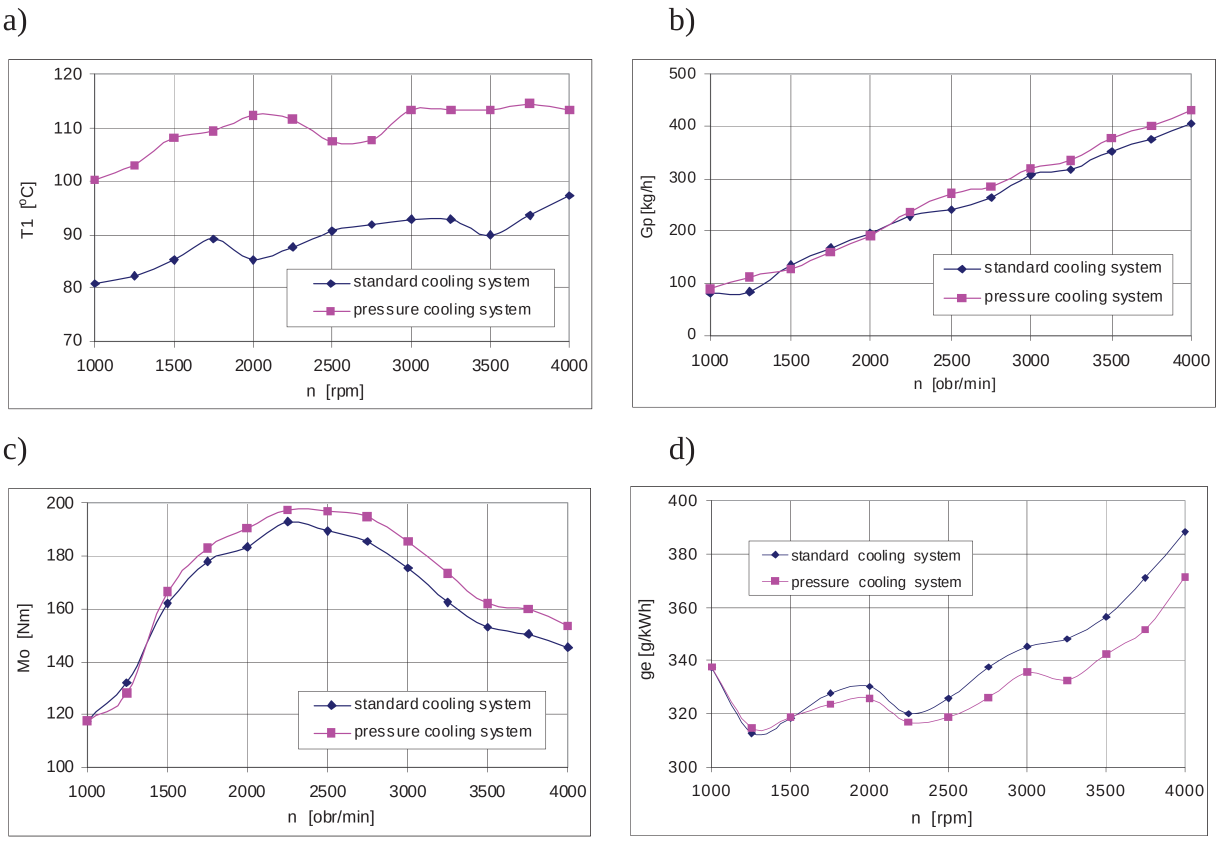

Fig. 4. Comparison between the engine parameters with standard and pressure cooling system: a – temperature of cooling liquid T_1, b – air consumption, c – torque, d –specific fuel consumption

The torque of an engine with a pressure cooling system is the most visible at speeds above 1500 rpm. The torque increased up to. 10 Nm at the speed 3000 rpm, which gives an increase 7% (Figure 4c). The engine power increased respectively to the torque changes. Because the fuel consumption had similar values for the two kinds of cooling systems (low and high pressure), increasing engine power caused relevant decreasing of the specific fuel consumption in higher temperatures of the coolant (Figure 4d).

The load characteristics were determined through a full range of engine speeds. In this paper, however, only chosen characteristics have been be presented at the engine speed 1000 rpm because it is the speed the engine is at during the beginning of driving. Minimum to maximum engine loads were measured with equal torque step 30 Nm.

The results of measurements resulted in the discovery that the temperature of the coolant was increased from 6^{o}C at a very small load, and up to 15^{o}C at a full load. Maximum coolant temperature at 1000rpm measured in the thermostat chamber averaged from 78^{o}C to 97^{o}C (standard thermostat was dismounted). This temperature was lower than the water boiling temperature but increased pressure inside the cooling system showing that inside the cooling systems are volumes where the coolant temperature is higher than boiling temperature. This phenomena was confirmed during while testing other engines through the usage of the thermovision camera, which showed that the highest temperature of the engine wall was noticed in the lowest part of the cooling jacket [1, 2].

The effects of the increase in coolant temperature and thus the temperature of the engine combustion chamber were reductions of the carbon monoxide concentration (20…30%) and hydrocarbons concentration (40…50%). The greatest reductions were affirmed at low engine load (Figure 5a and 5b). After an increase of the load above 50% of the maximum engine torque,

differences in the concentration of these component in exhaust gases between the two cooling systems are reduced. This was the result of an increase exhaust gases temperatures up to 250…300°C (Figure 5d). This initiated the effective work of the catalytic reactor. During the higher engine speeds, similar changes in concentration of unburned exhaust gas components were observed, but differences decreased.

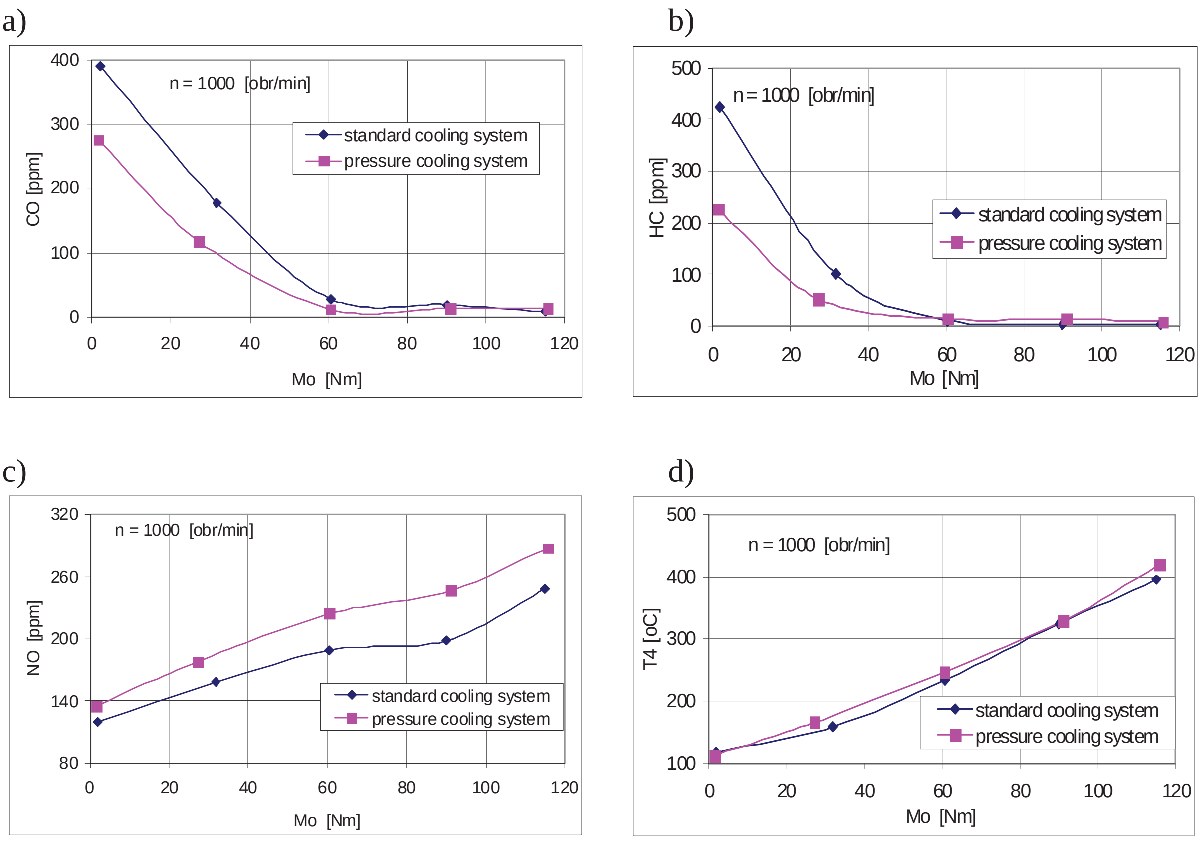

Fig. 5. Comparison between volume concentrations of the exhaust gas components at speed 1000 rpm: a – carbon monoxide, b – hydrocarbons, c –nitric oxides, d – temperature of the exhaust gas

The effects of the increase in coolant temperature and thus the temperature of the engine combustion chamber were reductions of the carbon monoxide concentration (20…30%) and hydrocarbons concentration (40…50%). The greatest reductions were affirmed at low engine load (Figure 5a and 5b). After an increase of the load above 50% of the maximum engine torque, differences in the concentration of these component in exhaust gases between the two cooling systems are reduced. This was the result of an increase exhaust gases temperatures up to 250…300°C (Figure 5d). This initiated the effective work of the catalytic reactor. During the higher engine speeds, similar changes in concentration of unburned exhaust gas components were observed, but differences decreased.

The disadvantage in the method of increasing coolant temperature is higher nitric oxides emission, which is the result of higher starting temperature in the combustion chamber (Figure 10c). The emission of nitric oxides can be reduced by increasing exhaust gas recirculation in the low and medium range of the load. Deceasing nitric oxides emission at maximum load, however, requires a more efficient reducing reactor.

6. Conclusions

1. By applying a pressure cooling system it was possible to maintain a stable, increased ca. 20°C, coolant temperature for a standard engine cooling system at low overpressure. Higher

temperature could be achieved with higher pressure in the cooling system. It is possible to achieve a temperature between 130 – 140°C for an overpressure of 0.3 MPa in the cooling system. It needs a special cooler, however, and leak proof pipes.

2. The increase of the coolant temperature in the 4CT90 engine of up to 110°C resulted in a decrease of the product portions of incomplete combustion in the exhaust gases (CO and CH) 20…50% at low speed and low load of the engine as well as in an increase of engine work efficiency up to 7% at high load and high speed which was achieved by increasing the portion of the Nitric Oxides by a few percent.

3. The practical application of the pressure cooling system in engines requires new technologies and structural solutions of electronic control in the cooling system units. Within this, an independently driven and controlled pump of the cooling liquid, as well as flexible materials connecting the system units resistant to increased temperature and pressure is also required.

7. References

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