INFLUENCE OF THE COOLANT TEMPERATURE ON EMISSION OF TOXIC COMPOUND AND ENGINE WORK PARAMETERS

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Abstract

The selected results of investigations of the cooling system for the combustion engine working with higher temperature of the cooling liquid were presented. The temperature of this liquid were increased to the temperature of boiling water, as a basic compound of the cooling liquid. This system was designed for the four cylinder diesel engine 4CT90 with indirect fuel injection system.

Investigation was realized on the dynamometer stand equipped with standard measure devices (measures: speed, torque, temperatures, flows) and exhaust gas analyzers. The speed and torque engine characteristics were determined. The overpressure inside cooling system was limited up to 0.07 MPa regarding lower pressure structural integrity of the standard units of this system. Intensity of the cooling, protective against too higher pressure, were changed by switching small and full liquid circulation, and one or two fans of the cooler. Temperature inside cooling system was increased up to 110^{o}C.

Results of increasing of the cooler temperature were lower frictions of unburned products of combustion process (CO and HC) in the exhaust gas (up to 50%) in low torque and low engine speed. This is area when catalytic reactor does not work because too low is exhaust gas temperature. It was found that engine economy was increased to 7% in maximum load and high engine speed.

Keywords: *combustion engines, cooling systems, higher coolant temperature*

1. Introduction

Effective management of energy and protection against toxic emission connected with energy conversion are the most important challenges of today's civilization. Evolution of civilization as well as conditions of the people's life depends on sources of energy and effective exploitation. It concerns energy used for propulsion wheeled vehicles which are fundamental means of transport in urban areas. These vehicles are propelled by combustion motor vehicles still. Combustion engines must be far the most common form of engine or prime mover. New models of the piston combustion engines are still improved, first of all for increasing their efficiency and decreasing toxic compound and noise emission. This is achieved mainly by more perfected control systems [12, 13].

Increasing of the efficiency is possible by decreasing energy loses on engine cooling, as well as lower loses by convection and exhaust gas [3, 7]. Energy released during combustion process is converting on engine work and lost with exhaust gas and heat transfer average the same fraction. Fourth, lower steam of energy emitted by radiation. Example for small diesel engine is presented on the Figure 1.

Part of exhaust gas energy could be regained for turbocompressor propulsion or for propulsion additional turbine which are joined to engine crankshaft for increasing total engine efficiency. Reducing of the heat loses is possible by applying the ceramic coating of the combustion chamber walls, called "adiabatization" [5]. Ceramic coating is expensive technology and it is useable for turbine engines but in the case of piston engines, which have reciprocate elements under heavy inertial forces it is unreliable and comparatively little effective. Moreover the large increasing of temperature in the inlet channel causes reduction of the mixture or air in the engine cylinders and lower useful engine power.

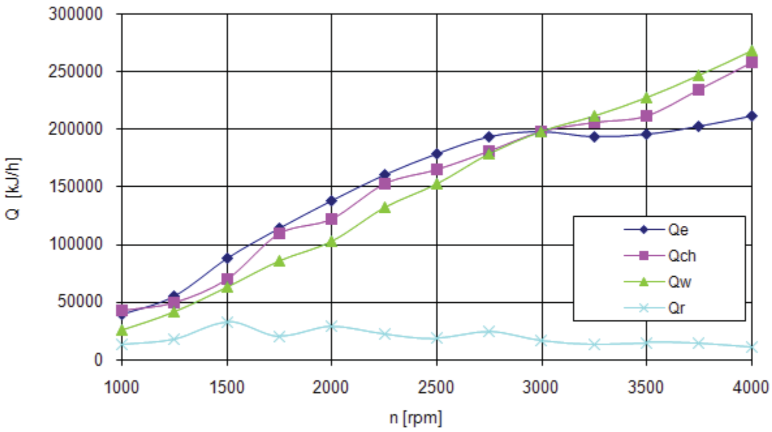


Fig. 1. Energy transformed from working engine:
Qe - effective work; Qch - losses by cooling, Qw - losses with exhaust gases, Qr - radiation

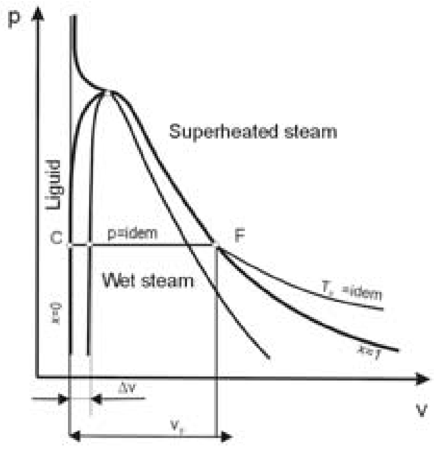


Fig. 2. Transition of the water phases

Second method of energy reducing is decreasing the heat losses is increasing of temperature of the cooling liquid but barrier in this application is temperature of the fluid liquid based on water having boiling temperature 100°C in normal conditions. Vapour forming when water is boiled causes increase total volume Δv of the coolant and pressure inside the system simultaneously (Fig. 2). In this case the cooling system should be resistant to inside pressure, for example with using special connection to environment [6].

The results of analysis of properties of constructional materials and lubricants showing that temperature of cooling liquid could be increased up to 140 – 160°C [2, 11]. It should essential increase engine efficiency and decrease emission of unburned toxic compound of the exhaust gas. Possibilities and results of temperature increasing in the cooling system over water boiling temperature were the main goal of the presented work.

2. Result of investigations on dynamometer test stand

The turbocharged diesel engine 4CT90 is four cylinders diesel engine with indirect fuel injection system to the combustion chamber RICARDO COMET VB was used as the object of investigations. The main engine parameters are: engine cubic capacity 2.417 dm^3, power rating/speed 66 kW/4100 rpm, compression ratio $\varepsilon = 21.1$. The engine was equipped with cooling made by using standard sets like cooler with two electric independently powered fans and water pump (Fig. 3). Full and small water circulation systems were changed by add valves instead standard thermostat. Changing of the water circulation and switching two fans were hand realized in depending on pressure in the cooling system.

On the stand were measured the engine work parameters, coolant temperature and pressure, temperature in inlet and outlet systems and volume friction of toxic compound of exhaust gas versus engine speed and load. The volume friction of exhaust gas components: carbon monoxide, carbon dioxide, hydrocarbons and nitric oxides were measured by the measure system CEB II.

Measures the engine work parameters versus rotational speed and engine load were realised for engine equipped with standard and heighten pressure cooling system, which was called “pressure cooling system”. The control of the system was made by two steeps intensity. When the liquid overpressure in the cooling system exceeded 0.05 MPa, the main cooling circulation was switched on, but when the pressure exceeded 0.07 MPa the fans were successively switched on. Overpressure was limited for pressure integrity of cooling system arisen from application the standard cooler.

a)

b)

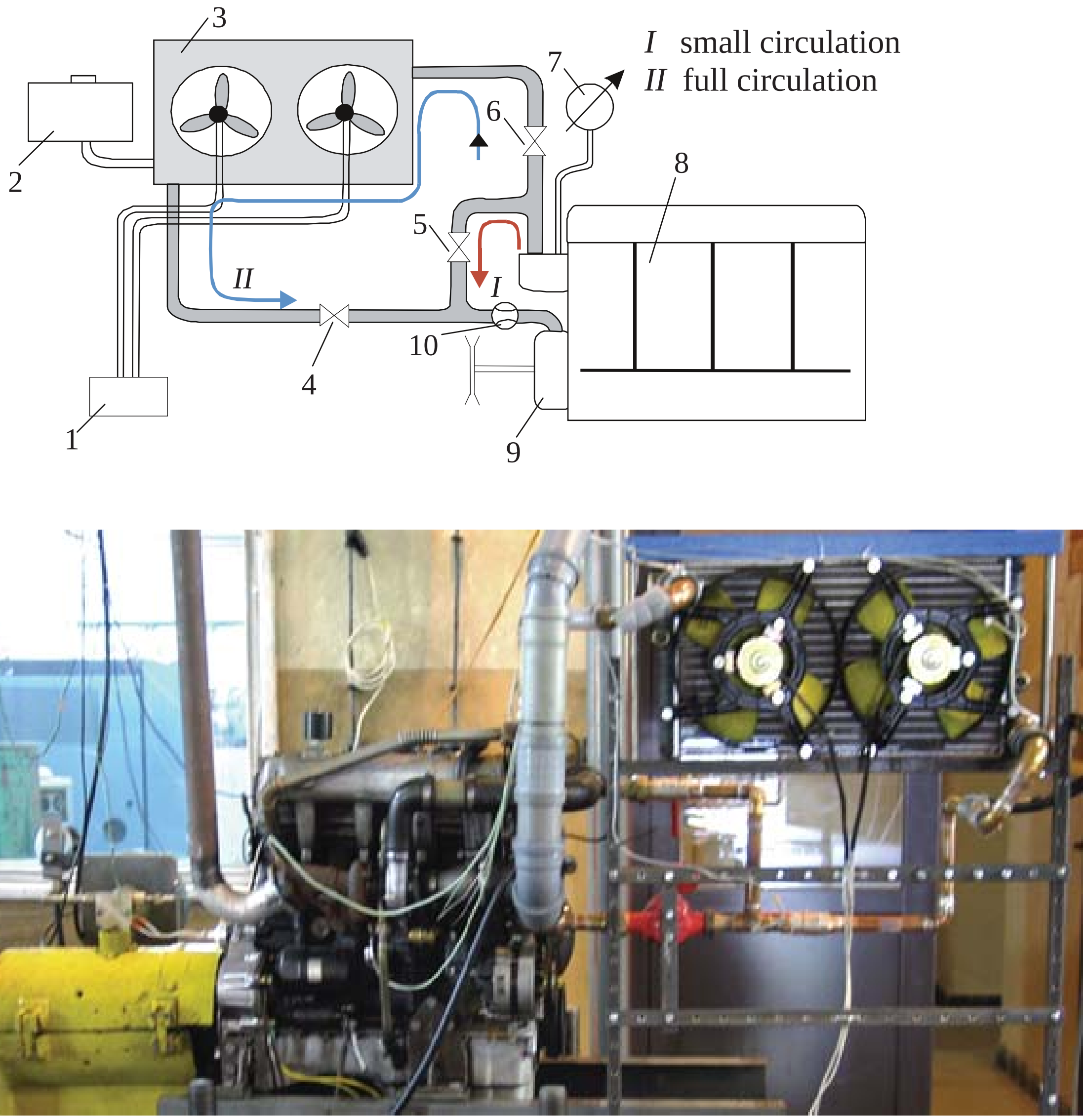


Fig. 3. Schema of the cooling system (a) and view of the engine with this system (b):
1 – fan controller, 2 – trim tank, 3 – radiator, 4, 5, 6 – valves, 7 – manometer, 8 – engine, 9 – water pump, 10 – water flow meter

Allow for presented restrictions, it was possible to keep the temperature of the cooling liquid higher ca. 20°C than the temperature of the coolant for the engine with 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 range of 110-115°C (Fig. 4a).

Air temperature T_5 in the engine suction manifold increased ca. 3…4°C (Fig. 4c). Also air mass consumption was significant increased despite higher air temperature and lower air density (Fig. 4b). Increasing air consumption was visible when the engine speed exceeds 2000 rpm. Air consumption was ca. 8% higher with compare to standard cooling system at maximum engine speed. It could be explain as a result of the higher turbo compressor efficiency in these conditions.

a)

b)

c)

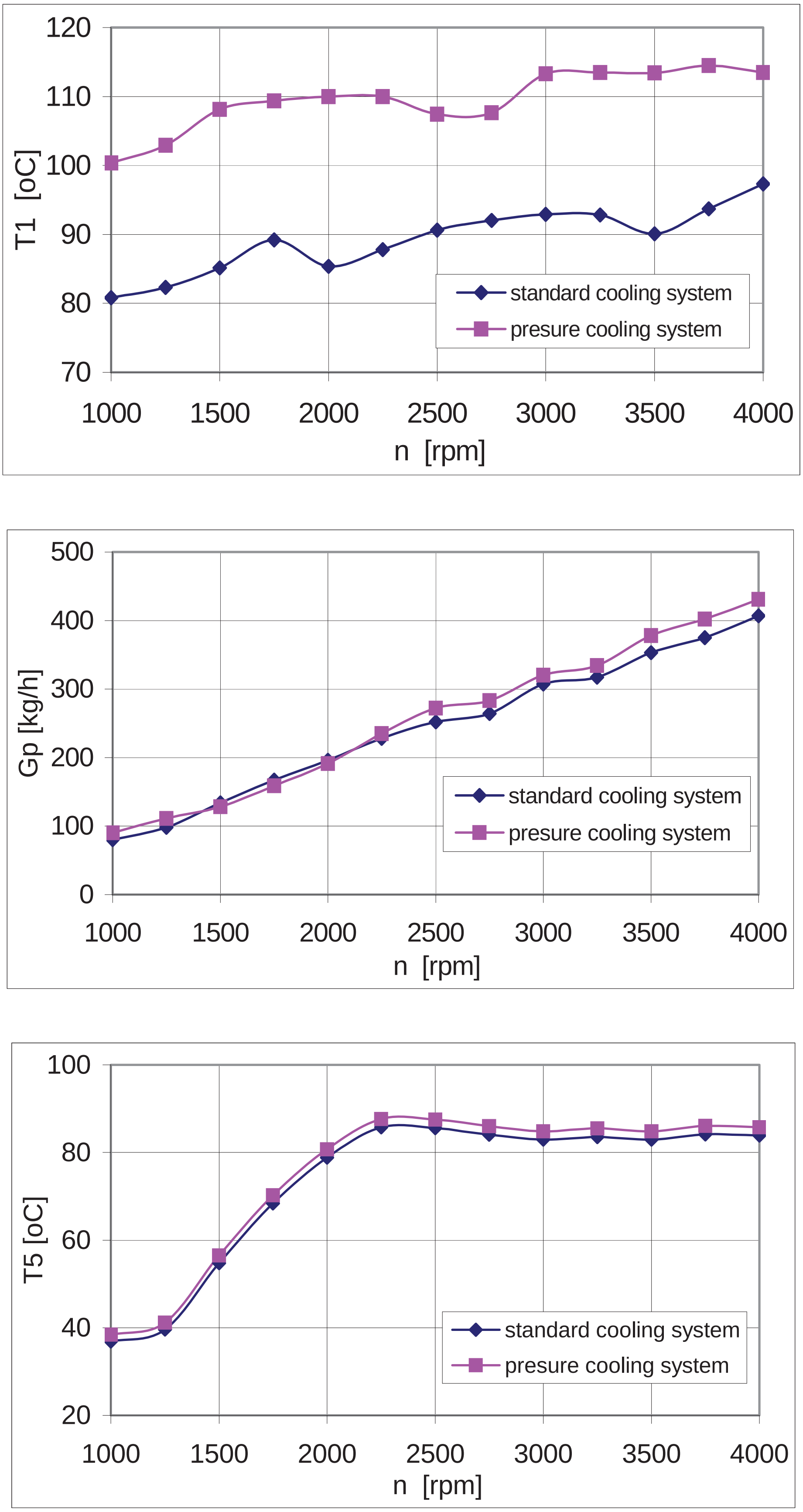
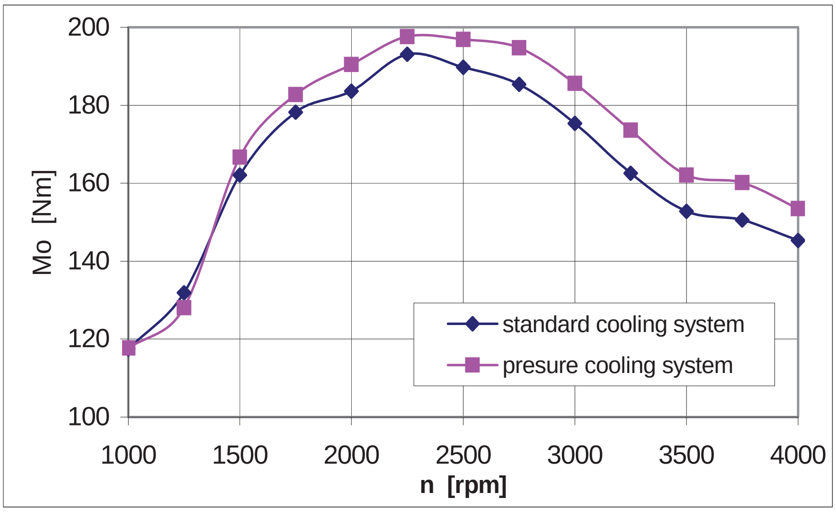


Fig. 4. Comparison between the engine parameters with standard and pressure cooling system: a – temperature of cooling liquid T_1, b –air consumption, d – temperature of inlet air T_5

a)



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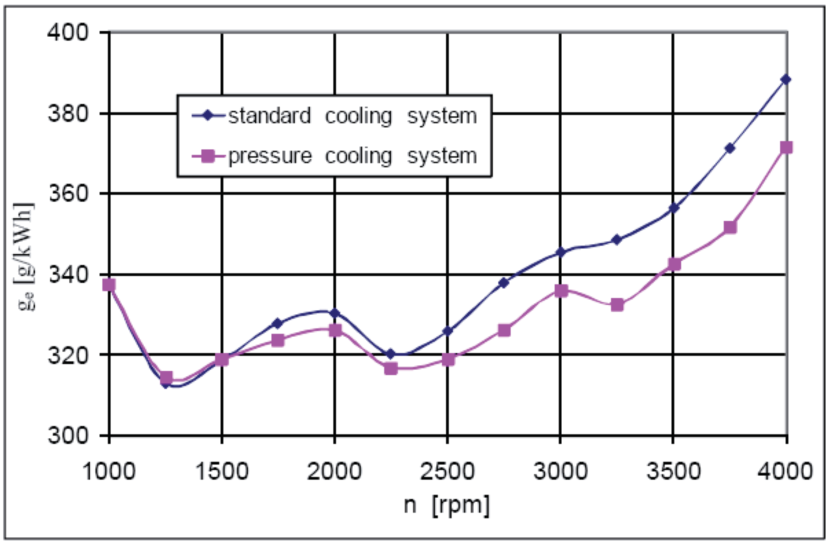


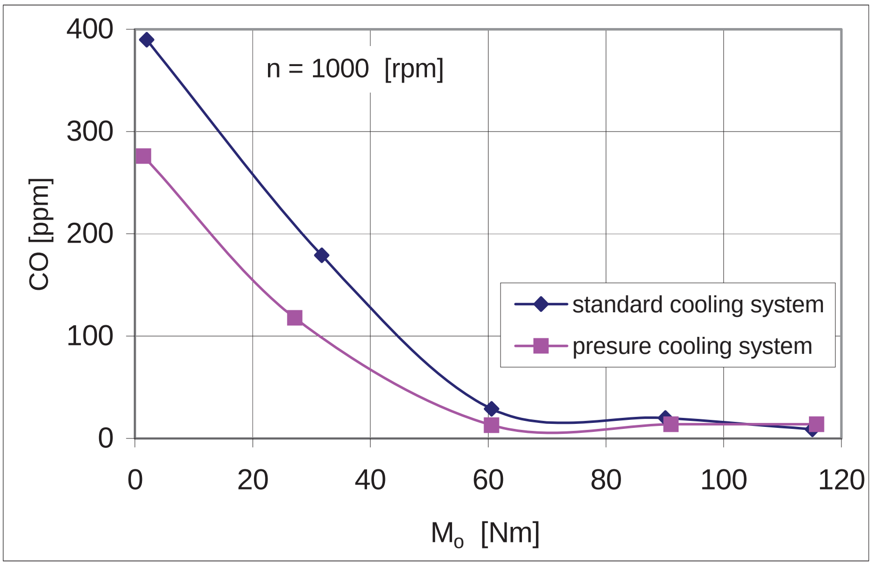
Fig. 5. Comparison between parameters of the engine with standard and pressure cooling system: a – torque, b –specific fuel consumption

The torque of the engine with pressure cooling system is higher at speed above 1500 rpm. The torque difference was ca. 10 Nm at speed 3000 rpm, what gives an increase in output torque ca. 7% (Fig. 5a). The engine power increased respectively to the torque increasing. Because fuel consumption was similar for two kinds of cooling systems, increasing engine power caused relevant decreasing of the specific fuel consumption by the engine having higher temperature of the coolant (Fig. 5b).

The load characteristics were determined in full range of the engine speed, however in the paper were presented only chosen characteristics at the engine speed 1000 rpm. Measures were run from minimum to maximum engine load with equal torque step ca. 30 Nm.

On the basis of measures result it was found that temperature of the coolant was increased from 6°C at very small load to 15°C at full load. Maximum coolant temperature at 1000rpm measured in the thermostat chamber average from 78°C to 97°C (standard thermostat was dismounted). It was lower than water boiling temperature but increasing pressure inside cooling system testify that inside cooling systems are volumes where coolant temperature is higher than boiling temperature. This phenomena was confirmed during investigation other engine by using thermovision camera, when was found that the highest temperature of the engine wall was noticed in the lowest part of the cooling jacket [1, 4].

a)



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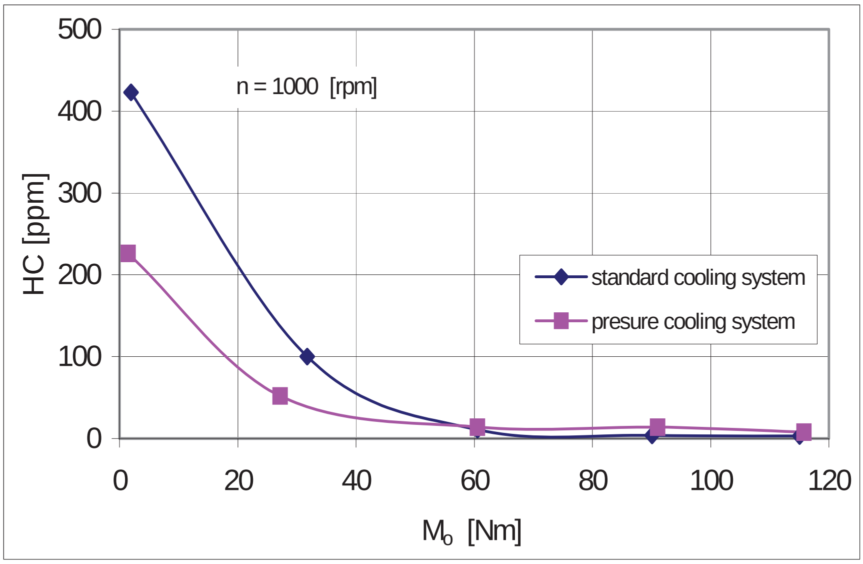

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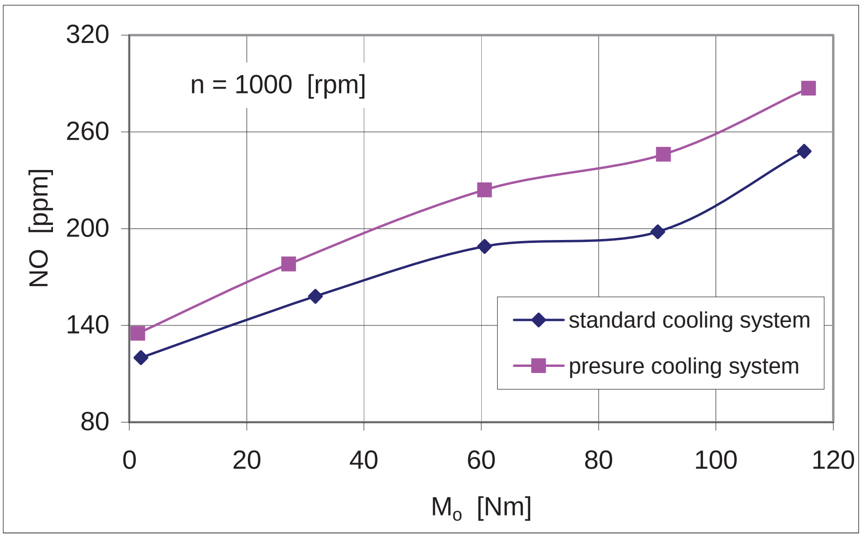

Fig. 6. Comparison between volume friction of the exhaust gas components at speed 1000 rpm: a – carbon monoxide fraction, b – hydrocarbon fraction, c –nitric oxides fraction

The effects of the increased temperature of the cooling liquid and thus the temperature of the combustion chamber of the engine were reductions of the carbon monoxide fraction (ca. 20…30%) and hydrocarbons fraction (ca. 40…50%). The greatest reductions were affirmed at low engine load (Fig. 6a and 6b). After an increase of the load above 50% of the maximum engine torque, differences of these components fraction in exhaust gases between two cooling systems are reduced. This was result of increasing of the exhaust gases temperature up to 250…300°C that initiated an effective work of the catalytic reactor. In the higher engine speed observed similar changes fractions of unburned exhaust gas components but differences were lessen.

Disadvantages method of increasing temperature of the cooling liquid is higher emission of the nitric oxides. It is result higher beginner temperature in the combustion chamber. In the low and medium range of the load emission of nitric oxides can be reduced by increasing exhaust gas recirculation, but deceasing of nitric oxides emission at maximum load of the engine requires more efficient reducing reactor.

3. Conclusions

1. By applying a pressure cooling system with standard units it was possible to obtain increasing temperature of the cooling liquid ca. 20°C in tested object (engine 4CT90) in long time. It was required add system for control of cooling intensity in order to limitation pressure inside cooling jacket up to 0.05…0.07MPa. Higher increasing cooler temperature needs stronger units for assembling cooling system protecting against higher vapour pressure inside cooling jacked and multistage cooling.
2. The increase of the temperature of the cooling liquid in the engine 4CT90 (maximum up to ca. 110°C) resulted decreasing of the fraction of the incomplete combustion products in the exhaust gas (CO and CH) ca. 20…50% at low speed and low load of the engine. In full range of the engine load increased nitric oxides fraction by few percent of in exhaust gas simultaneously. The efficiency of the engine work increased ca. 7% at high load and high engine speed.
3. Increasing the temperature of the exhaust gas and combustion chamber walls because the lower emission unburned product of the combustion process in area of low engine speed and engine load when the catalytic reactor not works for lower temperature of the catalytic cartridge. It is significant advantage of the engine with higher temperature of the coolant.
4. Practical application of the pressure cooling system in engines requires new technologies and structural solutions in electronic control of the cooling system units, also should be used independently driving and controlling coolant pump, as well as flexible materials connecting the system units temperature-proof and pressure-proof.

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