ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1137

INFLUENCE OF SPEED AND LOAD ON THE ENGINE TEMPERATURE AT AN ELEVATED TEMPERATURE COOLING FLUID

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Abstract

In this article has been found that the most popular and widely used method of cooling is liquid cooling, which ensures uniformity of temperature around the combustion chamber and easy acquisition and transfer of heat, although the properties of water are limited by maximum temperature of the coolant. Preliminary scientific research of such a system indicates the possibility of increasing overall efficiency and reducing toxic components in exhaust gases at low engine loads when the engine exhaust temperature of the classic system is too low for efficient catalytic action. This paper presents the dynamometer test stand designed and built using original components of diesel engine 4CT90 production of WSW "ANDORIA" SA. Presented system was designed for the four cylinder with indirect fuel injection system. Research was made on the engine dynamometer stand, which was equipped with standard measure devices (measures: speed, torque, temperatures, flows) and exhaust gas analysers. The temperature of this liquid was increased to the higher level than temperature of boiling water in normal conditions. Overpressure inside the cooling system was limited to 0.3 MPa, the temperature inside the cooling system was increased to 115–120°C. During the test, the cooling system was filled with coolant at 90%. The selected results of investigations of the cooling system for the combustion engine working with higher temperature of the cooling liquid, where the influence of speed and load on the engine temperature were presented.

Keywords: *combustion engines, cooling system, coolant temperature*

1. Introduction

Internal combustion engines known for their low efficiency are still widely used to drive vehicles. Although the introduction of hybrid vehicles is still being developed, technical difficulties cause their application is a matter of the future since other research is still focused on developing internal combustion engines with increased efficiency and reduced toxic exhaust components [2, 3].

The most popular and widely used means of cooling internal combustion engines are through liquid cooling, which ensures greater uniformity of temperature around the combustion chamber than direct air cooling to spite the properties of water being limited to the maximum temperature of the coolant [1, 4, 5, 7].

The efficiency of liquid cooling systems can be increased by the use of electronic control work of the assembly equipment, as well less intense engine cooling thus reducing heat loss. In the case of systems in which coolant-containing water is applied, raising the boiling point of the coolant requires an increase of pressure in the cooling system, which requires a reasonable accommodation system and strengthening its structure. Preliminary scientific research of such a system indicates the possibility of increasing overall efficiency and reducing toxic components in exhaust gases at low engine loads when the engine exhaust temperature of the classic system is too low for efficient catalytic action [6].

The aim of this work was to develop a pressure cooling system for internal combustion engine cooling system as well as checking the possibility of maintaining the established pressure in the system and attaining a high coolant temperature. Next effect of speed and load on the engine temperature at an elevated temperature of the coolant was determined.

2. Research object

The turbocharged diesel engine 4CT90 680/59 was the object of research. It is a four-cylinder engine with indirect fuel injection into the vortex chamber performed in the cylinder head. 4CT90 engines are designed to drive vehicles with total weight up to 4.5 tons, and can be used as a source drive off-road vehicles, power generators and other stationary equipment. The development and construction of a pressure cooling system problem is to ensure that there is no cooling system leak. A cooler is particularly sensitive to the pressure, therefore, a charge air cooler made of steel was used as a cooler, where all the elements are connected by welding and form a compact structure. In the model research, this exchanger fulfilled its role, whereas in the research on the real engine above a certain load there was an uncontrolled growth of both pressure and temperature in the system. So finally, a shell-and-tube type heat exchanger was installed in the system. View of the engine dynamometer is shown in Fig. 1.

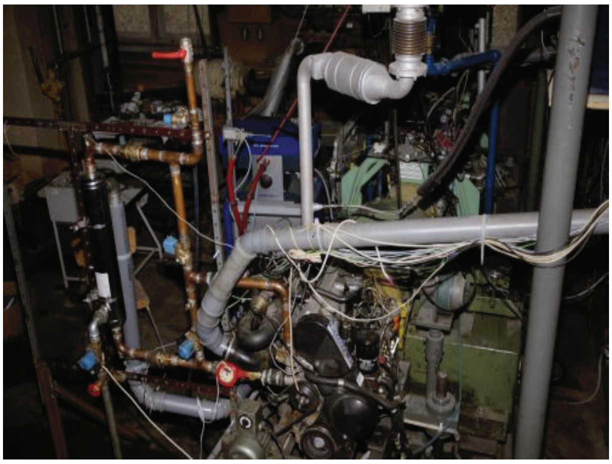

Fig. 1. Engine 4CT90 on the dynamometer with pressure cooling system

Fig. 2. Computer recording measured values

Full and small water circulation in the system were changed by using electromagnetic valves instead of the standard thermostat.

During the tests, the engine was loaded by electro rational brake Schenk W 230 with a maximum power of 230 kW. Between the brake housing and the base, the strain gauge torque meter was installed, by which torque was measured. The brake was periodically calibrated using standard weights placed on saucers appearing over the load cell. The engine speed was measured using a pulse transducer cooperating with a toothed rim located on the shaft brake. Computer, as shown in Fig. 2 registered the results of measurements of all points.

3. Research of the cooling system with increased temperature of the coolant

This research aimed to determine the effect of engine speed and load on the engine temperature at an elevated temperature of the coolant. External speed characteristics were made with standard and pressure cooling systems. While performing the characteristics of the engine was loaded up to the entire range of engine speed from 1000 to 4000 rev/min.

3.1. Effect of speed on engine temperature

The increase of pressure in the engine cooling system about 0.3 MPa through evaporation caused an increase in the coolant temperature of the liquid flowing out from the engine to around 115°C in the rotation speed range over 2000 rev/min (Fig. 3a). Below this speed, the temperature

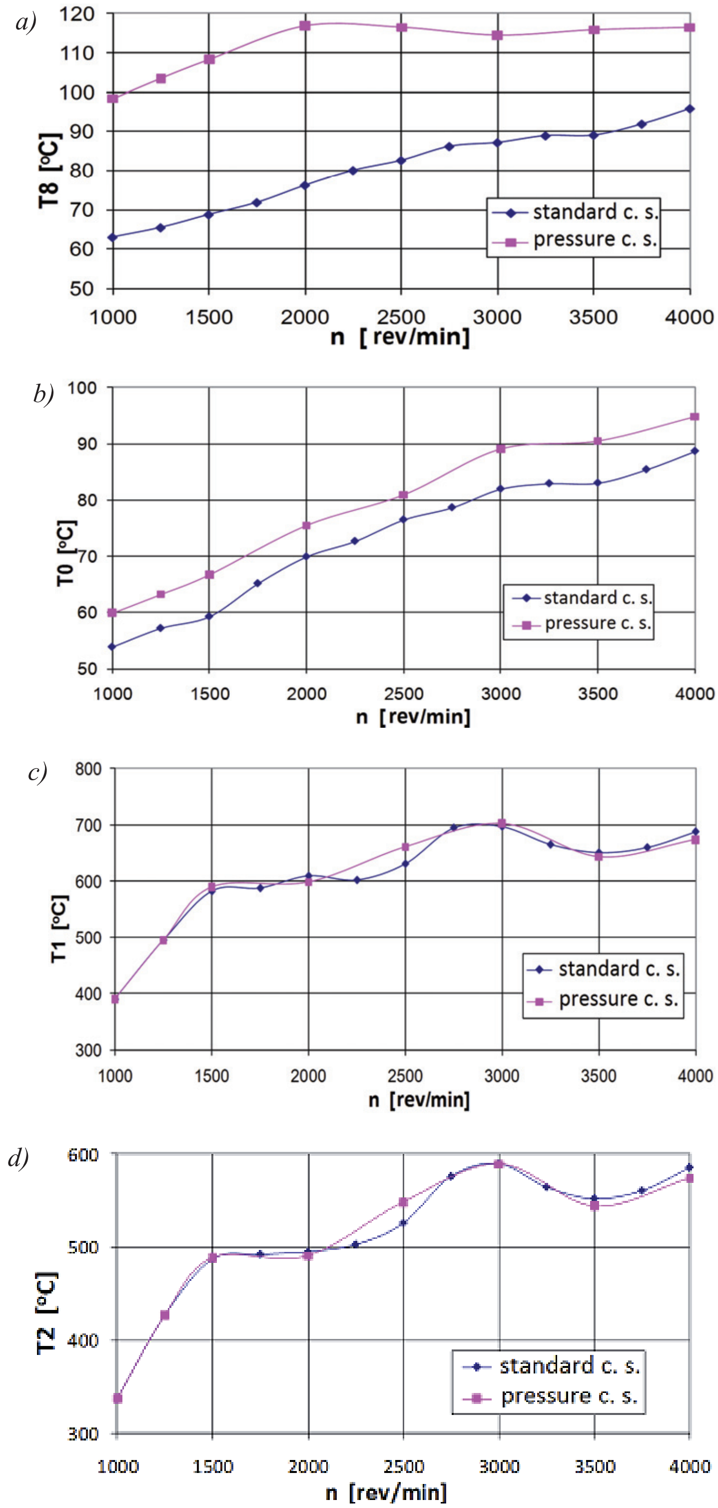

Fig. 3. 4CT90 engine speed characteristics with standard and pressure cooling system: a – coolant temperature before the radiator, b – coolant temperature before the engine block, c – exhaust gas temperature before the turbine, d – exhaust gas temperature behind the turbine

dropped to about 100°C. In this way, almost 40-degree increase in temperature of liquid flowing out of the engine in speed range of 1000-2000 rev/min was obtained. The difference decreased to about 25-20°C in speed range of 3500-4000 rev/min. After obtaining such a temperature increase of the engine, the intensity of the cooling liquid in the cooler was increased, whereby the temperature of the liquid before the cylinder block decreased to 60°C at a speed of 1000 rev/min and 95°C at a speed of 4000 rev/min (Fig. 3b). This temperature was only 7-8°C higher than using a standard cooling system. Increased pressure and coolant temperature had no influence at the measured temperature of the exhaust gas, both before the turbine driving the air compressor and the behind the turbine (Fig. 3c and 3d). Only at a speed of 2500 rev/min temperature of exhaust gas from the engine equipped with a pressure cooling system was higher by about 30°C before the turbine and about 25°C behind the turbine. The temperature difference before and behind the turbine was an average about 100°C in the range 1500-4000 rev/min and reduction the temperature of the exhaust gas flowing through the turbine at a lower speed was approximately 70-80°C.

The temperature of charge, between engine equipped with a standard and pressure cooling system, were comparable in the range of 1000-1500 rev/min. Over speed of 1500 rev/min, charge temperature of the engine equipped with a pressure cooling system was higher than the average of about 3-5°C, which means that with increased air consumption a pressure of fresh air charge has grown. Cause of the charge temperature increase, may be greater efficiency of the compressor, although there was no increase in exhaust gas temperature and the heating of charge from the walls of the collector with a higher temperature. Processes turbocharger operation at a higher temperature coolant to be further examined in further research. Temperature of the cylinder liner of the first cylinder from the exhaust, as measured by thermocouples placed along axis of the cylinder also increased. The temperature increase was greatest at the measurement point located in an upper part of the cylinder liner (T5) was about 10-26°C, the highest increase was detected at a speed of 2000 rev/min (Fig. 4b).

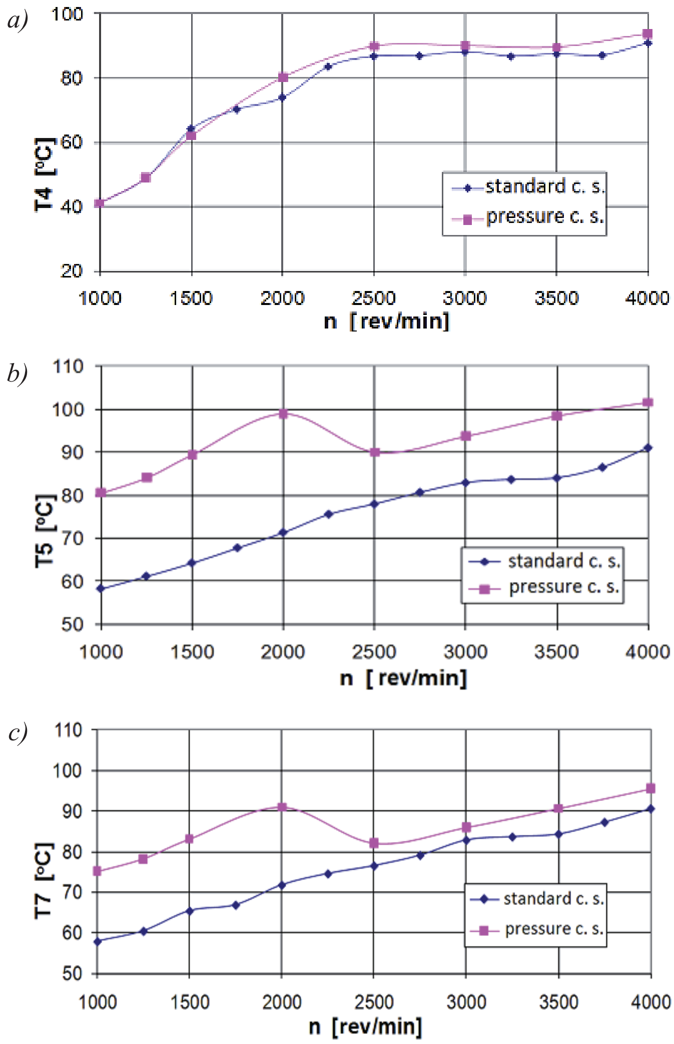

Fig. 4. 4CT90 engine speed characteristics with standard and pressure cooling system: a – temperature in the intake manifold, b – temperature of the cylinder liner wall (top), c – temperature of the cylinder liner wall (bottom)

The temperature of the cylinder liner slightly dropped with decreasing speed (to about 22°C at a speed of 1000 rev/min) and a greater decrease was found with increasing rotational speed. The rotational speed of 2500 rev/min temperature increase stabilized at 10°C. Temperature course of the cylinder liner for the pressure cooling system also affected by the increased temperature of the coolant at the outlet of the liquid from the cylinder block (Fig. 4a), which in the range of speed 1000-2000 rev/min was higher than the temperature of the standard cooling system by close to 40°C. At higher the engine speed and higher indicated power, decreased temperature differences comparing two different cooling systems. Cylinder wall temperatures measured in bottom sections of the cylinder liner (T7) was much lower primarily due to the lower temperature of the cylinder liner during the application of pressure cooling system. At engine speeds above 2500 rev/min cylinder liner temperature of the engine cooled by pressure cooling system was higher by about 5°C in the high speed range and about 15-20°C in the low speed range (Fig. 4c).

3.2. Effect of load on the engine temperature

The use of the pressure cooling system caused the coolant temperature at the inlet to the radiator T8 increased to 110-120°C, but temperature closer to upper value of the temperature range was dominated (Fig. 5a). Existing small variations in coolant temperature as a function of engine load were due to difficulties caused by manual control of the engine, which was also visible in the temperature courses measured at other points in the engine. The increase in temperature of the liquid flowed to the radiator of a few degrees, relatively large, compared with the standard engine cooling system with a thermostat and a pump and a fan driven directly by the engine crankshaft. Increased coolant temperature flowed from the engine was maintained at the equal level in the whole range of engine load, which is the result of external control engine temperature. The engine temperature with standard cooling system grew with increasing load. Temperature of the coolant inlet to the engine was an average of 20-30°C lower than the temperature of liquid which flowed to the radiator, and moreover on its course are visible fluctuations caused by manual control of the engine cooling intensity when the radiator, which allows the discharge of a large amount of heat was applied (Fig. 5b). Compared to the standard cooling system, the coolant temperature of the pressure system is higher by about 40°C with a small load, to about 10°C at maximum engine load. Exhaust gas temperature of the engine, which was equipped with pressure cooling system is higher than the exhaust gas temperature of the engine with standard cooling system in the whole range engine speed and engine load (Fig. 5c, d). The speed of 1500 and 2000 rev/min exhaust temperature difference reach 30°C in the whole range of engine load and concern both the temperature before the turbine and behind the turbine driving an air compressor. At the speed of 3000 rev/min and above differences in the temperature courses decreased to 10-20°C, while visible was an additional increase in exhaust gas temperature due to much higher torque.

The air temperature in the intake manifold of the engine with pressure cooling system (T4) was higher than in the engine with standard cooling system in the whole engine speed and engine load range (Fig. 6a). At low speed, and less air flow through the intake manifold, temperature growth of the charge was greater by about 10°C, while the growth speed caused an increase in air temperature, which was smaller and reached only 1-2°C, which means that the temperature courses of the charge to equalize. Temperature courses T5, T7 along the cylinder liner (Fig. 6b, c) were similar to the temperature of liquid flowing to the engine T0.

The temperature at the wall of the cylinder liner in the cooling liquid channel was higher by tens degrees than the temperature of the liquid with use of standard cooling system, and the courses were not aligned as a function of the load, especially at low speed (n = 2000 rev/min and 2500 rev/min). The reason was the manual control of the heat exchanger with high efficiency heat transfer.

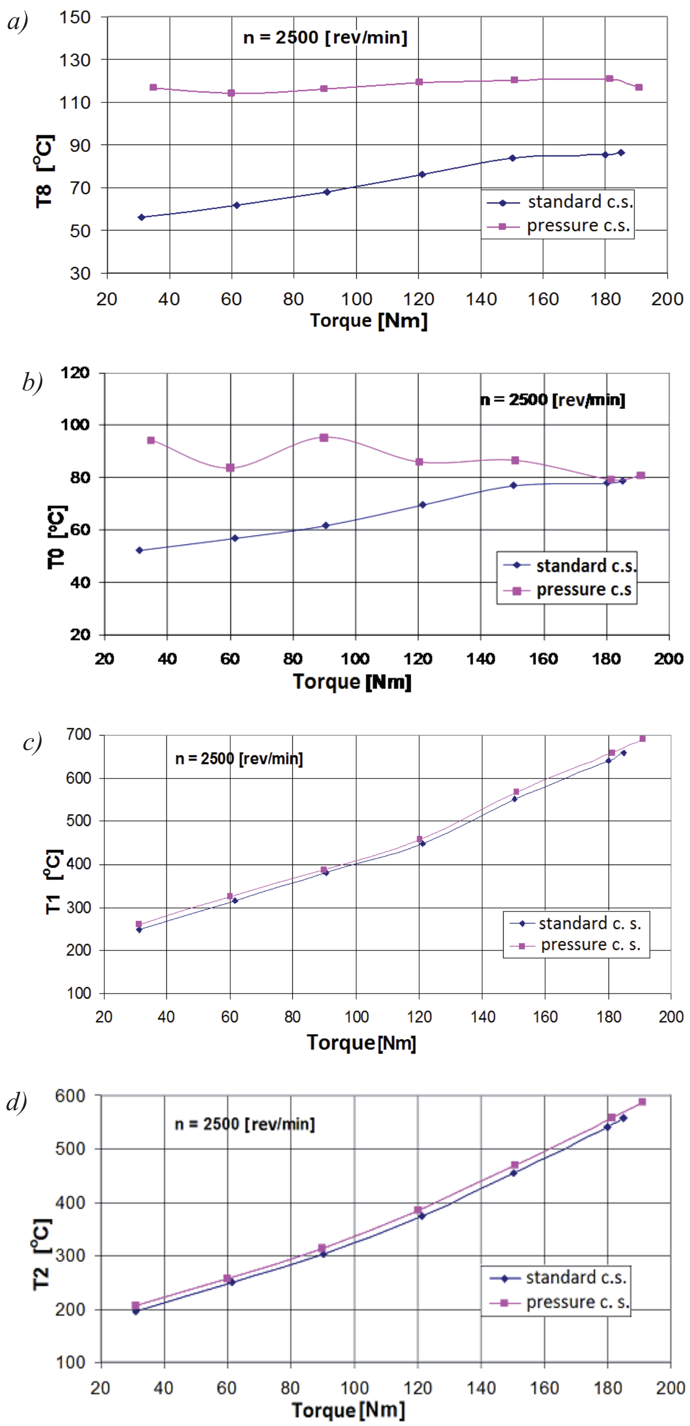

Fig. 5. 4CT90 engine load characteristics with standard and pressure cooling system at n = 2500 rev/min: a – coolant temperature before the radiator, b – coolant temperature before the engine block, c – exhaust gas temperature before the turbine, d – exhaust gas temperature behind the turbine

4. Conclusions

1) Pressure cooling system, where at an average overpressure of 0.3 MPa was 120°C, characterized by a higher charge temperature compared to the standard cooling system, which contributed to the improvement of fuel mixing and combustion.
2) Temperature of the coolant entering to the radiator was higher for the engine with pressure cooling system and reached a value of about 120°C at a speed of 2500-4000 rev/min in the whole range of engine load. However, the temperature of liquid coming out of the radiator and

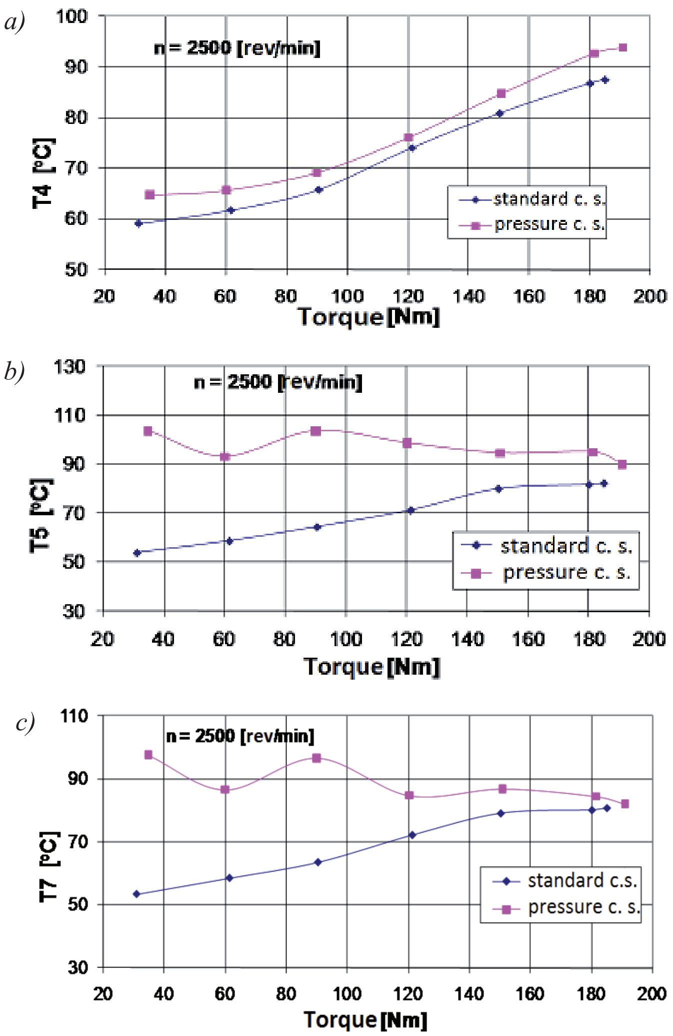

Fig. 6. 4CT90 engine load characteristics with standard and pressure cooling system at n = 2500 rev/min: a – temperature in the intake manifold, b – temperature of the cylinder liner wall (top), c – temperature of the cylinder liner wall (bottom)

into the engine had a similar course in each case, with the largest differences reaching 40°C, which occurred in smaller speeds.

3) Increased overpressure and coolant temperature did not significantly affect the measured temperature of exhaust gas, both before and behind the turbine driving the air compressor. The exhaust gas temperature of the engine equipped with a pressure cooling system was higher by about 30°C before the turbine and about 25°C behind the turbine compared to the standard cooling system.
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.

References

[1] Bernhardt, M., Dobrzyński, S., Loth, E., *Silniki samochodowe*, WKŁ, Warszawa 1988.
[2] Cortona, E., Onder, Ch. H., *Engine Thermal Management with Electric Cooling Pump*, SAE 2000-01-0965, Michigan 2000.
[3] Kneba, Z., *Kompleksowy model nowej generacji układu chłodzenia silnika spalinowego*, Silniki Spalinowe, SC1/2007.

[4] Ogrodzki, A., *Chłodzenie trakcyjnych silników spalinowych*, WKŁ, Warszawa, 1974.
[5] Rychter, T., Teodorczyk, A., *Teoria silników tłokowych*, WKiŁ, Warszawa 2006.
[6] Walentynowicz, J., Kałdoński, T., Szczęch, L., Karczewski, M., Rajewski, M., Sprawozdanie końcowe realizacji projektu badawczego pt.: *Układ chłodzenia tłokowego silnika spalinowego o podwyższonej temperaturze płynu chłodzącego*, PBG 457/WAT/2001.
[7] Walentynowicz, J., Krakowski, R., *Decreasing of Thermal Energy Loses in Piston Combustion Engines*, RSM System Level Thermal Management for Enhanced Platform Mobility, NATO RTO AVT – 178, Bucharest 2010.