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THE INFLUENCE OF THE REGULATION METHOD OF COOLING PUMP PERFORMANCE, AT HEAT TRANSFER INTENSITY IN THE PRESSURE COOLING SYSTEM

Rafał Krakowski

Faculty of Marine Engineering
ul. Morska 83 , 81-225 Gdynia, Poland
tel.: +48 58 6901398
e-mail: r.krakowski@am.gdynia.pl

Abstract

This paper presents a model test stand for testing the cooling system with increased coolant temperature. On the model stand, as a result of the research, determined the characteristics of temperature and pressure courses coolant. The study was preceded by the determination of the intensity of the liquid flowing out of the engine block and flowing through the radiator as a function of the opening of the valve throttling the flow of liquid and as a function of speed water pump. An adjustable valve was located in the water outlet duct of the engine. During the test the cooling system was filled with coolant at 90%. After preliminary studies, the degree of filling of the liquid was found to be optimal, because the greater the amount of water in the system observed difficulties in obtaining elevated temperature, whereas at lower amounts of liquid vortex centrifugal pump had problems with the rib. Then, the characteristics of the two ways of controlling the pump capacity were made, ie by throttling the discharge and change in speed. The characteristics indicate that the first way to adjustment of the pump flow rate and thus cooling intensity was less effective, because a small amount of throttling was not affect the change. The second way to adjustment of the liquid flow rate with changes in the speed of the water pump was more efficient, because it was easier to maintain the pressure established in the cooling system.

Keywords: *internal combustion engines, cooling system, model research, pump capacity*

1. Introduction

Piston internal combustion engines are still widely used for the propulsion of vehicles and work on their development are carried out, inter alia, to increase their efficiency. It is now widely used method of cooling is liquid cooling.

One way to improve the efficiency of the currently used internal combustion engines is a more accurate control of individual motor units, reducing heat loss resulting from the cooling and heat escaping from the exhaust (turbine drive air compressor) [5, 7].

So far, the known ways of reducing the loss of cooling and radiation was the use shielding of the engine and the so-called adiabatyzation, the shielding walls of the combustion chamber with ceramic liners. So far, this is the way expensive, and used in piston engines are unreliable and ineffective [1, 3]. In the case of direct engine cooling air, which allows the maximum increase in temperature of the engine components, there are also problems of uniform cooling of the individual cylinders of the engine and the head of a wide range of engine speed and engine load

For this reason, the most popular and widely used method of cooling is the cooling liquid, which provides a more uniform temperature around the combustion chamber, although the properties of the water is limited by the maximum temperature of the coolant.

Efficiency of liquid cooling systems as a comprehensive unit of energy management in vehicles, can be improved by the electronic control unit work, as well as the less intense cooling of the engine and thus reducing heat loss [2, 4].

The aim of this study was to determine the effect of adjustment performance of cooling water pump on the intensity of the heat transfer in the pressure cooling system.

2. The research object

The model test stand was built using original components and assemblies, where are used the cylinder block and head diesel engine 4CT90 (Fig. 1).

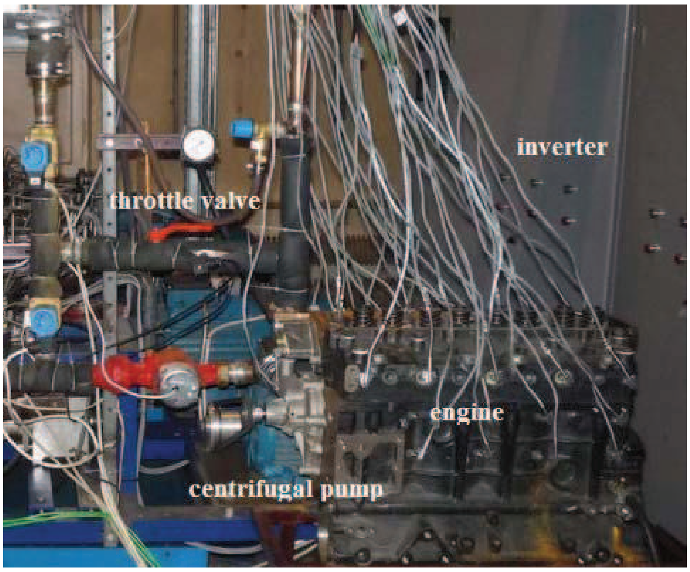

Fig. 1. The stand to research the influence of the regulation method of cooling pump performance

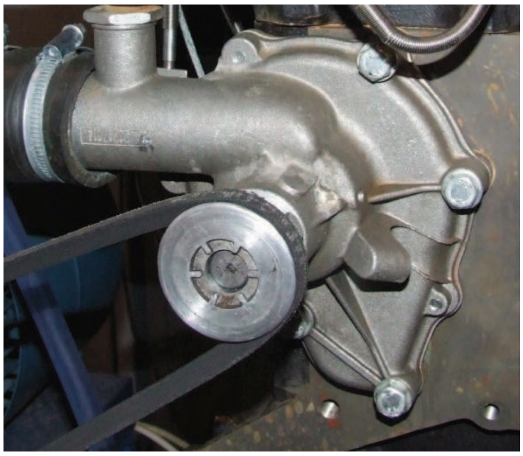

Fig. 2. View of the radial centrifugal coolant pump of the engine 4CT90

The cooling system was designed to operate with increased internal pressure, and consisted of the following components:

- radiator with two fans,
- flowmeter for measuring the flow of water in the system,
- unit thermocouples inside the block and cylinder head,
- water pump drive unit,
- engine block heaters,
- gauges to measure the pressure inside the system.

Inside each cylinder was placed heaters of different power. The test stand was equipped with a thermocouples located in the engine block and head, as well as the thermocouples placed in the heat exchange system with the environment. Thermocouples were connected to the computer temperature meter with three analog-to-digital measurement cards APCI-3200. Two fans provided in the channels with sensors to enable measurement of the temperature and air velocity. Water centrifugal pump was driven by an electric motor whose rotational speed was controlled in a programmed inverter, allowing control of cooling intensity by changing the coolant flow rate [6, 8]. The flow of liquid between large and small circuits was controlled by solenoid valves.

Electronic manometer with pressure transducer A-10 Danfoss and needle manometer the extent of 0,147 MPa were used to measure the pressure in the cooling system. Electronic pressure transducers connected to the measurement cards with special software that allows the configuration and execution of measurement.

3. The results of the cooling system as a model stand

Research of the effect of adjustment performance of cooling water pump on the intensity of the heat transfer was preceded by determining the intensity of the liquid flowing out of the engine block and flowing through the radiator as a function of the opening of the throttle valve and fluid flow as a function of speed water pump. As a measure of valve opening the number of valve rotation was assumed from the fully open position to the closed valve position. The total adjustment range was 6 rotation dial valve. Changes in flow rate as a function of the number of the valve revolutions and rotational speed of the water pump shown in Fig. 3

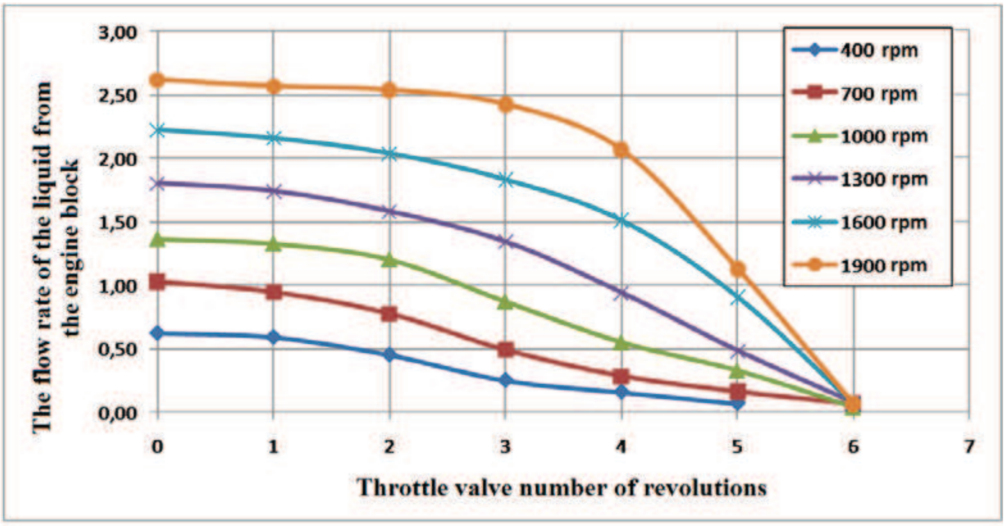

Fig. 3. The effect of the number of valve revolutions on the flow rate of coolant from the engine block at different speeds of the liquid pump

During the first cycle tests were performed with capacity control coolant flow by means of the throttle valve setting. The impact of this control method on the ability to maintain and stability of the pressure in the cooling system and its effect on the control of the intensity of cooling was checked. The water pump speed was set to n = 500 rev/min and was maintained at a constant level throughout the test. The valve at the water outlet from the engine was set in six positions, including a fully open position.

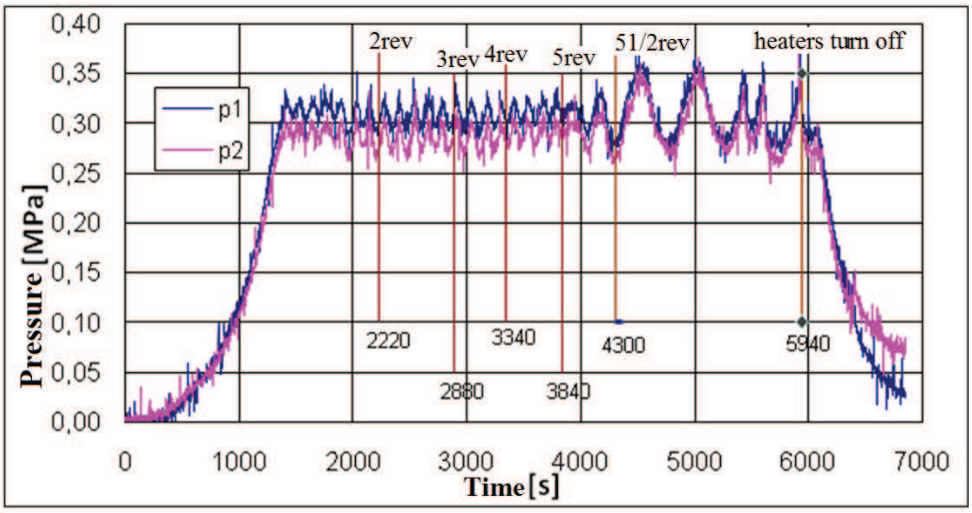

Fig. 4. Overpressure courses in the cooling system at 90% of the system filling in the coolant with flow control by a valve: p1 - overpressure at the outlet from the engine, p2- overpressure behind the radiator (the upper description - tap number of revolutions, the description of the bottom - time throttling settings)

After the warm-up and fully open the water valve, control the intensity of cooling takes place by switching on and off one or two fans at the same time so that the overpressure in the large circulation was about 0,3 MPa. In this way, you could keep the overpressure established between 0,28 ÷ 0,31 MPa (Fig. 4). In the figure, courses pressure of transducer placed at the liquid outlet from the engine P1 and behind the radiator P2.

After warming up the system and reducing the flow of coolant to the fourth rotation tap water valve, throttling growth generally did not affect the overpressure courses in the system (Fig. 4). Fluid overpressure behind the engine block was slightly higher than the overpressure behind the radiator. At the the liquid flow fans were switched on at the same time for several seconds at about 2 minutes regardless of throttling the flow of liquid, and the temperature inside the fan channels changed in the range 30 ÷ 58°C (Fig. 5). The air temperature was below in the channel of the lower fan.

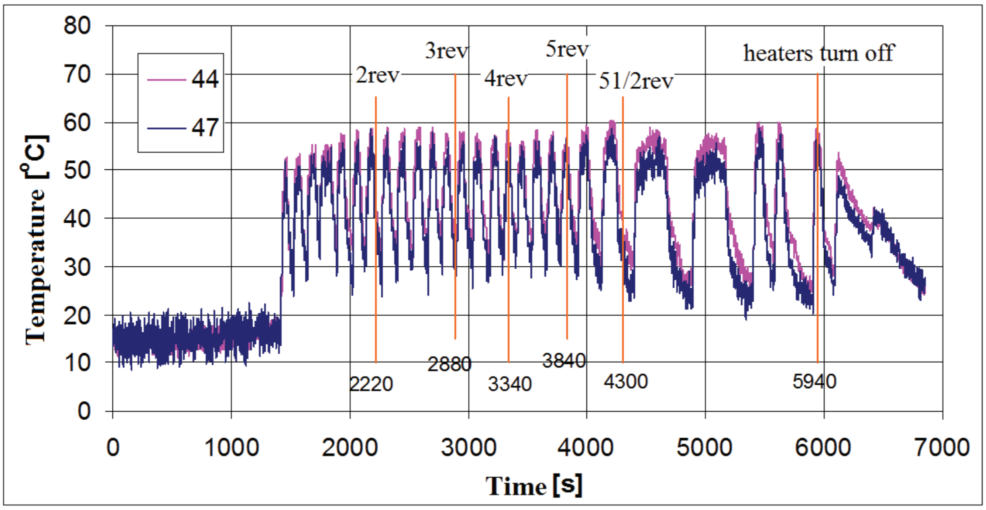

Fig. 5. Temperature courses in the fans channel at 90% of the system filling in the coolant with flow control by a valve: 44 - top fan, 47 - bottom fan (the upper description - tap number of revolutions, the description of the bottom - time throttling settings)

Try to turn on individual fans reduced the response time of the system and cause an excessive increase in overpressure in the cooling system. The difference between the temperature of the liquid at the inlet and outlet of the radiator was on average about 15 ÷ 20°C (Fig. 6). Coolant temperature changes in the engine block were smaller, and their amplitude changes in the range of valve opening was about 5°C near the inlet to the engine block (head before 1 cylinder) and head on the other side of the engine block (head behind 4 cylinder). Temperature of the liquid for the fourth cylinder was about 5°C higher than that of the head from the side of the coolant flow (Fig. 7).

Reducing the liquid flow of 5 (3840 seconds) and 5,5 rotation of tap valve (4300 seconds) resulted in an excessive throttling of the flow and as a result it was necessary to extend the cooling time of the liquid in the radiator to reduce the pressure, as shown in temperature courses in the fans channels (Fig. 5). Temperature of the cooling liquid behind the cooler in period of cooling was much lower and reached values of about 75°C at 5 rotations of valve, and spin of the valve of 5,5 rotation even reached 55°C (Fig. 6).

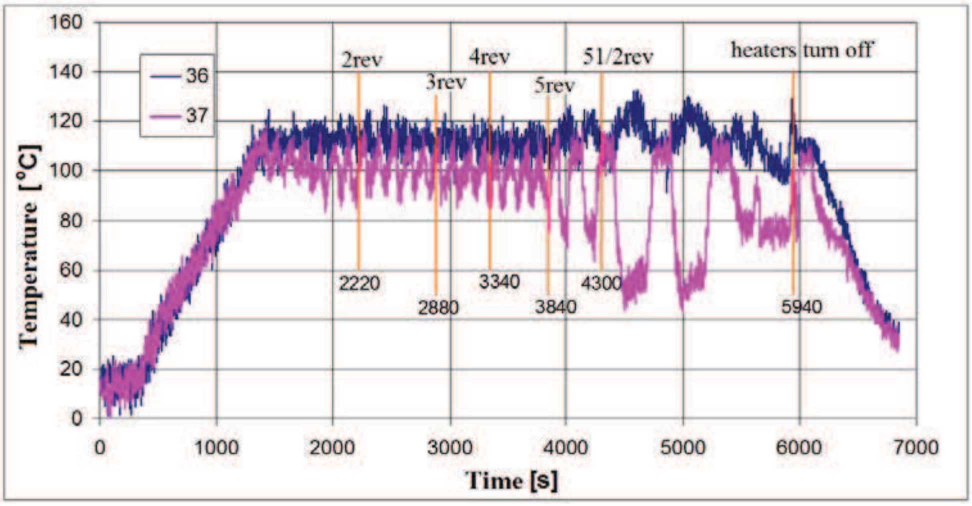

Fig. 6. Temperature courses in the cooling system at 90 % of the system filling in the coolant with flow control by a valve: 36 – flow of the liquid to the cooler, 37 – outflow of the liquid from the cooler (the upper description - tap number of revolutions, the description of the bottom - time throttling settings)

Moreover, with such a large flow throttling was difficult to obtain reproducible courses pressure and temperature, as can be seen between 4000 and 6000 second of measurement. Range overpressure changes in the cooling system increased significantly and overpressure changed in the range 0,26 ÷ 0,37 MPa (Fig. 4), and temperature changes in the cylinder head ranged from 110°C to nearly 130°C (Fig. 7).

The characteristics that were presented to show that method of adjustment the coolant flow by throttling valve located in the the water outlet channel of the engine, and thus the intensity of the cooling is not efficient, because small changes of throttle do not affect the changes in operating parameters of the system, while at increased throttling is overcool of the liquid in the radiator and a growing range of overpressure changes.

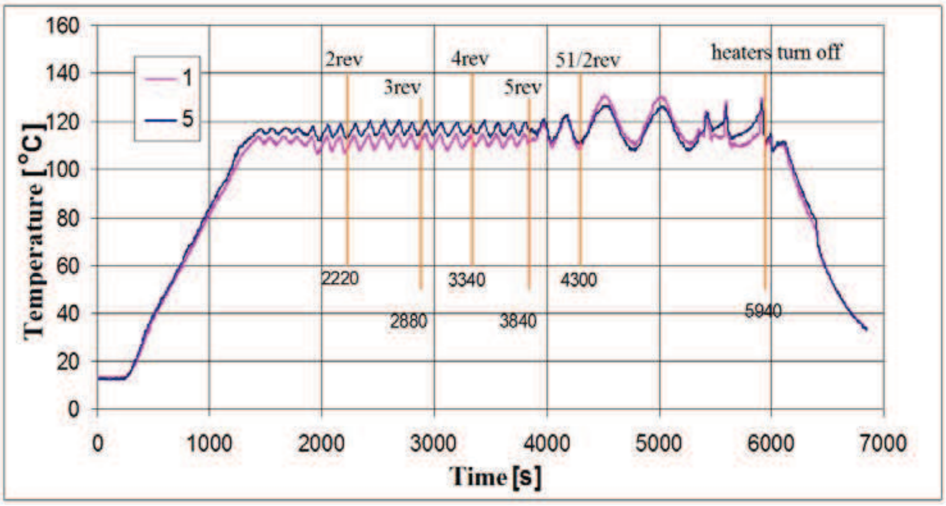

Fig. 7. Temperature courses in the cooling system at 90 % of the system filling in the coolant with flow control by a valve: 1 – engine head before 1 cylinder, 5 – engine head behind 4 cylinder (the upper description - tap number of revolutions, the description of the bottom - time throttling settings)

The second way to control the flow of liquid through the cooling system was control by changing the flow rotation speed of the water pump. The rotational speed of the electric motor which drives the pump was varied from 200 to 800 rev/min, the ratio of i = 2,4 gave the change of speed of the pump impeller 480 to 1920 rev/min.

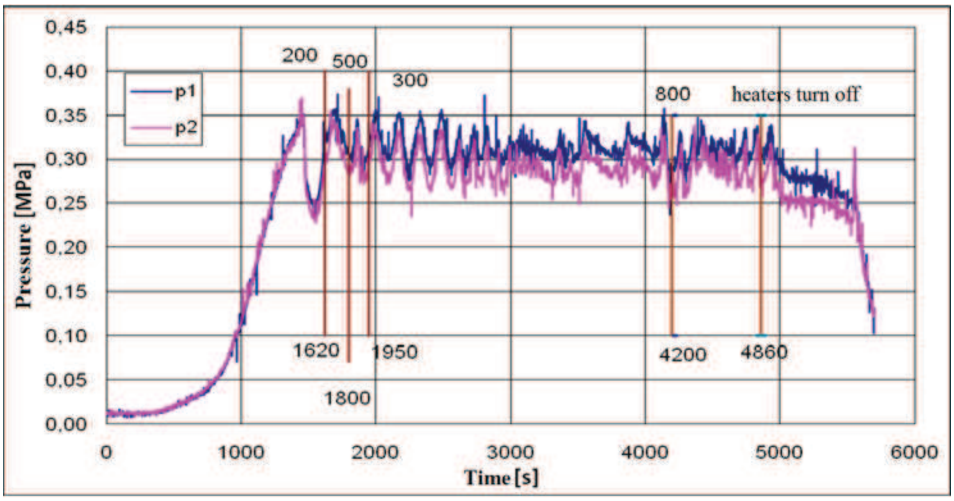

Fig. 8. Overpressure courses in the cooling system at 90% of the system filling in the coolant with speed control of the water pump: p1 – overpressure at the outlet from the engine, p2- overpressure behind the radiator
(the upper description – pump engine speed, the description of the bottom – rotation speed change time)

Figure 8 shows characteristic of the overpressure course which changed initially between 0,25 ÷ 0,35 MPa, and then between 0,27 ÷ 0,32 MPa. In Figure 9 it can be seen also the appearance of spontaneous circulation in the cooling system water after about 1000 seconds. When the water pump is turned off, it was caused by a phenomenon called thermosyphon, which is caused by a tilted heated water, due to its lower density and fall of cold water. After reaching the assumed overpressure (0,35 MPa) launched successively lower and upper fan.

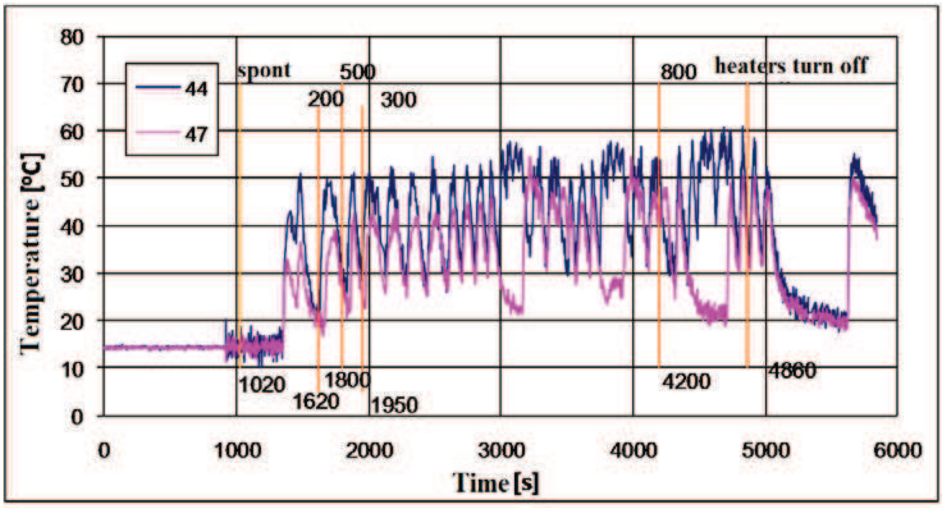

Fig. 9 . Temperature courses in the fans channel at 90% of the system filling in the coolant with speed control of the water pump: 44 – upper fan, 47 – lower fan
(the upper description – pump engine speed, the description of the bottom – rotation speed change time)

The next level of intensity of the cooling when the operating fan was not able to maintain the established pressure, was to start the engine of the water pump, initially at a speed of 200 rev/min (pump speed was n_p = 480 rev/min), and then the speed was increased to n = 500 rev/min (n_p = 1200 rev/min) and after some time, pump engine speed reduced to n = 300 rev/min (n_p = 720 rev/min). In about 4200 seconds to maintain established overpressure require increased engine speed drive the water pump to n = 800 rev/min (n_p = 1920 to rev/min).

Adjusting with variable speed water pump was more effective than control performance by throttling the discharge, because it was easier to maintain established overpressure. System quickly reacted to changes in pump speed, temperature and pressure courses were generally characterized by greater uniformity. In paragraphs 44 and 47 has changed nature of the courses between 3000 and 4000s and 4200 and 4800 s, because intensity control was tested with a single cooling fan to maintain a temperature of the coolant escaping from the radiator to the highest possible level. During this time, the work change or one fan, or two at a time. In the 4000 second worked two fans, but despite this it was necessary to increase the pump motor speed to 800 rev/min to maintain the established overpressure in the cooling system. Next cooling intensity control was done by means of fans. Temperature of the air flowing through the radiator changed within 23 ÷ 50°C (T44 and T47), and at the end of the cycle, the temperature in the upper fan channel even temporarily increased to 60°C (Fig. 9).

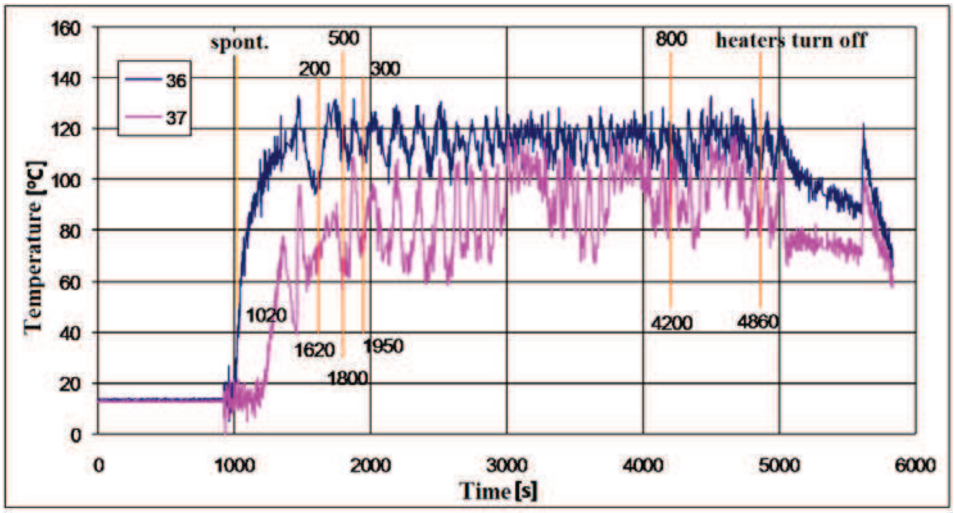

Fig. 10. Temperature courses in the cooling system at 90% of the system filling in the coolant with speed control of the water pump: 36 – flow of the liquid to the cooler, 37 – outflow of the liquid from the cooler
(the upper description – pump engine speed, the description of the bottom – rotation speed change time)

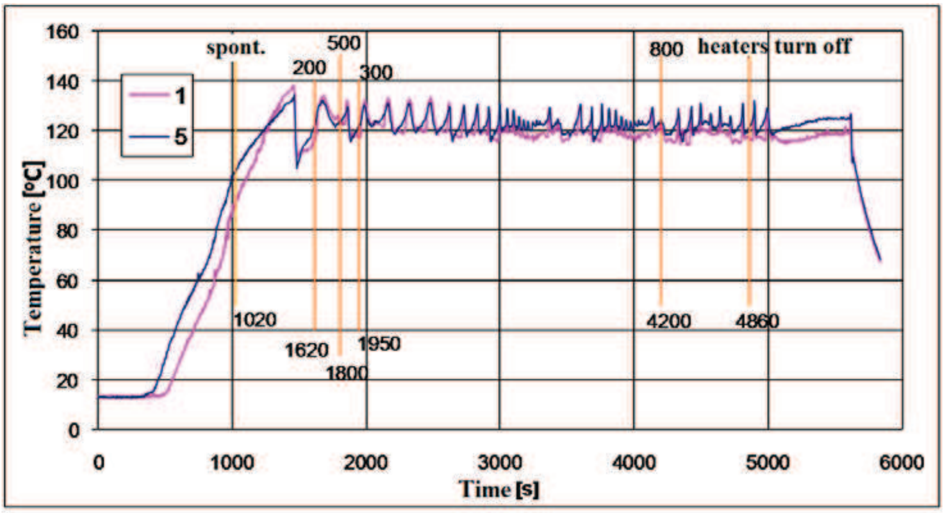

Fig. 11. Temperature courses in the cooling system at 90% of the system filling in the coolant with speed control of the water pump: 1 – engine head before 1 cylinder, 5 – engine head behind 4 cylinder
(the upper description – pump engine speed, the description of the bottom – rotation speed change time)

The temperature of the coolant flowing to the radiator (T36) changed within the limits of 110 ÷ 130°C throughout the study period, while the temperature of the coolant flowing (T37) from the radiator was lower and was at the level of 70 to 105°C and increased up to 112°C (Fig. 10). Courses temperature in the cylinder head are characterized by relatively high uniformity, and the temperature measured in the head at point T1 and T5 varied in the range 120 ÷ 130°C (Fig. 11).

The characteristics show that the method of adjustment by changing the intensity of the cooling speed, and thus the water pump flow rate, it is much more effective way to maintain required pressure and temperature. Courses of both temperature and pressure, as compared to the intensity of the throttle, are more uniform, and moreover is relatively easy to control the intensity of the cooling system.

4. Conclusions

During the test the cooling system was filled with coolant at 90%. The degree of filling of the liquid was recognized for the optimum preliminary studies because the greater amount of water in the system to cause difficulties in obtaining high temperatures, but with a smaller amount of liquid vortex centrifugal pump had problems with the rib.

During the study checked two ways to adjust the pump capacity, ie, by throttling the discharge and change of speed. The first way of pump flow control, and thus the intensity of the cooling is not efficient. Small throttling does not affect the change. Large throttling of flow causes significant the disorder, and work of water pump, similar to those that occur during the filling of a small liquid.

The second way to control the flow of liquid by means the pump speed changes of water is more effective than the control efficiency by throttling of the discharge. It is easier to maintain the pressure established. In addition, system more responsive to changes in pump speed, causing a corresponding change in the liquid flow rate. Therefore, the control flow by changing the speed of rotation was used in further studies.

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