SIMULATION RESEARCHES OF INFLUENCE OF COMPENSATION TANK VOLUME ON CONTROL PARAMETERS OF COOLING LIQUID TEMPERATURE IN THE PISTON COMBUSTION ENGINE

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Abstract

Mathematical model for simulation of operation of the cooling system for the combustion engine with the equalizing tank was described in this paper. Results of digital simulation of influence of the air volume changes in equalizing reservoir on the control parameters of liquid temperature in the cooling system were presented. Simulation model was worked out in AmeSim computation system. It was put that the temperature of the cooling liquid should be raised up to 125-130°C and the liquid pressure inside cooling system will be the main control parameter for pressure limited up to 0.3 MPa. Acceptable value of the pressure was provided by changing of liquid cooling intensity realized by switching two ventilators. The simulated courses of pressure, temperature, streams of heat bringing to the cooling system, efficiency of the liquid cooling pump as well frequency of turning the ventilator were presented in this paper. It was also shown, that is possible to achieve the acceptable pressure level up to 0.3 MPa with interval ± 0.005 MPa and obtain higher temperature of the liquid up to assumed value. It was shown that increasing air volume in the equalizing tank resulted decreasing frequency of fun turning. The optimum capacity of the equalizing reservoir was determined.

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

1. Introduction

In the piston internal-combustion engines only the part of the energy received during burning fuel is converted to useful work (Fig. 1). The energy which wasn't exchanged for the useful work, is dissipated to the atmosphere by the hot exhaust fumes, discharged by the cooling system, as well as radiating from the surface of the engine [1, 2].

An analysis of measurement results and literature data shows that about one third of separated fuel in the combustion process is discharged into the environment by the engine cooling system [3, 6, 10]. Reducing the amount of heat discharged by the cooling system will cause increasing the temperature of the engine coolant, but part of this heat can be used for increasing the useful work.

A rise in temperature of the coolant requires adapting of the cooling system for acting at the increased pressure, since a boiling point of cooling liquid depends on value of the pressure. Moreover, with increasing temperature rises a volume of liquid cooling, but this process rapidly accelerates during boiling bubble with a separation of water vapor. If simultaneously a volume of the cooling system isn't rising, then a fast rise in pressure is coming in the cooling system [3, 7]. These circumstances relate to the operation of the cooling system into account in the development of the simulation model and the simulation of the work of such a system. At the established, acceptable maximum pressure action of cooling system was simulated while increasing the volume of the tank space, or the quantity of liquid in the cooling system at a constant volume of the tank.

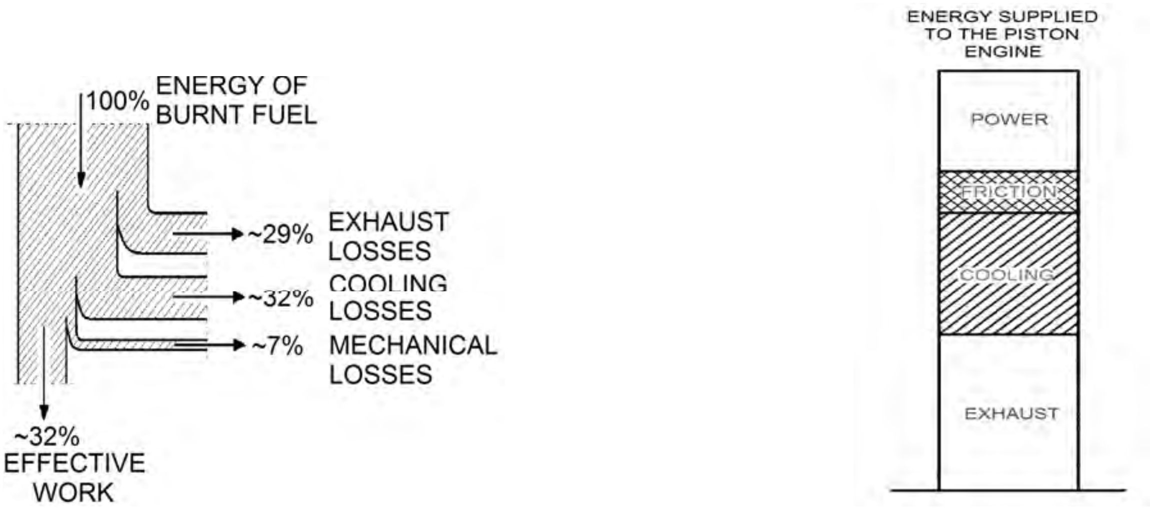

Fig. 1. Example of the heat balance of the piston internal-combustion engine [2, 12]

2. Mathematical model of the engine cooling system developed in AMESIM software

The mathematical model of the cooling system was developed in the AMESIM software on the basis of the scheme of the test stand with such a system. With block schemes of individual elements and teams of the diesel engine 4CT90 a structure of the test stand with the experimental cooling system was described [4, 9, 12].

a) b)

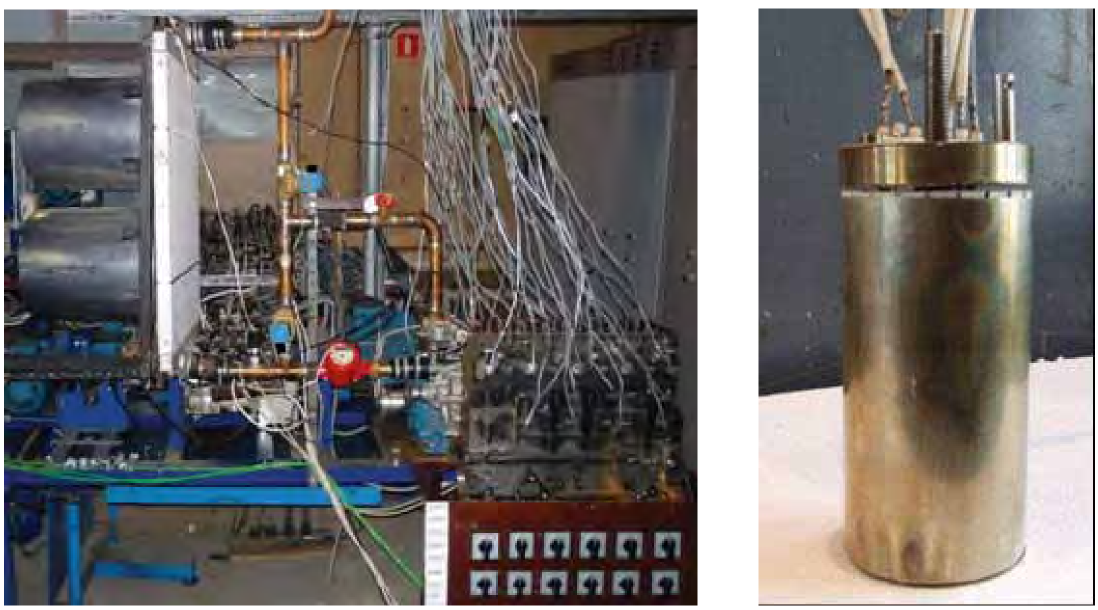

Fig. 2. The experimental research stand for cooling systems investigation: a) stand view, b) heating set

The experimental stand was built at using original elements and units of the 4CT90 engine (Fig. 2a). Instead of a combustion chamber units of electric immersion heaters, installed in every cylinder, fed with the energy were applied electric from the electric network (Fig. 2b). Immersion heaters had a length of the travel of a piston and were divided into three segments with different power: the highest of any segment of the heater power had 2.5 kW, central one had 1.5 kW, but the lowest one had a power of 1 kW. The test stand was equipped with thermoelements located in the engine block and the head, as well as into thermoelements placed in the system of heat exchange with the environment.

Two cooling fans placed in the channels with the sensors to enable measurement of the temperature and the rate of air flow. Channels of cooling liquid during measurements were shielded with foam reducing losses of the heat. The centrifugal water pump was driven with the electric motor, of which the rotation speed was controlled with the programmed inverter what enabled to control intensity of cooling by changing the coolant flow rate [5, 8]. Flow of liquid between the small and large circulation, was controlled with solenoid valves. The pressure in the system was measured with the electric manometer.

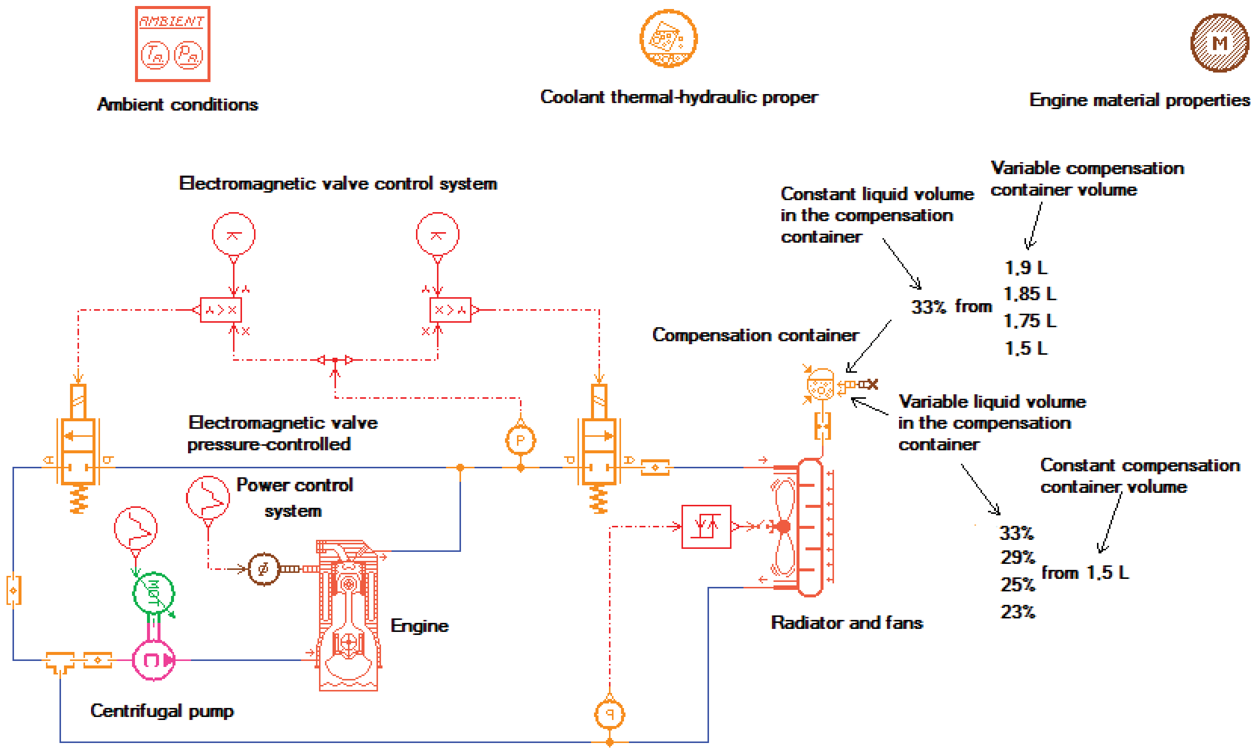

Fig. 3. The scheme of model stand of the cooling system developed in Amesim software

The model of the cooling system stored in the computing system AmeSim illustrates Fig. 3. In this model the segment representing the piston internal-combustion engine was changed. A piston-crank system was eliminated, and instead of it elements representing the block of the engine were entered with the system of permeating the heat through the walls and transferring the heat to the coolant given off by the electric heaters of various power. The representing block of the compensatory container enables the change of the content of cooling liquid in the container and the change volumes of this factor. Individual cases taken into account during calculations were described in Fig. 3. Using the model in the AmeSim software calculations and simulations courses of the pressure, temperatures and coolant pump flow rate, as well as of the flow of the heat stream and the work of fans for different air volumes in the compensatory container in the function of the time of heating up and heating the system up at establishing inside the acceptable pressure of system were performed.

3. Results of the simulation in the AmeSim software

During simulation research an influence of the participation of air in the volume of the closed compensatory container about the constant of the volume and the container about the increased volume to the temperature of liquid in the cooling system at the established limited pressure in the system to 0.3 MPa was examined. The first calculations were performed for following input data: initial pressure in the cooling system of 0.1 MPa, filling liquid up in the compensatory container of the 33%, what at v_{cc}=1.5 dm^3 of the volume of the container proves that in the container it was 1 dm^3 of air. The maximum pressure during the work of the cooling system was kept on the level 0.295-0.305 MPa (Fig. 3a) by changing the flow of liquid over in large and small circulations and through turning fans on (Fig. 3c). At such a way of controlling a temperature was get on the exit from the engine and the entry to the radiator within the limits of 114°C-117°C at the temperature of liquid on the exit from the radiator in the range 90°C-105°C (Fig. 3b). Since at the change of filling the compensatory container up with liquid all courses have very similar character, it was only described for one above described case, in addition courses of the temperature differed in only get values of the average temperature.

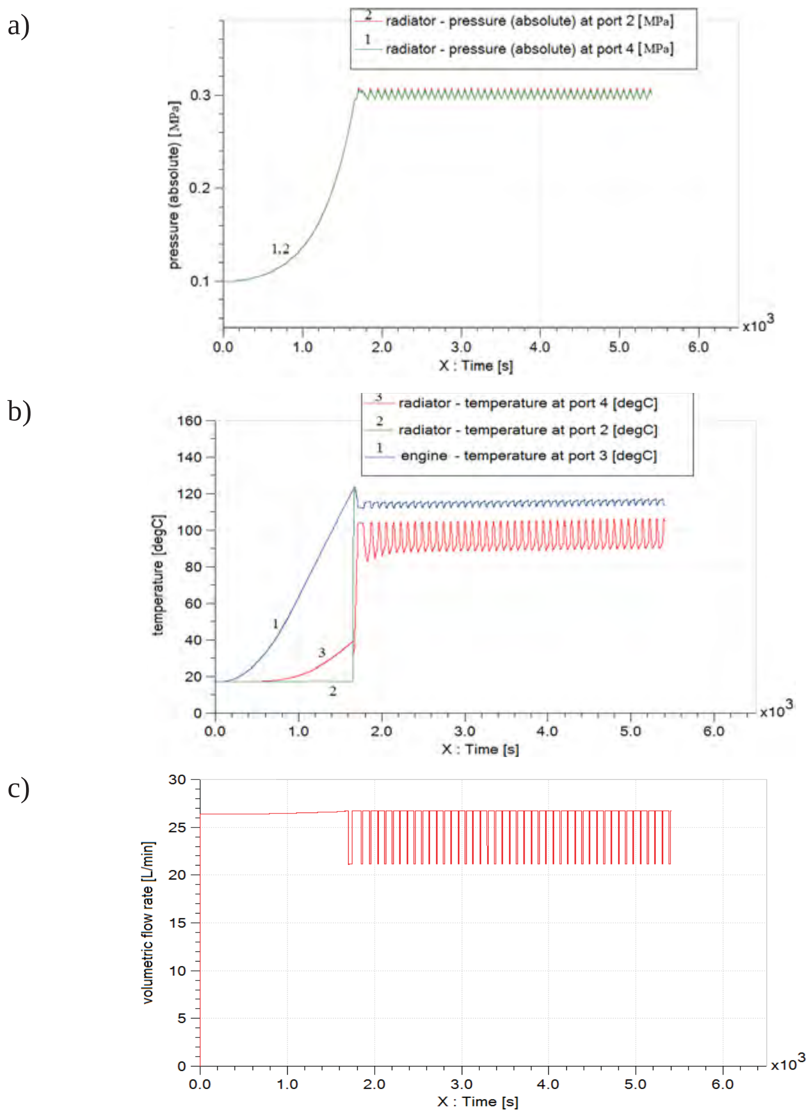

Fig. 3. Courses characteristics of chosen parameters of the simulated work of the cooling system at the pressure of 0.2 MPa and 33% of the filling up the compensatory container: a) course of the pressure: 1 – in the small circulation, 2 – in the large circulation, b) course of the temperature: 1 – exit from the block of cylinders, 2 – entry to the radiator, 3 – exit from the radiator, cooling c) course of the coolant pump flow

Next simulations were performed reducing the content of liquid in the compensatory container to 29%, at the maximum pressure in the range 0.295-0.305 MPa. Curtailment of liquid let on increasing the temperature on the exit from the engine and entering the radiator, as well as on the exit from the radiator about 5°C. Next calculations were performed for the 25% and the 23% of filling up the compensatory container with liquid. At the same maximum pressure they got on the output of the liquid of the radiator appropriately about 13°C and 15°C higher than for filling the 33% up. The temperature on the exit from the engine and the entry to the radiator in these conditions rose appropriately about 9°C and 13°C what is determining that the maximum achieved temperature on the entry to the radiator (for exit from the engine) took out 130°C, however on output 120°C. Next simulations were performed for at first established 33% of the content of liquid in the compensatory container and the same pressure 0.295-0.305 MPa at the increase in the volume of the compensatory container, and hence large amounts of air in the container. On account of the fact that remaining parameters remained unchanged, but courses of the pressure, the work of fans, the coolant pump flow and the stream of the flow are very similar, they weren't introduced in the paper. As regards courses of temperatures, it for v_{cc} = 1.75 dm^3 of the volume of the compensatory container, the temperature on the exit from the engine and the entry to the radiator shapes on level 130°C, and on the exit from the radiator is included within the limits of 103°C-120°C (Fig. 4).

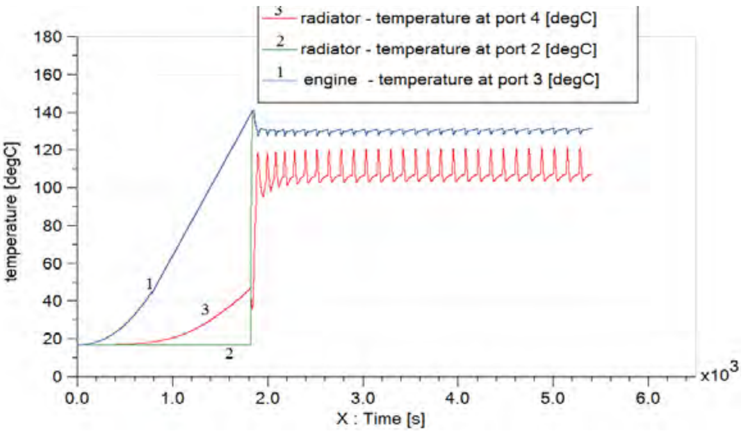

Fig. 4. Courses characteristic of the temperature at the pressure of 0.2 MPa and 33% of the filling with the liquid of the compensatory container for capacity 1.75 dm3: 1 – exit from the block of cylinders, 2 – entry to the radiator, 3 – exit from the radiator

By the compensatory container for capacities v_{cc} =1.85 dm^3 filled up in 33% with the coolant, temperature on the exit from the engine and the entry to the radiator gained out about 133°C, however on the exit from the radiator the temperature was included within the limits of 110°C-125°C. Another increase in the volume of the container to 1.9 dm^3, caused the other, more unstable course which took turns with the passage of time. It is visible particularly on the course of the pressure (Fig. 5). It results from it that further enlarging the volume of the compensatory container won't cause the improvement in parameters and stable action of the system of cooling. Temperature on the exit from the engine and the entry to the radiator gained out about 140°C, and on the exit from the radiator - 113°C-130°C. After simulation calculations at the established pressure of environment of 0.2 MPa simulations of the work of the system were still performed at the maximum pressure of 0.3 MPa and the 33% for filling the compensatory container up for v_{cc}=1.5 dm^3. In this case a temperature was get on the exit from the engine about 130°C which in the radiator is reducing to level 102°C-117°C. After lowering the level of liquid cooling volumes of the container up to the 25% an irregular and unstable course took place. Simultaneous increasing the pressure by 0.1 MPa and increasing the air volume aren't having the desired effect, and the system is working irregularly.

a)

b)

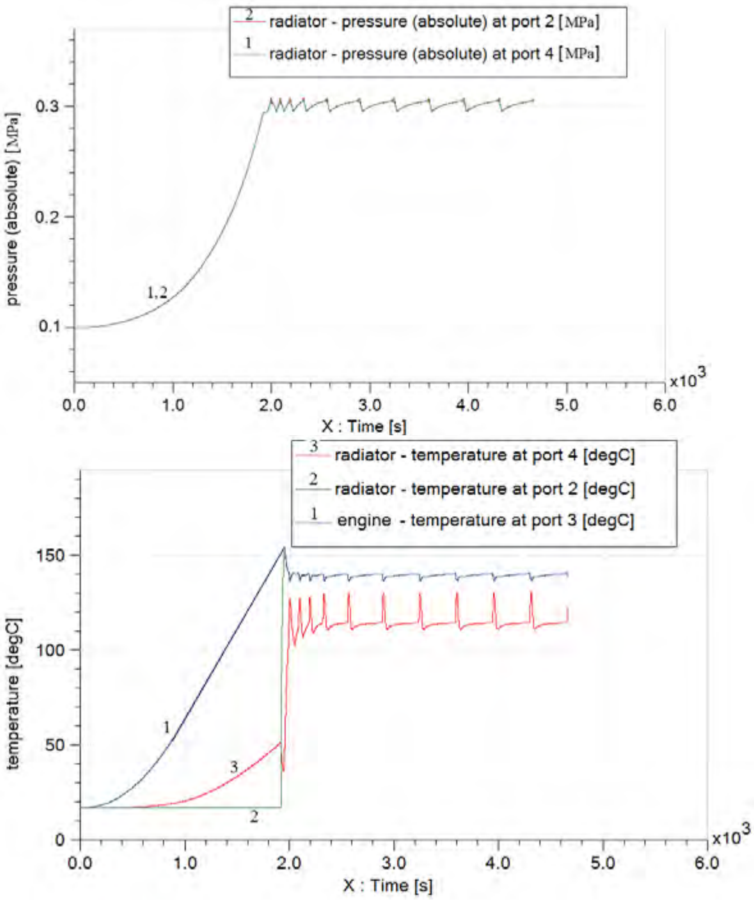

Fig. 5. Courses characteristics at the pressure of 0,2 MPa and 33% of filling up with coolant of the compensatory container for capacity 1.9 dm3: a) course of the pressure: 1 – in the small circulation, 2 – in the large circulation, b) course of the temperature: 1 – exit from the block of cylinders, 2 – entry to the radiator, 3 – exit from the radiator

4. Estimation and comparison chosen parameters

On the basis of simulation research characteristic parameters of these courses were put together: the maximum temperature, growing of the temperature in the time, of stream of the heat provided the system of cooling and the frequency of including and excluding the fan in the function of the amount entrusts in the compensatory container. All parameters were determined for different air volumes in the compensatory container, in the first case at reducing the number of liquid in the compensatory container, and in second at increasing the volume of the compensatory container. As can be seen on Fig. 6, the rise in the air volume about 0.15 dm^3 causes a rise in temperature around 115°C to 130°C in the first case, to about 140°C in the second case what is an effect of the further increase in the volume at the established pressure.

Growing of the temperature in the cooling system is described in Fig. 7 which is growing up linearly according to the given equation. They after analysis of all examples state, that change of the air volume located in a compensatory container isn't affecting the increase in a temperature, with result of what there is the same increase in a temperature for every case.

In case of the time of turn on and turn off the fan providing maintaining its position established pressure in range 3-0.005 MPa, it courses in are similar (Fig. 8), i.e. just enough of increasing the air volume in the compensatory container the time of turning the fan on is similar in the entire scope and amounts to the about 40-50 sec., however – shutdowns are being extended from 50 sec. at 1 dm^3 to the about 350 sec. at v_{cc} = 1.266 dm^3 (reducing the number of liquid in the container) and 90 sec. at v_{cc} = 1.155 dm^3 (increasing the volume of the container).

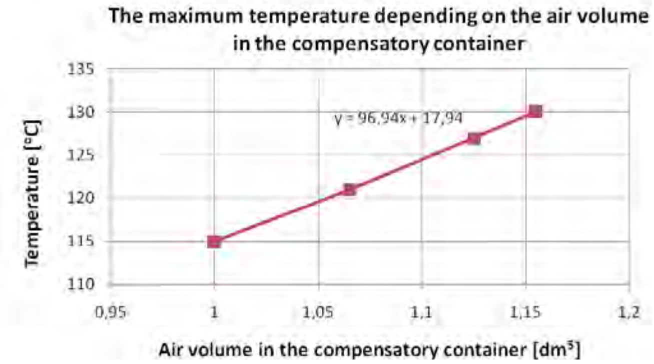

Fig. 6. Rise in temperature maximum in the function of the air volume in the compensatory container of the effect of reducing the number of liquid in the container

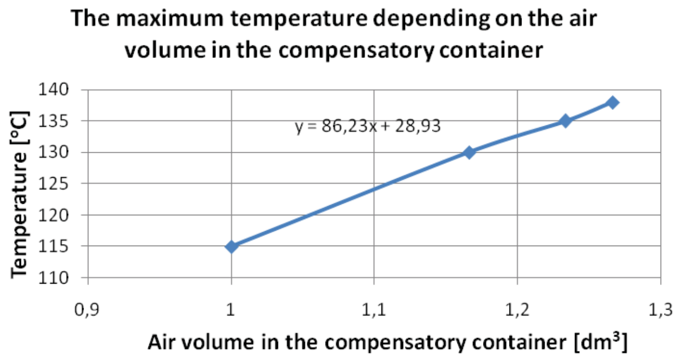

Fig. 7. Rise in temperature maximum in the function of the air volume in the compensatory container of the effect of increasing the volume of the container

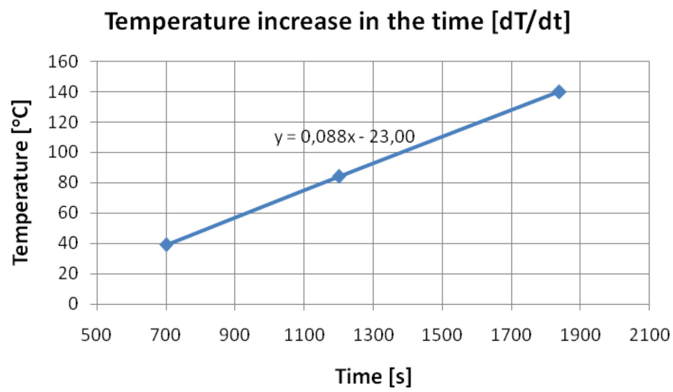

Fig. 8. Dependence of growing of the temperature in the time from the air volume in the compensatory container

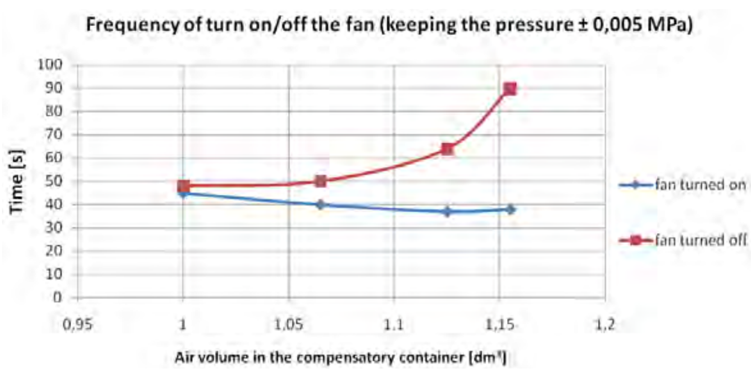

Fig. 9. Dependence of working hours of the fan after turn on liquid from the air volume in the compensatory container into results of reducing the number in the container

5. Conclusions

1. The model of the cooling system described in this paper was made out on the basis of the acting position. Simulation research and the verification of results on the experimental test stand were described at the work [11].
2. As a result of simulation research made at using the model of the system of cooling in the AmeSim software they stated the increase of the amount of air in the closed cooling system enables its work to increase the temperature.
3. The computational temperature of cooling liquid is rising from 115°C to 130°C at increasing the air volume by 0.15 dm^3 as a result of reducing the number of liquid in the compensatory container for capacities 1.5 dm^3 and filled up with water in the amount 0.5 dm^3 (total capacity of system 11 dm^3) and from 115°C to 140°C at the rise in the air volume about 0.27 dm^3 and the volume of liquid 0.5 dm3 as a result of the increase in the volume of the container. Calculations were conducted at the established maximum pressure in the cooling system of 0.3 MPa.
4. The rise in the air volume in the compensatory container affected the frequency of turning fans on. Working time of the fan are similar in the entire scope and took the about 40-50 sec. out. However a period grew longer between turn on 1.15 dm^3 from 50 sec. at 1 dm^3 of air at the air volume in the about 350 sec. (reducing the number of liquid in the container by 0.15 dm^3) and up to 90 sec. at the air volume 1.27 dm^3 (increasing the volume of the container by 0.27 dm^3).
5. In order to get the increased temperature in the system of cooling the engine in further research incomplete filling the system should be included in the greater degree and to increase the capacity of the compensatory container. Better results are being get as a result of applying of the additional free volume of the system, in which perhaps widening is taking place the radiator liquid as well as steam is accumulating.

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