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METHOD OF IMPROVING ENERGY, ECOLOGICAL AND STENGTH CHARACTERISTICS OF THE VEHICLE DIESEL ENGINE

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Abstract. *The article deals with a complex method of deterioration of economic, ecological, and strength indicators of 16ЧН26/27 transport diesel engine. According to the offered method, there were considered conjugated problems applicable to the transport diesel engine combustion chamber and cooling cavities of the cylinder head. Based on the complex research conducted.*

Key words: *diesel engine, conjugated problem, level of strains, finite element method.*

МЕТОДИКА СОВЕРШЕНСТВОВАНИЯ ЭНЕРГО-ЭКОЛОГИЧЕСКИХ И ПРОЧНОСТНЫХ ПОКАЗАТЕЛЕЙ ТРАНСПОРТНОГО ДИЗЕЛЯ

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Аннотация. *Рассмотрена методика улучшения экономических, экологических и прочностных показателей транспортного дизеля 16ЧН26/27. Согласно предложенной методики с использованием численных методов рассматриваются сопряженные задачи для камеры сгорания дизеля и полостей охлаждения головки цилиндра.*

Ключевые слова: *дизель, сопряженная задача, уровень напряжений, метод конечных элементов.*

МЕТОДИКА ВДОСКОНАЛЕННЯ ЕНЕРГО-ЕКОЛОГІЧНИХ ТА МІЦНІСНИХ ПОКАЗНИКІВ ТРАНСПОРТНОГО ДИЗЕЛЯ

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Анотація. *Розглянуто методику поліпшення економічних, екологічних та міцнісних показників транспортного дизеля 16ЧН26/27. Згідно із запропонованою методикою з використання чисельних методів розглядаються спряжені задачі для камери згоряння дизеля та порожнин охолодження головки циліндра.*

Ключові слова: *дизель, спряжена задача, рівень напружень, метод скінчених елементів.*

Introduction

Improving the economic, environmental and resource indicators of modern internal combustion engines (ICE) should be considered as a comprehensive task that requires concerted research in the field of workflows, fuel equipment, control systems, assessment of temperature levels, stress and strain of the combustion chamber components as well as environmental performance evaluation. With regard to the high-powered vehicle diesel engines, taking into account the modern methods of arranging the working cycle of the diesel engine [1-11] it is necessary to take into account the mutual influence of changes in the operating cycle parameters on the level of thermal and mechanical strength of the combustion chamber parts. Solution of conjugate tasks gas-wall allows revealing the main influencing factors on the studied parameters and reducing the cost of finishing the diesel engine.

Content analysis

The world's leading companies dealing with operational development of ICE, for example, such as AVL [12] use an integrated approach that involves consideration of the operating cycle as well as heat tension of the combustion chamber parts (conjugate problem). At this, the researchers do not only consider individual parts but groups of parts that form the combustion chamber (head, piston, cylinder and valves). This approach allows assessing the relative influence of various factors, and improving the accuracy of the results obtained during the study. One of the promising directions of improving the methodology of design estimation of the heat-stressed state of (HSS) the cylinder head is the approach according to which the conjugate problem while modeling the process of heat exchange between the walls of the cooling cavities and the cooling fluid can be solved [12]. As it is known, the cylinder head is a part of a very complex internal and external form.

The configuration of the cooling cavity has a decisive influence on the process of coolant circulation and heat dissipation efficiency from the most heat-stressed areas of the cylinder head fire bottom. Consideration of the dual problem for the cooling cavity in simulation of HSS of the cylinder head allows performing a more correct description of boundary conditions of the heat conduction problem and, thus, improving the accuracy of the results of subsequent HSS modeling [12].Hence, we can conclude that the improvement of techniques to upgrade the economic, environmental and durability rates of modern diesel engines by using complex numerical modeling of heat mass transfer processes is an important and promising trend in the development of the internal combustion engine.

The purpose and task setting

Purpose – to develop a comprehensive methodology for improving the economic, environmental and strength characteristics of a vehicle diesel engine, using numerical methods.

The paper deals with the following tasks:
– to conduct a literature review on modern methods of modeling diesel engine workflows, assessment of their environmental and strength indicators;
– hydrodynamic modeling of heat transfer processes in the cooling cavities of the diesel engine cylinder head (conjugate problem);
– numerical modeling of the diesel engine operating cycle;
– calculation of the thermal stress state of the diesel engine combustion chamber parts (conjugate problem);
– formation of conclusions and recommendations on the specifics of using a complex technique to improve the economic, environmental and strength characteristics of modern vehicle diesel engines.

Main stages and results of the study

The main stages and results of the study. The object of study is the energy and environmental performance and strength characteristics of a vehicle diesel engine when operating in a rated power mode. The algorithm of the conducted comprehensive study is shown in fig. 1.

For hydrodynamic modeling of the heat transfer process in the cooling cavities there was synthesized a design area and a computational grid that describes the configuration of the cylinder head cooling cavities. Further, there was formed an array of boundary conditions to describe the process of coolant circulation in the cooling cavities of the cylinder head and the conditions of heat exchange fluid - wall. The main results of hydrodynamic modeling of heat transfer processes in the cooling cavities of the diesel engine cylinder head are shown in fig. 2.

The estimation grid describing the complex configuration of the cylinder head cooling cavities is shown in fig. 2, a. The grid has 1200340 computational cells. Calculated distribution of the coolant flow rate in the cooling cavities is shown in fig. 2, b. The flow rate ranges from 2 to 12 m/s. The distribution of the coolant temperature during the cooling fluid circulation in the cavities of the cylinder head is shown in

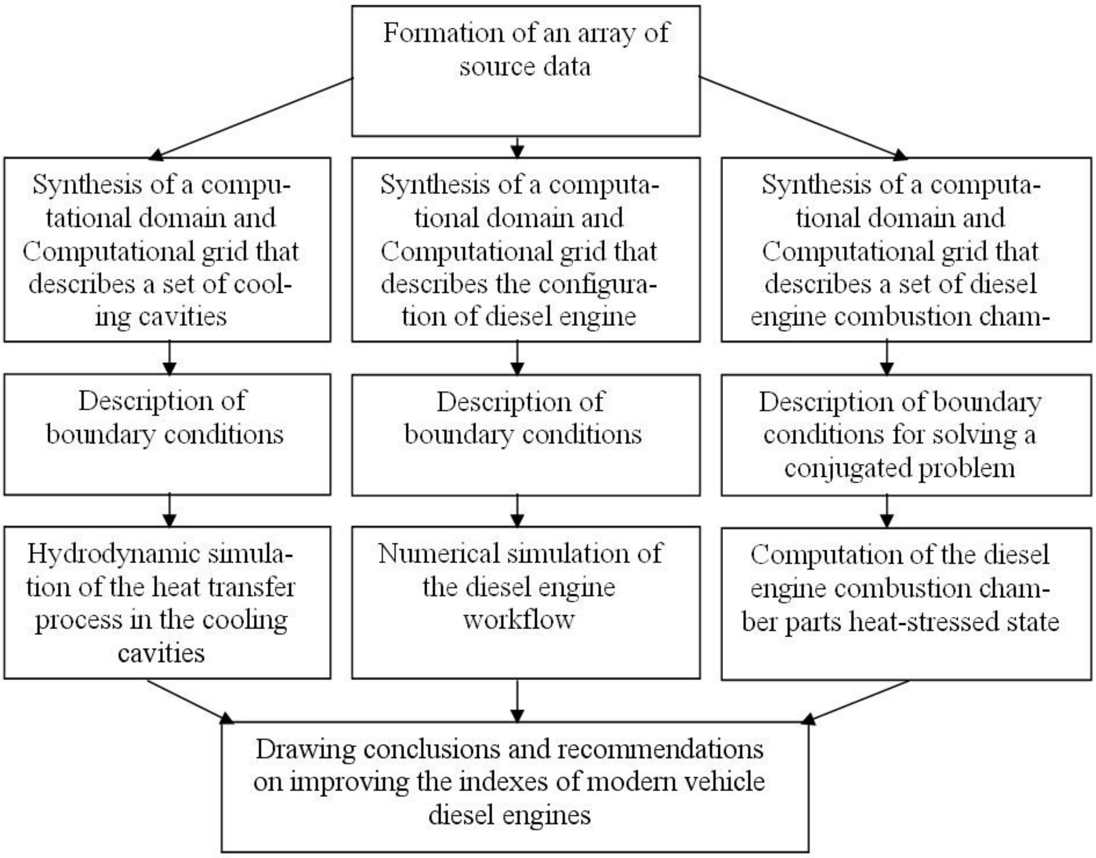
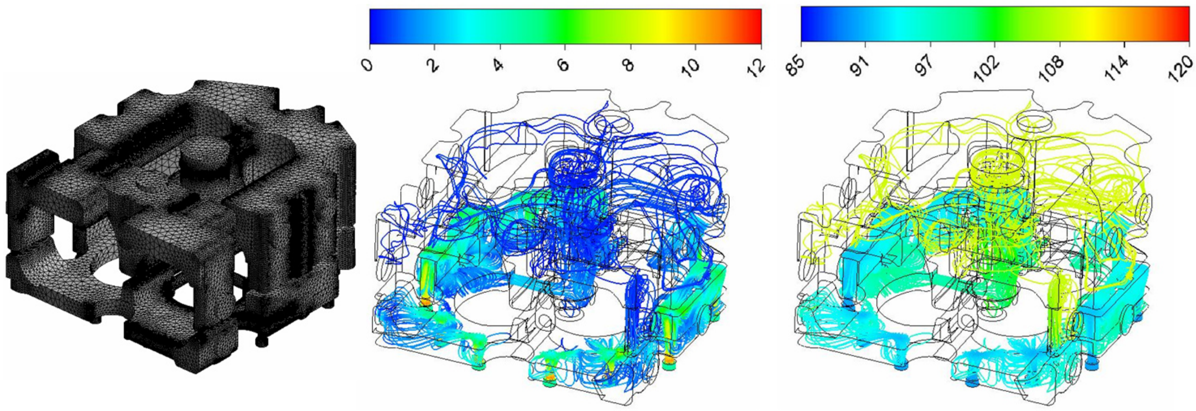


Fig. 1. Algorithm of the conducted comprehensive study



a b c

Fig. 2. Numerical simulation of heat transfer between the walls of the cooling cavities and the coolant: a – computational grid; b – distribution of the coolant flow rate, m/s; c – distribution of the coolant temperature, °C

Fig. 2, b. The maximum coolant temperature reached 112 °C, and on the average it is in the range of 93–105 °C (fig. 2, c). Further, there was carried out numerical modeling of the three-dimensional diesel engine working cycle. Features of the technique of the working cycle simulation are discussed in detail in work [9]. When modeling there were dealt with the processes of fresh charge intake, fuel injection, mixture formation and combustion as well as combustion products formation. The main results of diesel engine numerical simulation are shown in fig. 3.

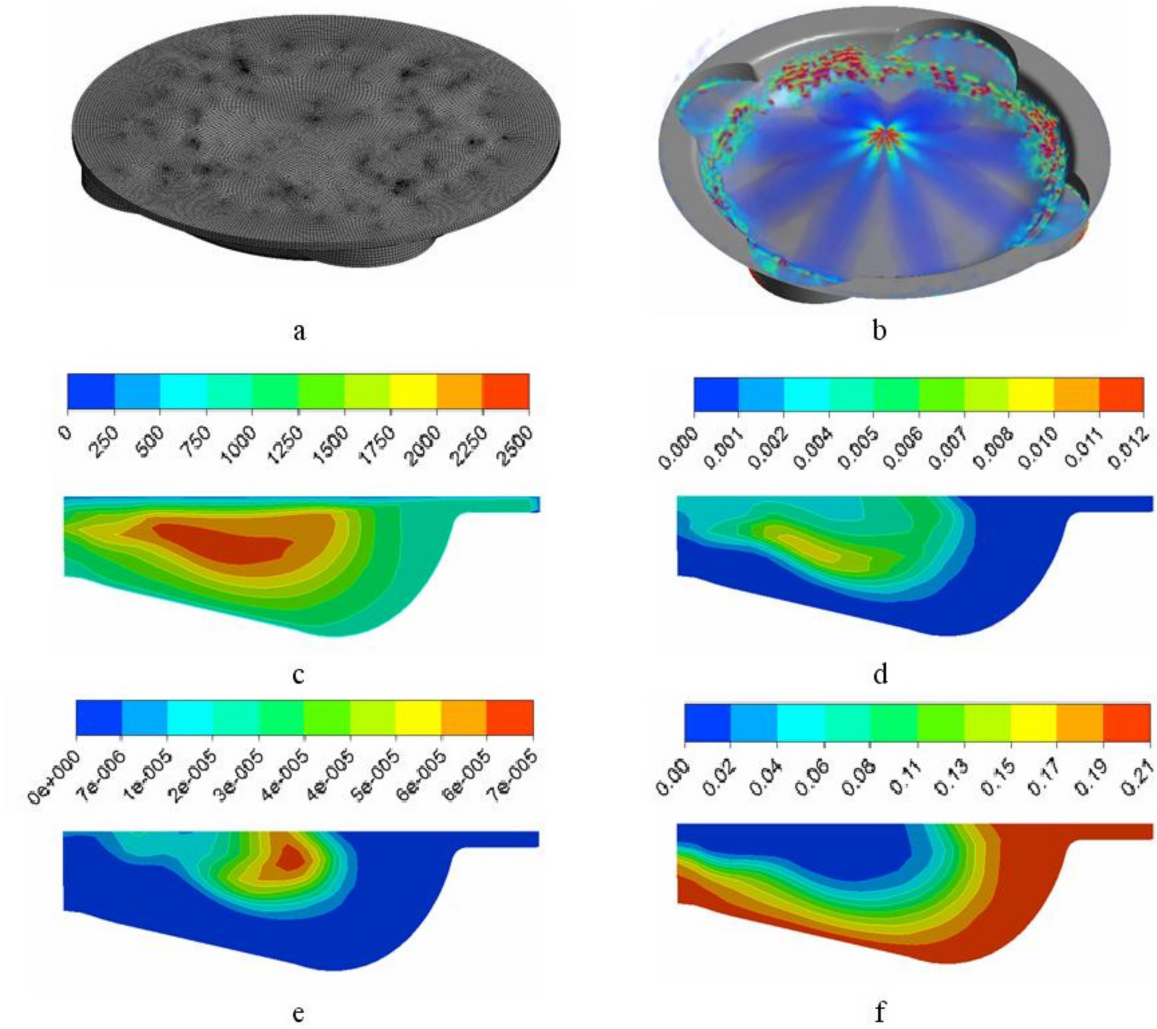


Fig. 3. Numerical modeling of the diesel engine working cycle: a – computational grid; b – fuel distribution over the volume of the COP (simulation of the injection process); c – temperature distribution in section K of the COP; d – distribution of the mass fraction of NO in the cross section of the COP; e – distribution of solid particles in the cross section of the COP, kg/m^3, f – distribution of the mass fraction of O_2 in the cross section of the COP (φ = 352 deg.)

The estimated grid describing the configuration of the combustion chamber is shown in fig. 3.The grid numbers 2124500 computational cells. The results of modeling of the fuel injection process – distribution of fuel torches in the combustion chamber are shown in fig. 3, b. The temperature distribution in the combustion chamber of a diesel engine is shown in fig. 3, b. The maximum design temperature in the combustion chamber reaches 2500 K, and near the walls of the combustion chamber the temperature varies from 850 to 1300 K. Distribution of the mass fraction of NO in the cross section of the combustion chamber is shown in fig. 3, g. Distribution of solid particles in the cross section of the combustion chamber is shown in fig. 3, d. Distribution of the mass fraction of O_2 in the cross section of the combustion chamber is shown in fig. 3, e, as it can be seen from the presented results, the combustion process is characterized by high local values of the coefficient of excess air, which is typical for the surround mixing method, implemented in the test vehicle diesel engine.

The estimated indicator diagram when the diesel engine is in operation in the rated power mode is shown in fig. 4. The maximum combustion pressure reaches 11.8 MPa.

Using the results of calculation of the diesel engine working cycle, further there will be analyzed the nature of distribution of heat conduction problem boundary conditions for areas of the heat transfer surface of the combustion chamber components, compared and made consistent with the resulting heat-transfer coefficient from the gas to the walls of the combustion chamber as described in Annand method [13] (fig. 5) and then, in the given work there was carried out calculation of the heat-stressed state of the most loaded parts of the combustion chamber. Results of calculation of the thermal state of the fire bottom of the cylinder head and piston is shown in fig. 6.

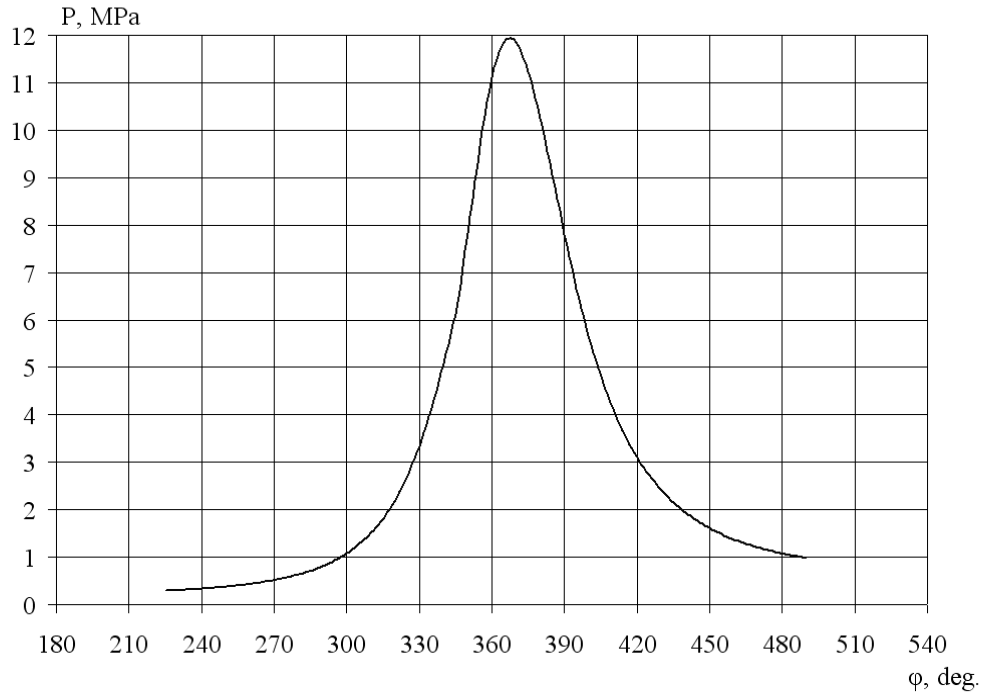


Fig. 4. Indicator diagram

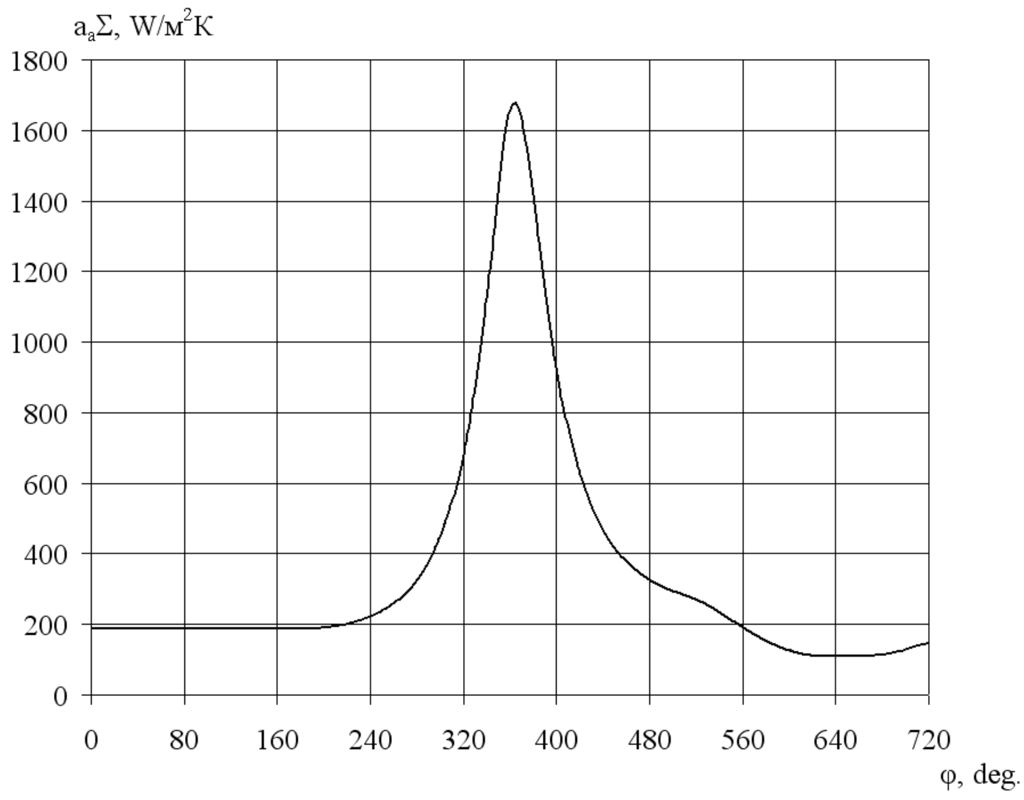


Fig. 5. Changes of the resulting heat transfer coefficient from the gas to the walls of the combustion chamber according to Annand method

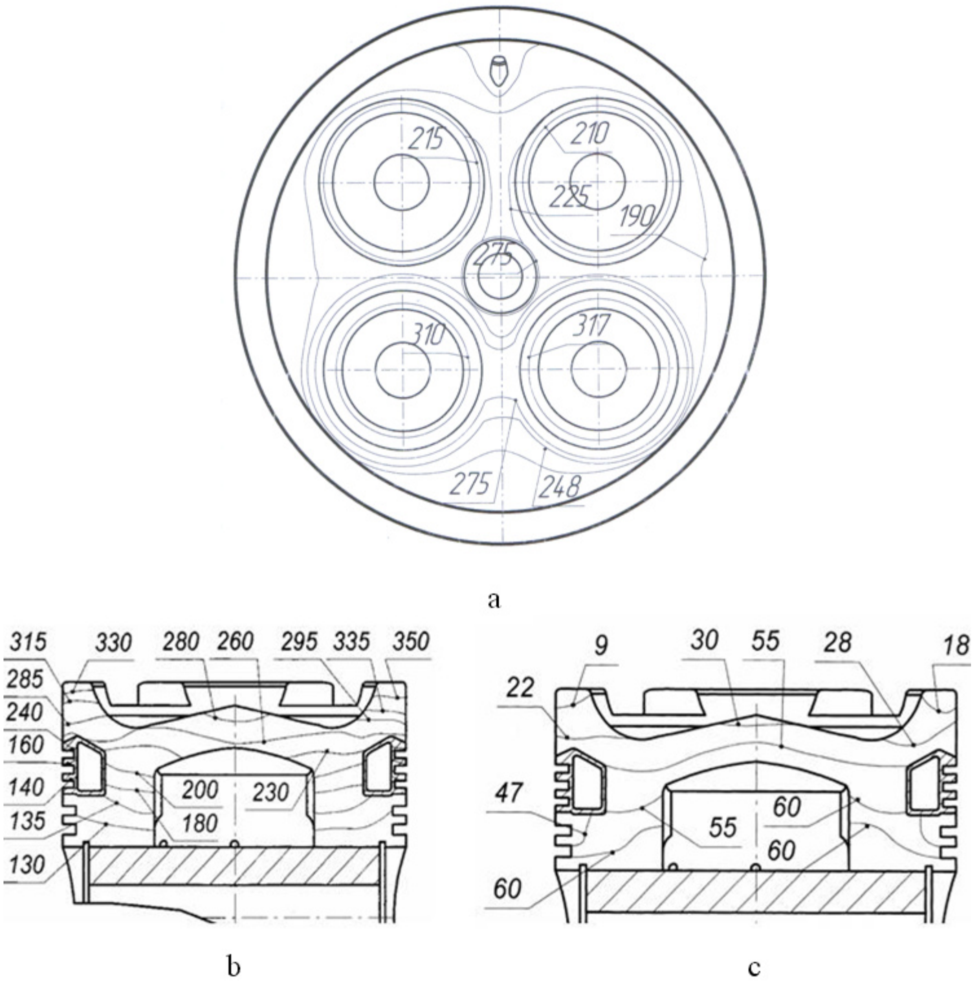


Fig. 6. Results of calculation of particular parts of the combustion chamber: a – fire bottom temperature distribution of the cylinder head, ° C; b, c – piston temperature distribution, °C and stress intensities, MPa in the meridian section along the piston pin axis

Maximum design temperature of the fire bottom of the cylinder head is marked in the injector hole – 275 °C (fig. 6, a). In the area of exhaust valves seats the temperature varies from 248 to 317 °C. In the area of the intake valves seats – from 210 to 225 °C, and in the peripheral areas of the fire bottom the temperature varies from 200 to 180 °C (fig. 6, a).

The temperature in the piston head of the exhaust valves samples is an average of 340–350 ° C, and the temperature of the intake valves samples was 330 °C (fig. 6, b). Circumferential unevenness of the temperature field of the piston fire bottom reaches 45–55 ° C (not shown in the fig.). The central part of the piston fire bottom in the propellant region reaches the temperature of 260–280 °C. In the region of the ring holder the temperature varies from 240 to 140 °C and in the scraper region the temperature ranges from 140 to 130 ° C (fig. 6, b).

The stress intensity in the central part of the piston fire bottom ranges from 35 to 55 MPa (fig. 6, b). In the samples, in the piston head near the valves the stress intensity varies from 9 to 18 MPa. In the region of ring holder the stress intensity ranges from 47 to 60 MPa (fig. 6, c).

Conclusions

According to the results of the comprehensive study, the following can be noted:

– solution of the dual problem gas-wall - joint consideration of the operating cycle of the diesel engine and the heat-stressed condition of the combustion chamber parts allows at a fundamentally new level explore the mutual influence of design, adjustment and mode parameters on the economic, environmental and strength characteristics of the diesel engine;

– hydrodynamic modeling of the heat transfer processes in the cylinder head cooling cavities in

the solution of the dual problem with respect to the cylinder head allows to more correctly describe the boundary conditions of the heat conduction problem and, thus, improve the accuracy and reliability of the results obtained;
– the considered complex technique makes it possible to significantly reduce the time spent on finishing the diesel engine and improve its technical, economic, environmental and strength characteristics.

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