

# DECREASE OF HEAT LOAD DENSITY OF CYLINDER-PISTON GROUP DETAILS

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## Introduction

The present research work is aimed at the investigation on heat load density of cylinder-piston group details in piston internal combustion engine. Development modern engine-building is connected with obtaining of optimum technical and economic characteristic of the internal combustion engine and that conducts to growth of thermal stress level of the components exposed to heat load. Cylinder-piston group details are subjected to maximum thermal stress. New and operative solutions are necessary at designing and operational development of the engine, which first of all are directed to optimisation of a design and perfection of working processes to force power density, to improve economic and ecological parameters, to gain optimum parameters.

The paper describes definition method of heat condition and ways of decrease of heat load density of cylinder-piston group details. The work presents also the definition method of heat condition by means of sensing transducers «IMTK» (the metre of the maximum temperatures crystal).

The basic ways of decrease of heat load density of cylinder-piston group details are the certain constructive changes of a detail promoting decrease of a thermal resistance of a detail, or temperature drop decrease in details, certain changes of parameters of the engine operation at invariable engine load and engine speed leaders to decrease in temperatures of a cycle.

In the experimental way definition of local temperatures difficultly and in some cases is impossible. Analytical definition of a heat condition does not possess the practical significance as for that solution considerable simplifications and assumptions are characteristic.

To define ways of decrease of heat load density of cylinder-piston group details, the knowledge of a heat condition of these details is necessary. Promptly and qualitatively to solve a problem of decrease of heat load density it is impossible without promptly of physical processes proceeding in the engine.

## Technical paper

Development modern engine-building is connected with obtaining of optimum technical and economic characteristic of the internal combustion engine and that conducts to growth of thermal stress level of the components exposed to heat load. Cylinder-piston group details are subjected to maximum thermal stress. The thermal stress of the detail is determined similarly by its temperature and temperature gradient, and it may appear in different forms. In the heat loaded components of the internal combustion engines significant thermal stress is often generated, in addition to mechanical stresses. Combustion temperatures in the cylinders of internal combustion engines can reach values of 2700 K and higher [14]. Without adequate cooling, temperatures of this magnitude would quickly destroy engine components and lubricants. If cylinder walls are allowed to exceed temperatures above 200°C, material failures would occur and most lubricating oils would break down. The temperature of the combustion chamber wall is an important factor with to mixture formation and combustion process aspect. Precise determination of the heat condition in cylinder-piston group details, particularly in the case of a complicated construction and complicated heat exchange presents is a very difficult problem. Definition of a thermal condition of the heat loaded details of the engine is an actual problem that confirms a lot of tasks linked with heat load density study [2,4,6,12].

The temperature state of the cylinder-piston group details on the steady-state conditions of the engine operation is observed as stationary. Temperature fluctuation of the combustion chamber surface, that

caused by working cycle into the combustion chamber, is passed round only in a surface layer of a detail [2,5,7,10,11,13]. Heat exchange on unsteady conditions of the engine operation is insufficiently studied because of complexity of definition of authentic data of heat exchange boundary conditions.

The greatest complexity is studying of heat exchange of a gas and a piston head. The majority of researches were conducted in a direction of definition of local heat transfer coefficients. Local heat transfer coefficients are defined from average heat transfer coefficient proceeding from characteristic distribution of temperatures in details.

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For decrease thermal heat load density of combustion chamber elements become actual perfection of characteristics of injection of fuel for restriction of intensity of a born-out in a combustion process initial stage.

Design factors rendering essential agencies on heat load density of the engine are the following a thickness of walls of a cooled detail, a thermal resistance on a way of heat flow from heat-stressed section, a flow area of channels for a cooling fluid and arrangement of channels concerning a cooled surface, physical properties of a cooling fluid, a material of details, ways of cooling of the most heat-stressed details, relations of the combustion chamber square to the combustion chamber volume.

Temperature drop in a cylinder sleeve wall decreases if to reduce a thickness of a wall of a cylinder sleeve. The temperature drop the less thermal stress of a detail there is less. Decrease of a thickness of a wall of a cylinder sleeve reduces a wall thermal resistance that conducts to increase in a heat flow in a coolant. For decrease in temperature of a working surface of the cylinder carry out channels in cooling jackets promoting disproportionate of thermal streams. The temperature of the cylinder wall influences the lubrication and wear condition. To avoid thermal breakdown of the lubricating oil, it is necessary to keep the cylinder wall temperatures from exceeding 180°-200°C [13,14]. As lubrication technology improves the quality of oils, this maximum allowable wall temperature is being raised.

The heat load density of a piston depends on a number of design and operational factors. The most important design factors affecting the heat condition of the piston are piston diameter, piston crown thickness in the ring zone. The most important operational factors are piston surface output, oil-cooling of the piston crown, coolant temperature. The piston diameter, in the case of geometrically similar pistons, considerably influences temperature distribution of the piston. Increase the diameter of the piston head lead to increasing temperature. That is results from the fact that the heat flow through a piston head to piston-rings increases. The piston crown thickness, too, considerably influences temperature distribution. Decrease the piston crown thickness, in the case of geometrically similar pistons, can lead to increase the temperature of the piston top center and increase the maximum temperature drop of the crown.

Intensification of local cooling of pistons at use of aluminium alloys, application of materials with high durability to cyclic thermal loadings and development of a design of compound pistons are main routes of optimization of pistons in engines. To reduce a thermal expansion of a piston carry out a thermal resistance between a piston crown and other part of the piston, however in this case the piston crown is more thermal loading. In this case a piston crown is made of a high-alloy steel or a high-temperature alloy. To increase thermal stability a piston head is covered by a high-temperature material, the dusting of a ceramic material or an anodic oxidation of a surface of the piston is for this purpose applied. Thermal stress level is influenced strongly by height of heat belt at which increase the thermal stream through the overhead compression ring decreases, in too time it increases "parasitic" volume of the combustion chamber. For additional cooling the piston crown from the crankcase spaces is sprayed by oil. Gallery cooling provides livelier local cooling of elements of a piston. The volume, the surface participating in heat exchange, the square, the form and arrangement of a lateral section, and also characteristics of dependence of the charge of oil through a cooling cavity are basic parameters of a cooling cavity which define the heat transfer. After absorbing energy from the piston, the oil flows back into the oil reservoir in the crankcase.

Application of inserts around grooves of piston-rings promotes decrease of thermal stress level of rings that is a consequence of raise of a thermal resistance of a zone of compression rings. Walls of a piston crown carry out massive enough for distribution of a heat flow on piston-rings. The radius of transition from the piston head to a sealing belt should not create additional thermal resistance.

To rate a heat load density of detail it is expedient to define a thermal condition of this detail or in other words define temperature patterns of this detail. It is difficult and in some cases it is impossible experimental to define local temperatures and temperature patterns. Precise determination of the heat condition in a cylinder-piston group details, particularly in the case of a complicated construction presents a very difficult mathematical problem. For analytical definitions of a thermal condition are characteristic considerable simplifications and assumptions. Therefore analytical solutions are not practically significant.

Promptly and qualitatively to solve a problem of decrease of heat load density it is necessary to predict and simulate physical processes proceeding in the engine and it is necessary to simulate a heat condition of cylinder-piston group details. To define a thermal condition of details it is possible in universal program complexes. Modeling level is defined by structural features, the purposes and calculation appointment. Quality modeling is defined by heat exchange boundary conditions.

Heat exchange inside internal combustion engine is a complex process. Heat transfer owing to forced convection, for example, depends mainly on the hydrodynamic factors, whereas the gas flow remaining in the cylinder after suction, the intensity and spectrum of the turbulence due to the flow proper are also difficult processes for definition. Heat exchange process in the combustion chamber of the internal combustion engine is radiation-convection [5]. It means simultaneous presence of radiation, convection and conduction heat transfer [5, 14]. At it is radiation-convection heat exchange, it is impossible to observe complex heat exchange only as parallel act of three mechanisms of a heat transfer in physical process. For example it is impossible to define a heat flow as an algebraic sum of the heat transfer due to convection and heat transfer due to gas radiation which have been defined independently from each other. It is caused by that radiation affects a boundary layer that leads to change of a heat flow on a surface of a wall of heat exchange [5].

The following order of definition of a heat condition of cylinder-piston group details is offered.

At first the diagram of an instantaneous value of temperatures of gases in the cylinder by means of a crank angle indicator diagram of gas pressure in cylinder is calculated. Simultaneously with indication it is executed measurement of temperatures in characteristic points of the detail. Reception of the instantaneous value of temperatures of gases directly measurement is a challenge, the characteristic gas equation therefore is used. It is necessary to note that volume-average temperature it is possible to characterize processes in the cylinder only as a first approximation. In the paper [3] it is offered to consider local values of temperatures, the author observes multi-zone model unlike one-zone in which parameters of temperature are equal on all volume. In cases of two-zone model for any moment of a time the working volume is divided on two parts. One part is a zone with an unburned fuel and second there is a with a combustion gases [5].

To define temperature in characteristic points it is offered to use sensing transducers "ИМТК" (the metre of the maximum temperatures crystal) [1,8,9]. The principle of the act of sensing transducers of type "ИМТК" is based on dependence of properties of a crystal lattice of the irradiated material on temperature and a time of affecting of an external thermal loading. At diamond radioactive irradiation, either silicon carbide, or other materials there is a crystal lattice infringement. In the irradiated material radioactive are formed defects that conduct to crystal lattice expansion that conduct to increase in its parameters. Partial or full restoration a lattice of crystals occurs depending on temperature and an interval of thermal affecting. Lattice imperfections annealing at diamond and silicon carbide occurs smoothly [8]. These properties allow to build the calibration curves which then can be used for temperature definition. Crystal lattice parameters are defined by radiographic analysis.

Further the local factors of the heat transfer coefficient are defined by results of the measurements of local temperatures of the piston and the average value temperature of a working medium in the cylinder. The value of an instantaneous value of factor of the heat transfer coefficient from a working medium in combustion chamber walls it is computed using the crank angle indicator diagram of gas pressure and the diagram of an instantaneous value of temperatures. For scaling of an instantaneous value of a heat transfer coefficient Voshny formula is most often used. Then equivalent stationary boundary conditions are computed. The average factor of a heat transfer coefficient from a working medium in a piston head is converted to local a heat transfer coefficient taking into account a qualitative picture of a field of distribution of temperatures in details.

The thermal condition of details is defined in universal program complexes taking into account boundary conditions. In the presence of experimental values of local temperatures, it is carried out by correction of boundary conditions on the basis of comparison of the settlement and the experimental temperatures in checkpoints of sections of heat transfer [7].

### Conclusions

To decrease of heat load density of cylinder-piston group details it is necessary to know a thermal condition of these details. Promptly and qualitatively to solve a problem of decrease of heat load density it is impossible without promptly of physical processes proceeding in the engine.

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