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Experience of the Diesel Engine Cooling System Simulation

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Abstract

The cooling system of the designed diesel engine was investigated using specially prepared models. For selected initializations of a cooling fluid in the available cooling jacket, quantitative estimates of the levels of the heat flow to the coolant and of the temperature of the cooling surfaces of various cylinders were made. Changing the terms of the initiation of the cooling fluid flow (for example, the places where the coolant penetrates into the jacket) is accompanied by a significant redistribution of the convective component of the heat sink and this influences the temperature of the cooling surfaces. It is shown that the uniformity of the cylinder cooling and the intensity of cooling of the cylinder heads can be controlled by choice of the place of coolant penetration into the jacket for the considered design of a crankcase and cylinder heads.

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Keywords: diesel engine; cylinder head; crankcase; cylinder liner; cooling system; redistribution of coolant; FEA; thermal stress

1. Introduction

The degree of speeding up of the IC engine is sometimes limited by the failure of existing cooling systems to prevent the local temperature rise of individual parts [1]. Most susceptible to overheating are the bottom of the cylinder head, the upper belt of the cylinder liner, the piston crown, the upper compression ring and the exhaust-valve cap. The stresses from moving thermal field in these elements, due to the periodic nature of the work of the internal combustion engine, may give rise to fatigue crack propagation with specific mechanisms, more dangerous than crack propagation mechanisms in static thermal fields [2]. Nonuniform heating of the structure gives rise to thermal stresses and thermal displacements. Thermal displacements of the main bearings and the distortion of the cylinder liners cause increased engine wear [3].

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Improving the thermal state of these parts can be achieved by levelling the unevenness of the temperature fields and the restriction of their absolute value. During engine design a uniform distribution is achieved of the coolant flow through the cooling cavities each cylinder [4, 5]. Modern possibilities of the settlement analysis of movement of heat flows allow the thermal load on the engine to be reduced by controlling the convective component of heat flows using the changing flow pattern of the coolant in the cooling system [6].

2. Review

Both experimental and computational methods are used for the analysis of the thermal state of the IC engine components.

The thermometry method and the method of depositions are experimental methods. Thermometry provides data about the temperature in the points of interest for heat-loaded details. Thermocouples, mounted directly onto the metal parts, give evidence of a change in the temperature over time at the point of the thermocouple installation, but do not allow an estimation of the temperature gradients in the space. The installation of thermocouples causes some difficulties and sometimes the thermocouple itself can affect the nature of the heat distribution.

The method of depositions is the experimental method that allows the determination of the nature of fluid flow within a cylinder [7]. The essence of the method is as follows: in the engine before full-scale tests pour water with a high content of calcium and iron. During engine operation limescale is formed on the walls of the sleeve. The limescale is almost absent from the sleeve in the areas with heavy liquid traffic, while in areas with less traffic there is a thicker layer of limescale. In that way it is possible to make a judgement about the presence of dead zones in the cooling system. If such zones are present, they may provoke the steam stopper and impair motor cooling.

Definition of the vortex nature of the flow of coolant by experimental methods is difficult.

Determining the local hydrodynamic parameters of the coolant flow, taking into account the turbulence and vortex flow pattern in the channels, is possible using numerical methods based on CFD (Computational Fluid Dynamics) models, such as the finite element method, implemented with the help of CAE (Computer Aided Engineering) technologies [8, 9]. 3D model of engine cooling cavity is created in a specialized CAD (Computer-aided Design) program. The power of the irreversible loss of heat energy, the consumption of the coolant and the temperature of the engine compartment are taken as initial data for the calculation. A library of the materials, integrated into the application package can be used to detail the thermal properties of materials of the modelled design [10, 11]. The results of the thermal calculation by the finite element method can be represented as a velocity field of fluid flow in the inner space of the cooling system in the form of heat or thermal field flow. Modern computer technologies allow the creation of a model of the heat-loaded parts in the CAD program, using appropriate CAE software to simulate the thermal load on the workpiece. The CFD modelling results of a separate head cylinder coolant jacket are presented in articles [12, 13]. In works [14-16] the cooling flow models of engines coolant jackets are considered. Reduction of input data requirements in work [17] have achieved by underhood modeling. Adequacy of numerical models is estimated by comparison with some experimental results [13, 18].

3. Description of physical models

Questions of heat transfer or heat exchange are the main issues in the design of internal combustion engines. There are three types of heat transfer: a) heat conduction; b) convection, or the transfer of heat by moving particles of matter; c) by radiation.

The calculation of heat conduction phenomena is based on Fourier's law:

$$dQ^{\langle Cond \rangle} = -\lambda \frac{dt}{dl} dS \,, \tag{1}$$

where T is the temperature; $dQ^{\langle Cond \rangle}$ is the amount of energy per time unit dt passing through the inside area dS of the body taken normal to the line l along which the energy flux flowing in proportion to the time dt, area dS and temperature gradient; λ is the thermal conductivity coefficient. The thermal conductivity coefficient λ is