THE LIGHT "KNIFE" METHOD FOR STUDYING AERODYNAMIC PROCESSES IN THE COMBUSTION CHAMBERS OF DIESEL ENGINES

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It is well known that in order to optimize the working process of internal combustion engines (ICEs) it is necessary to know the laws governing the motion of air in the combustion chambers (CCs) throughout the entire period of compression as a preparatory stage before mixing and burning of the fuel. This question has never been completely studied, though more than one generation of investigators in different countries has studied it intensively [1-5 and others]. In the opinion of many of these investigators the question can be reduced to two problems that reflect the main difficulty in the experimenal study: choice of measurement methods and organization of the optical access to the CC.

Among the modern methods for performing measurements the methods based on contact-free optical principles must be singled out. Thus, compared with the traditional contact methods [6, 7], the contact-free methods inherently have a high accuracy, which is especially important, and the compression process is not disturbed. For this reason they can be used to study complicated aerodynamic processes in the CCs of ICEs. The light "knife" method stands out among the methods used in practice [8]. In this work this method is chosen because it has significant advantages over the other methods.

The realization of optical access directly into the CC, situated in the piston, is an extremely difficult technical problem. We shall study the traditional methods for solving this problem for the following examples. In [9] a model of a piston whose bottom was made in the form of a transparent insert and the skirt was equipped with a cut is described. A mirror was rigidly fastened inside the piston in the zone of the cut at an angle to its longitudinal axis. The cylinder contained an optically transparent window, opposite which a motion picture camera was placed. The errors introduced by the refraction of the light rays on the curved surface as well as the great technical difficulties in preparing the apparatus make it difficult to use this model for studying the aerodynamic qualities of semidivided CC in diesel engines.

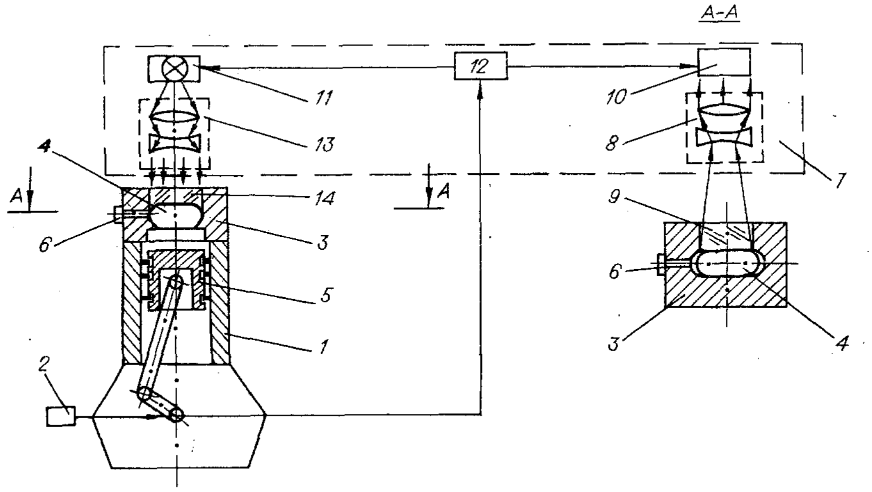

Fig. 1

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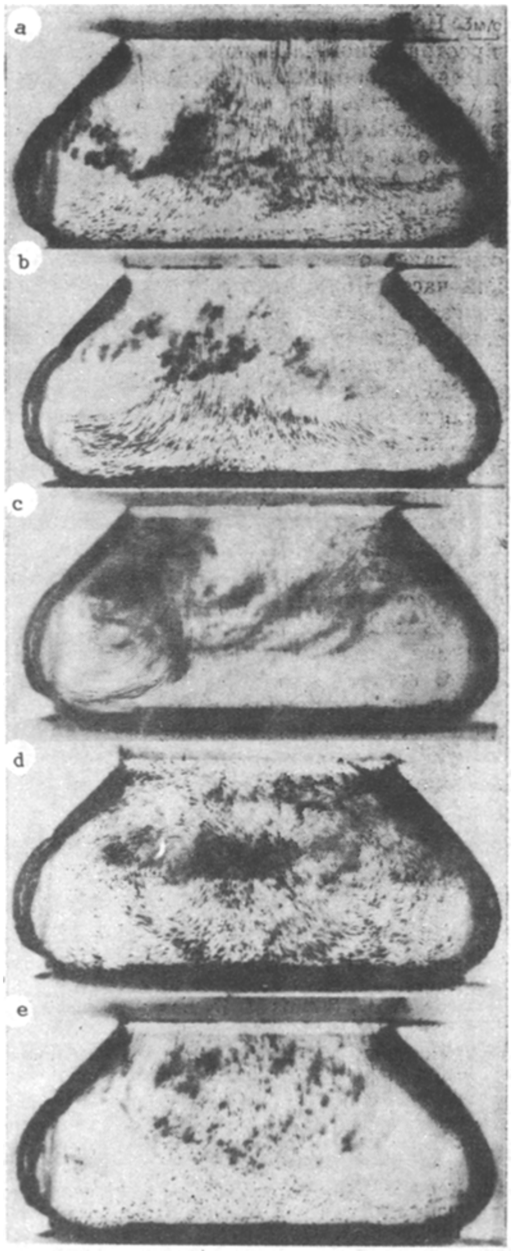

Fig. 2

In [10] a dynamic setup, in whose housing a piston with a head having a rectangular cross section was placed, was employed. Plane-parallel transparent windows were placed in the side walls of the CC coaxially with the optical Töpler tubes [8], placed in the top part of the cylinder barrel. Aside from the great difficulty of making the apparatus, the apparatus also had other significant drawbacks — it is impossible to obtain reliable information about the processes under study, in view of the fact that the shape of the CC is far from realistic.

Our experimental study was based on a single-cylinder model of a 1 Ch 8,5/11 diesel engine, shown in Fig. 1. It consists of the motor setting 1, which is put into rotation by an electric motor with a regulatable power supply 2, the cylinder top 3 with the CC 4, a piston 5, a system for dusting with light-scattering aerosol 6, and an instrumentation system for data acquisition 7. To simplify the optical access directly into the CC the internal configuration of the cylinder top was made similar to the geometry of the bottom of the piston, while the configuration of the bottom was made similar to the geometry of the inner surface of the top of the model setting of the motor. The volume of the model CC, shown in Fig. 2, and the area of its through cross section were divided according to the similarity theory. The instrumentation system included the following (Fig. 1): an optical insert 8, a system of focusing lenses 9, a camera 10, a pulsed light source (PLS) 11, a sensor for determining the angle of rotation of the crank shaft (ARCS) 12, a system of cylindrical lenses 12, and an optically transparent window slit 14.

The measurements were performed in the following order. The ARCS sensor was actuated at a definite angle of rotation of the crack shaft; the output signal from the sensor simultaneously triggered the PLS and the camera. The central part of the CC was illuminated through the window with a plane-parallel beam of light, formed by the system of lenses. The light flux scattered by aerosol particles injected into the CC before the experiment was started was recorded with the camera through the optical inset and the system of lenses. The flow velocity in the axial cross section of the CC was determined from the length of the tracks of the light-scattering particles taking into account the fixed width of the illumination pulse.

The total error in the measurements of the axial component of the velocity of the air charge was estimated to be of the order of 26%. This error consisted of the error in tracking the dusting particles of finely dispersed lycopodium powder in the flow (25%) [8] and the error owing to the change in the relative position of the surfaces of the piston and the top of the cylinder (1%) [11].

The purpose of the work was to study the distribution of the velocity field in the widely used CC of the TsNIDI system at the compression stage. Figure 2 shows an image of the profile of the CC and the tracks of the light-scattering particles with rotation of the crank shaft (RCS) from 80° RCS in front of the top dead point (TSP) to 20° RCS after the TDP. The tests were performed with the crack shaft rotating at a speed $n = 50$ rpm and a degree of compression $\varepsilon = 10$. Analyzing the photographs we note that for positions of the piston corresponding to 80° RCS and 60° RCS from the TDP (Figs. 2a and b) there is a powerful flow of air into the CC. The air flow, detaching from the edge of the throat, moves primarily into the central part of the CC. Near the bottom the flow changes direction and then, moving along the boundary of the CC, it completes a closed cycle, thereby forming the prerequisites for the formation of a toroidal vortex, which can be clearly seen in Fig. 2c (20° RCS from the TDP). When the piston is located at the TDP, according to Fig. 2d, when the flow of air into the CC stops, precession of the vortex in the direction of the symmetry axis is observed; this precession is caused by the nonstationary level of turbulence and the rarefaction remaining in this region. Finally, when the piston moves by 20° RCS beyond the TDP (Fig. 2e) the vortex motion practically degenerates. The air flows out of the CC into the space of the diesel above the piston. At this stage compression stops.

The study of the aerodynamic characteristics of the CC of the TsNIDI system performed with the help of the light "knife" made it possible to obtain adequate information for choosing the moment at which fuel injection should be started and the direction of fuel injection in order to improve the quality of mixing.

In conclusion we note that the structural simplicity of our model apparatus with the cylinder top containing easily replaceable inserts that, stimulate the profiles of different CCs will make it possible in the future to determine the main methods for optimizing the aerodynamic qualities of CCs.

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