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STUDY OF THE INFLUENCE OF COMBUSTION CHAMBER THERMAL INSULATION AND GAS MEDIUM PULSATIONS ON THE OPERATION OF A DIESEL ENGINE

Abstract: *The paper discusses research into new ways to improve the energy and environmental performance of marine diesel engines. The paper presents the results of a comparative study of a diesel engine operating with standard and experimental pistons; Also, the results of the analysis of theoretical and experimental studies.*

Key words: *diesel engine; fuel; environmental pollution; piston; fuel consumption.*

Language: *English*

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Introduction

The priority areas of scientific research in the marine diesel industry are working towards further reducing the effective specific fuel consumption and decreasing the amount of harmful substances from exhaust gases.

Analysis of best-known approaches for reducing the effective specific fuel consumption has shown that one of the promising methods is to reduce heat losses in the walls of the combustion chamber [1, 2]. However, the information available in this field is very contradictory and insufficiently studied.

The conducted research has shown that one of the methods for improving the economic and environmental characteristics of marine diesel engines is the modernization and further research of the engine's intake and exhaust ports, piston and combustion chamber designs [3, 4, 5, 6]. Therefore, it is necessary to conduct comparative experimental research on water-free diesel fuel, water-fuel emulsion, and vegetable oil when working on standard and experimental heat-insulated pistons.

It is proposed in the paper [1] to compensate for the negative effects associated with the increase in the diffusion combustion period by organizing additional air charge generation in diesel engines with thermally insulated combustion chambers.

Research methodology

The paper uses both theoretical and experimental research methods. The study of the characteristics of the diesel operating process when operating on standard and experimental pistons was carried out on a load stand. With the help of a gas analyzer and a smoke meter, the concentration of fluid II substances and the transparency of exhaust gases were determined. The heat release characteristics were calculated using indicator diagrams on a computer. The research was carried out in the research laboratory of the Faculty of Engineering of the Batumi State Maritime Academy. Fig. 1 shows a photograph of the research object, and Fig. 2 shows a research piston.

The object of study is the processes of fuel mixture formation and combustion in diesel engines.

The research was carried out in the research laboratory of the Faculty of Engineering of the Batumi State Maritime Academy.

In Fig. 1 shows a photograph of the research object, and Fig. 2 - photograph of a research piston.

Research Findings

Based on the analysis of well-known designs of thermally insulated combustion chambers, a technology for manufacturing a prototype piston has been proposed, which is based on applying a ceramic coating using zirconium dioxide powder to the walls of the combustion chamber of the mass-production piston.

Fig. 1. Research object

Fig. 2. Piston construction

To that end, the technology of applying thermal insulating coating was developed, and models of experimental pistons with a thermally insulated combustion chamber were manufactured with a flat and profiled upper surface, which was intended to excite gas dynamic vibrations in the form of a radial standing wave.

The works of A. Yu. Konkova and other scientists are devoted to modeling the combustion process [7, 8, 9].

A comparative analysis of the standard piston and experimental pistons was carried out in the Marine Internal Combustion Engine Laboratory on a special experimental rig made based on the 2Ч 10.5/12 diesel engine.

During comparative experimental studies, torque, crankshaft rotation frequency, fuel and air consumption, temperature, exhaust gas composition, and smoke were measured.

A schematic diagram of the charging stand is presented in Figure 3.

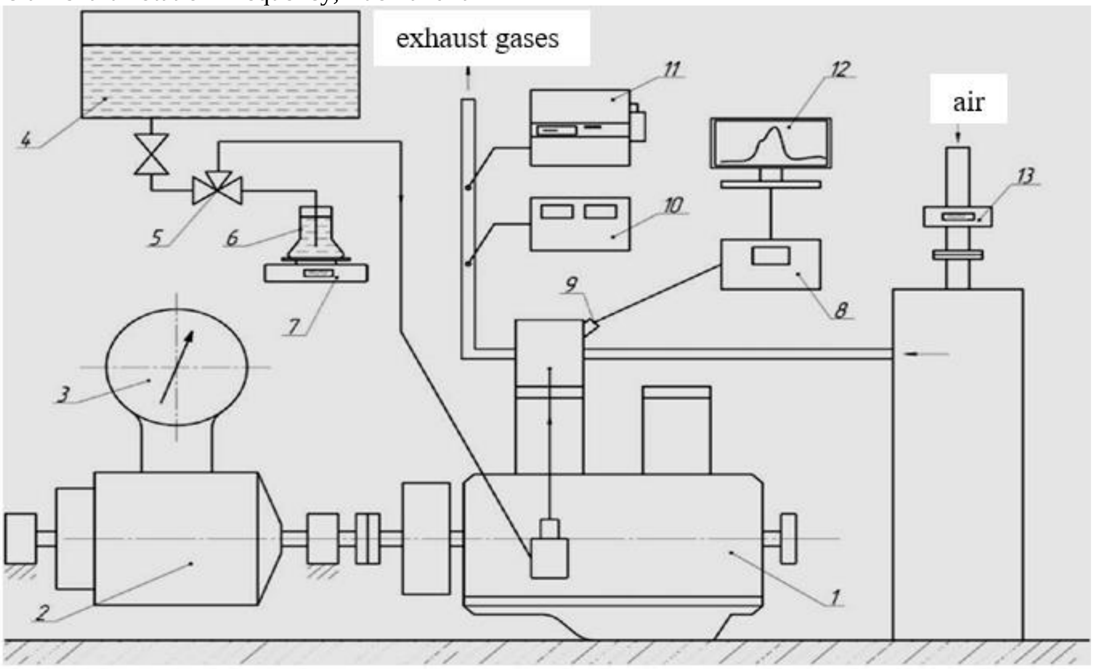

Fig. 3. Schematic diagram of the experimental setup

Diesel fuel from tank-4 was supplied through three-way valve-5 to measuring container-6 installed on electronic scale-7. When the three-way valve was switched, fuel from the measuring container entered diesel engine-1. The time taken to consume a 100 g portion of fuel was measured using an electronic stopwatch. The leaked fuel was collected in a separate container, weighed, and taken into account when conducting calculations.

The pressure in the diesel cylinder, depending on the angle of rotation of the crankshaft, was measured by a piezo-quartz sensor-9 and a device-8. As a result, the indicator diagrams were processed on a computer.

The turbidity of exhaust gases was measured with the “META-01MP 0.1” device-10. In order to determine the concentration of pollutants in exhaust gases, the "EXPERT" gas analyzer-11 was used, which measures the concentrations of nitrogen oxides, carbon monoxide, total hydrocarbons, sulfur dioxide, and oxygen.

Airflow was measured using a differential pressure manometer-13. The exhaust gas temperature was measured using a thermocouple connected to a potentiometer.

Comparative tests of the diesel engine on standard and experimental pistons were conducted according to the load characteristic at a crankshaft rotation frequency of 1500 rpm.

After recording the process parameters and taking an indicative chart on the standard piston, it was replaced with experimental pistons.

By the test program, the studies were carried out in the following sequence:

1 - standard piston with a flat upper surface;

2 - experimental piston with a thermally insulated combustion chamber and a flat upper surface;

3 - Experimental piston with a thermally insulated combustion chamber and a profiled upper surface.

Comparative studies of diesel characteristics on a standard piston and experimental pistons were carried out under the same environmental conditions (temperature, pressure, and air humidity).

Figure 4 presents the results of comparative tests of standard and experimental pistons with a thermally insulated surface. Figure 5 shows the indicative diagrams of a diesel engine when operating on standard and flat-surface thermally insulated pistons. Figure 6 presents the results of a numerical study of the heat release characteristics obtained after processing the indicative diagrams shown in Figure 5.

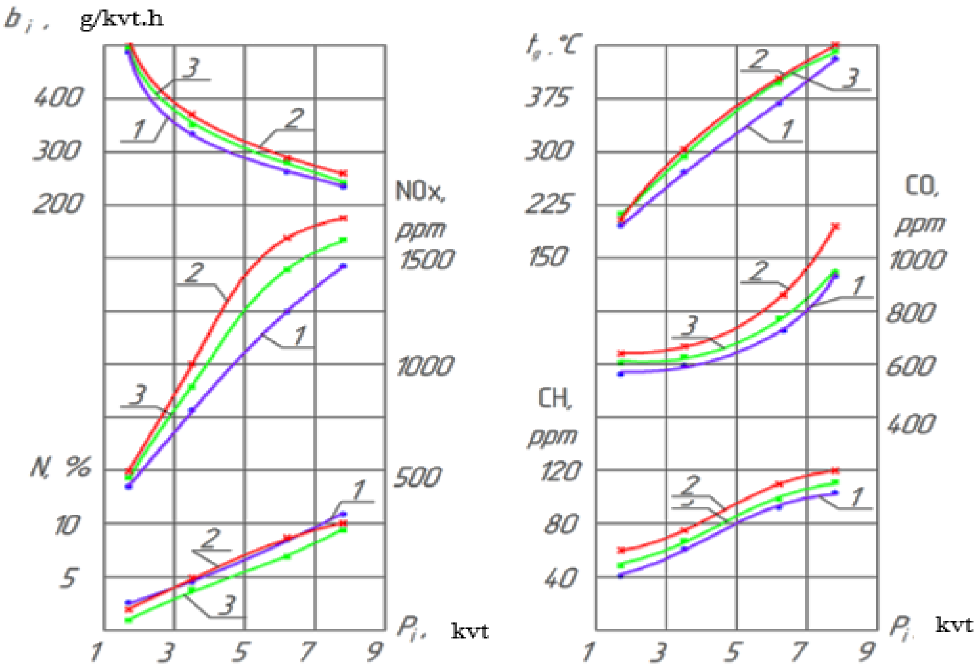

Fig. 4. Load characteristics of the diesel engine Ч 10.5/12 at a crankshaft speed of 1500 min^{-1}:
1 – Standard piston; 2 – Thermally insulated piston with a flat top surface; 3 – Thermally insulated piston with a profiled top surface, designed to activate gas dynamic oscillations.

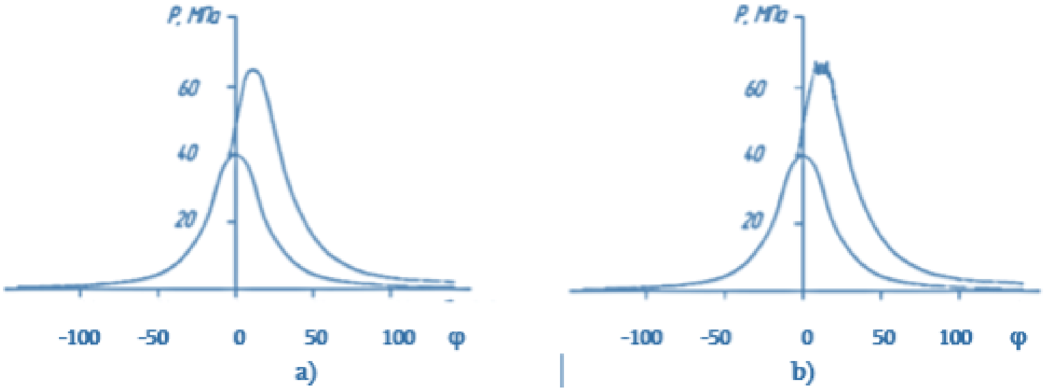

Fig. 5. Indicator diagrams of the diesel engine Ч 10.5/12:
a) Thermally insulated piston with a flat top surface;
b) Thermally insulated piston with a profiled top surface.

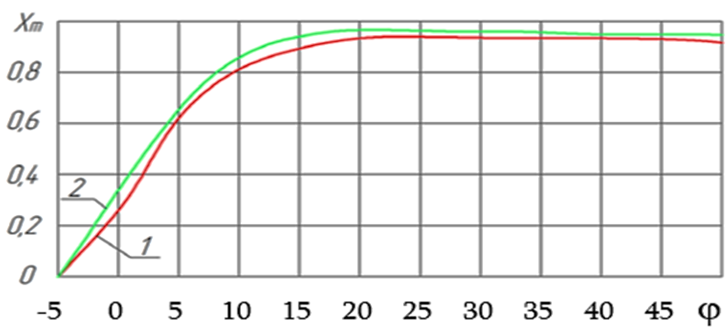

Fig. 6. Heat release characteristics of an experimental diesel engine obtained when operating on thermally insulated pistons of various designs:
1 – Thermally insulated piston with a flat upper surface;
2 – Thermally insulated piston with a profiled upper surface

Figures 4, 5, and 6 clearly show that the use of an experimental piston with a profiled upper surface reduced the diffusion combustion period by enhancing the gas and mass transfer process between the gaseous environment and the fuel droplets.

This simultaneously improved the diesel engine's energy and environmental performance and made it possible to approach the performance of a standard non-thermally insulated piston.

The reduction in the concentration of nitrogen oxides in the exhaust gases occurred due to the redistribution of high-temperature areas of the working fluid caused by the pulsation of the gaseous environment.

Due to the reduction in the diffusion combustion period, the temperature and soot content of the exhaust gases decreased.

Analysis of the indicator diagram and heat release characteristics showed that the main reason for the negative result was the additional heating of the fresh air charge entering the cylinder from the walls of the combustion chamber.

The presented conclusions do not contradict the provisions of various scientists and the monograph of R.Z. Kavtaradze [10, 11, 12, 13].

Conclusion

The results of testing and numerical studies of heat release characteristics showed the following:

1. When replacing a standard piston with a flat top surface with a heat-insulated piston, the overall energy and environmental performance of the diesel engine deteriorated significantly. This was due to the additional heating of the fresh air charge from the hot walls of the combustion chamber.

The filling ratio and the fuel ignition delay period decreased. At the same time, the diffusion combustion period increased. The delay in the combustion process to the expansion line led to an increase in the indicative specific fuel consumption and exhaust gas temperature. With an increase in the maximum temperature of the working mixture in the combustion chamber, the rate of oxidation of nitrogen in the air charge increased.

2. When replacing the thermally insulated piston with a flat upper surface with an experimental thermally insulated piston with a profiled upper surface, designed to excite gas dynamic vibrations, the negative impact on the working process associated with additional heating of the air charge from the walls of the combustion chamber was reduced.

Gas pulsation enhanced the explosion process of the sprayed fuel droplets and reduced the diffusion combustion period. This made it possible to partially compensate for the negative effects on the working process associated with additional heating of the air charge from the walls of the combustion chamber.

3. Cooling the ambient air by 8 degrees Celsius with a heat-insulated profiled piston on a diesel engine improved all economic aand environmental indicators. Specific fuel consumption, exhaust gas temperature, smoke, and emissions of polluting chemical compounds were reduced.

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