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Research Article

EXPERIMENTAL INVESTIGATIONS OF A DEVICE FOR USEFUL HEAT UTILIZATION OF DRILLING EQUIPMENT INTERNAL COMBUSTION ENGINE

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ABSTRACT

In the beneficial use of the heat of the internal combustion engine of drilling equipment has great scientific and practical importance.

The article presents a heat exchange device for the beneficial use of thermal energy, which occurs during operation of an engine with an internal combustion chamber of a diesel power plant used in drilling operations and experimental studies to increase the efficiency of work using a thermoelectric generator.

KEYWORDS

Diesel power plant, heat, thermal energy, internal combustion engine, fuel energy, energy losses, drilling, heat consumption, energy losses.

INTRODUCTION

Tests were carried out to determine the operability and efficiency of the device for utilizing the heat of the internal combustion engine of the developed drilling equipment, as well as the values of the electrical and heat flows generated in it.

The first stage of the experiments was carried out during industrial production at the DES-100.1 diesel power plant with a nominal power of 100 kW. During the experiments, it was found that the heat released in the radiator of the cooling system of the internal combustion engine of a diesel power plant can be

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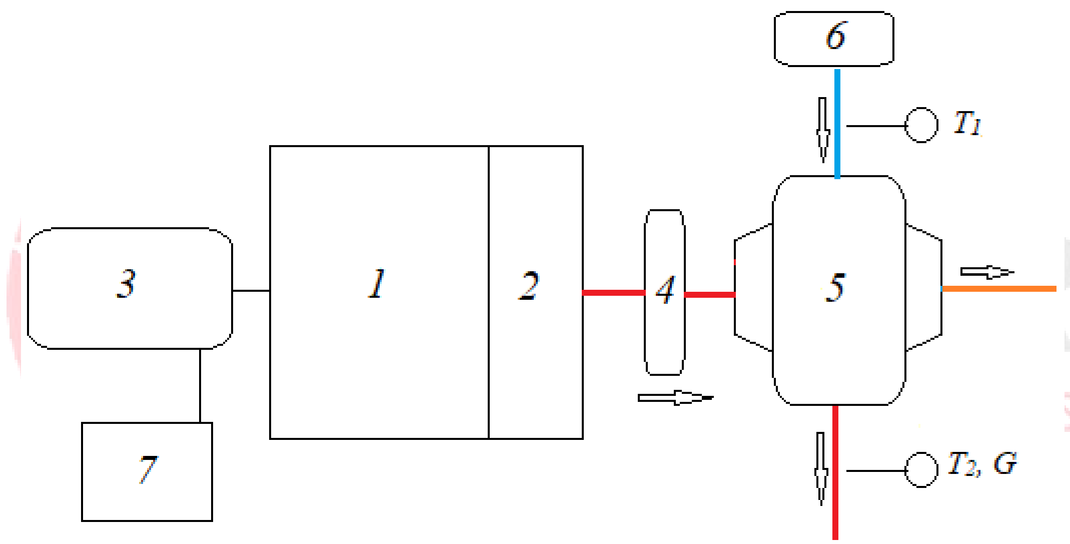
usefully used with the help of a heat exchanger, that the heat generated in the radiator depends on the load applied to the engine and the magnitude of heat flows.

The following tools and equipment were used in the experimental work:

- diesel power station;
- cooling radiator;
- fan (2 pcs.);
- heat exchanger;
- water heater for loading the engine;
- airflow direction pipes;
- animometer to measure the speed of the air flow;
- thermometer to measure temperature.

The schematic view of the experimental equipment is presented in Fig. 1.



1-internal combustion engine, 2-cooling radiator, 3-generator, 4- and 6-fans, 5-heat exchanger, 7-water heater, T1, T2 - points for measuring the temperature of the inlet and outlet air flow to the heat exchanger. (℃) , G-point for measuring the air flow rate at the outlet of the heat exchanger (kg/s).

Figure 1. Schematic view of the experimental device.

The experiments were carried out in the following order: after starting the internal combustion engine (2), a water heater (7) with a rated power of 50 kW was connected to the generator (3). The fan (4) was installed outside the radiator (2) and connected to the

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heat exchanger (5) by an air duct. The heat exchanger (5) was cooled by a fan (6).

After the internal combustion engine reached its nominal operating mode, a load of 10 kW was supplied to it using a water heater, and the hot air flow was transferred from the fan (4) to the heat exchanger (5). The coolant was supplied to the heat exchanger from the fan (6) and the air flow rate and temperature were measured at the outlet of the heat exchanger. In the course of experimental work, the temperature and air flow were recorded at engine loads of 10, 20, 30, 40, and 50 kW. The air flow directed from the radiator to the heat exchanger is 0.3; 0.5; 0.7 and 0.9 kg/s, the air flow was provided by changing the fan speed.

The air flow in the heat exchanger was determined from the air flow, and the temperature of the incoming and outgoing air was measured using a two-channel thermometer.

The air flow rate from the engine radiator, as well as the flow rate of air entering and exiting the heat exchanger, were determined by knowing the pipe diameter and air flow rate using the following expression 1.

$$G=v_x \cdot \frac{\pi d_x^2}{4} \cdot \rho_x, \text{ kg/s}; \qquad (1)$$

where, v_x is the speed of air flow, m/c;

d_x – pipe diameter, m;

ρ_x - air density, kg/m^3.

We determined the power of the heat flow using the following 2nd expression.

$$Q=s_x \cdot G(t_1-t_2), \text{ Vt}; \qquad (2)$$

where, s_x – heat capacity of air; J/kg·°S;

G – air consumption, kg/c;

t_2 – heated air temperature, °C;

s_x – heat capacity of air, J/(kg·grad);

t_1 – temperature of the air entering the heat exchanger, °C.

As a result of the analysis of experimental work, the dependence of the power of the heat flow coming out of the heat exchanger (Q), the air flow (G) at different loads (N) to the engine, this dependence is presented in a graphic form in Fig. 2.

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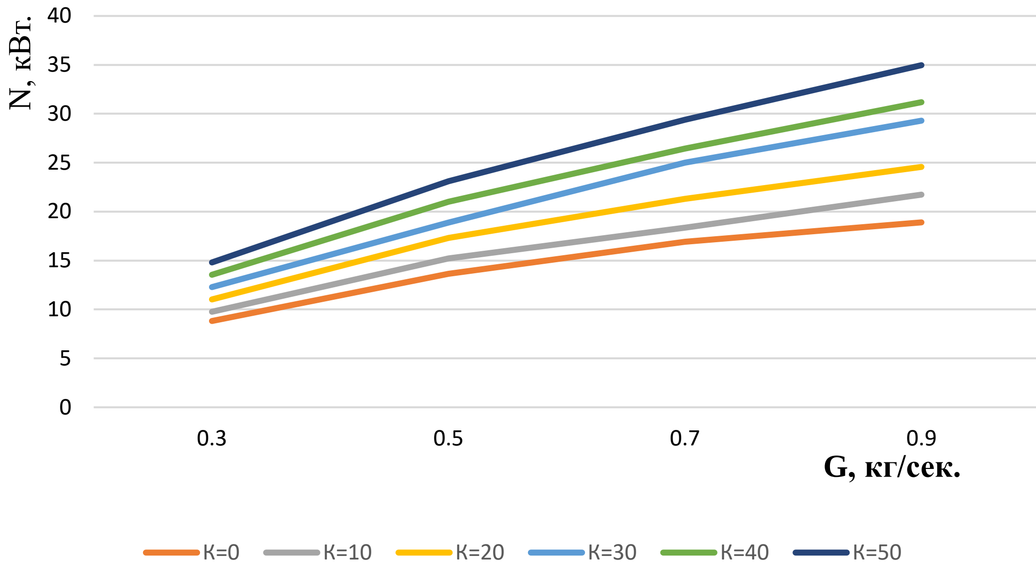

Figure 2. The graph of the dependence of the power of the heat flow (Q) on the heat exchanger and the consumption of the air flow (G) at different loads.

An analysis of the results of experimental work shows that when the internal combustion engine is running in a cold state, the heat release from the radiator of its cooling system is less, that is, when the hot air flow is directed from the radiator to the heat exchanger, the secondary air coolant flow rate is 0.3 kg/s, the heat flow rate is , used in the heat exchanger, was 8.82 kW, with an increase in the flow rate of the secondary heat carrier air to 0.9 kg / s, it was 19 kW. By increasing the consumption of secondary heat-carrying air, it is possible to increase the power of the utilized heat flow.

As a result of increasing the loads applied to the engine, it is possible to increase the power of the heat flow from the heat exchanger. At an engine load of 50 kW, the secondary air-coolant consumption was 0.3 kg/s, the power of the heat flow used in the heat exchanger was 14.8 kW, with the secondary air-coolant consumption increased to 0.9 kg/s, it was 35 kW.

As can be seen from the results of the above experimental work, by increasing the load applied to the engine, it is possible to increase the power of the heat flow from the heat exchanger. But, on the other hand, as a result of an increase in loads, an increase in fuel consumption also occurs, and this aspect must be taken into account when designing or using heat recovery devices.

The second stage of experimental work was the installation of a thermoelectric generator set in the

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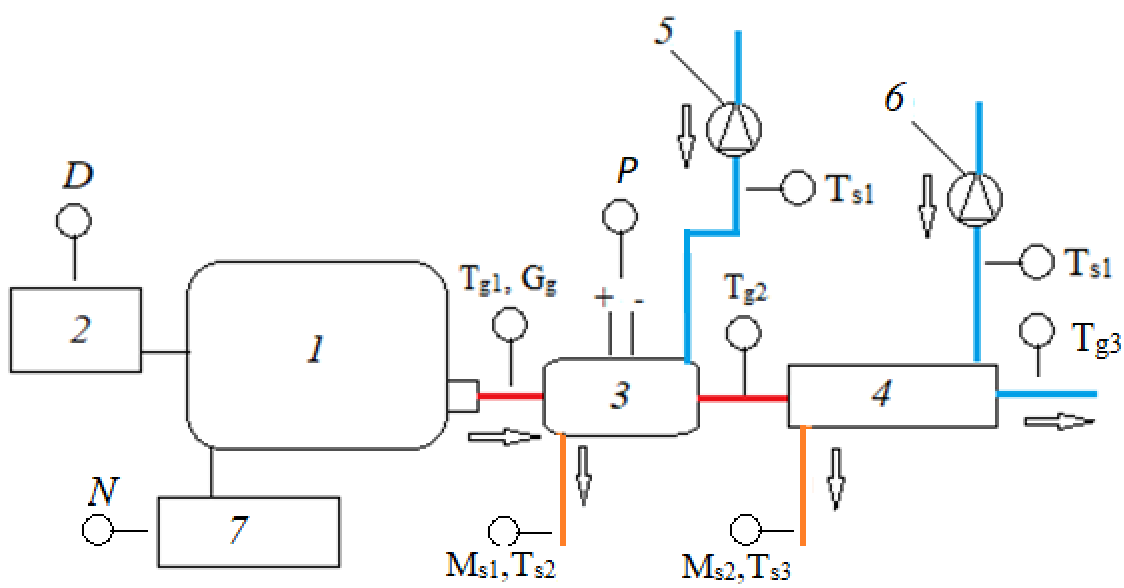
engine exhaust pipe, its performance, electric current that can be obtained from a thermoelectric generator set, and hot water that can be used for technological and domestic needs. The need for a heat removal device was carried out in order to study the possibility of obtaining it.

During the experimental work, the following tools and equipment were used: an internal combustion engine (2 kW), a lamp block (2 kW), 36 thermoelectric generators, a heat exchanger, a water pump, a thermometer (UNI-T), an animometer, and a balance. .

A schematic view of the experimental setup is shown in fig. 3.



1-internal combustion engine, 2-fuel tank, 3-thermoelectric generator unit, 4-heat exchanger, 5,6-pump, 7-lamp unit for creating a load on the engine, Tg1-engine exhaust gas temperature, Tg2- the temperature of the flue gas supplied to the heat exchanger, Gg -flue gas consumption, Ts1-the temperature of the water leaving the pump,

Ts2, Ts3- the temperature of the water leaving the thermoelectric generator unit and heat exchanger, , Ms1, Ms2- the consumption of water leaving the thermoelectric generator unit and the heat exchanger, R - the point of measuring the output power of the thermoelectric generator, D - measuring the fuel consumption point, the load applied to the N-engine.

Figure 3. Schematic view of the experimental device.

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The experimental device was used in the following order, a block of lamps (7) was connected to the motor (1) to create a load, the block of lamps allowed to increase the load from 0 to 2000 Watts, from 500 Watts. To measure the fuel consumption of the engine, the fuel tank (2) is separately removed and mounted on the scale. The thermoelectric generator unit (3) is connected to the exhaust pipe of the engine, the thermoelectric generator unit is connected to the heat exchanger (4) on the other side, cold water is supplied from the pump (5) to cool the thermoelectric generator unit and the heat exchanger.

When the engine is running, the temperature of the flue gases leaving it (Tg1), the flow rate (Gg) and the temperature of the flue gases at the inlet and outlet of the heat exchanger from the thermoelectric generator (Tg2) and (Tg3) are measured; heat exchanger outlet water temperature (Ts2), flow rate of outlet water from the thermoelectric generator set and heat exchanger (Ms) and the amount of electrical energy output of the thermoelectric generator (R) is recorded.

During the experimental work, all the indicators were recorded by giving the engine loads of 0, 500, 1000, 1500 and 2000 Watts.

To cool the thermoelectric power plant, water with a temperature of 20 °C and a volume of 0.12 l/s was pumped through the pump (5). The diameter of the water inlet pipe to the heat exchanger (4) was 20 mm, the diameter of the outlet pipe was 8 mm. The difference in the diameters of the inlet and outlet pipes ensures a decrease in the rate of water circulation into the heat exchanger, that is, it improves the process of temperature exchange of heat carriers.

Experimental tests of the device for utilizing the heat of an internal combustion engine made it possible to obtain the following results:

- the temperature of the flue gases leaving the engine (Tg1) depends on the load (N) applied to the engine;

- dependence of engine fuel consumption (D) on engine load (N);

- consumption of exhaust gases of the engine (Gg) depends on the engine load (N);

- water temperature at the outlet of the heat exchanger (Ts3), that is, the dependence of the secondary heat carrier on the load (N) given to the engine when C1=const;

- dependence of the output power of the electric current (R) of the thermoelectric generator on the load (N) applied to the engine;

The dependence of the temperature of the exhaust gases of the engine (Tg1) on the load (N) applied to the engine is graphically presented in fig. 4.

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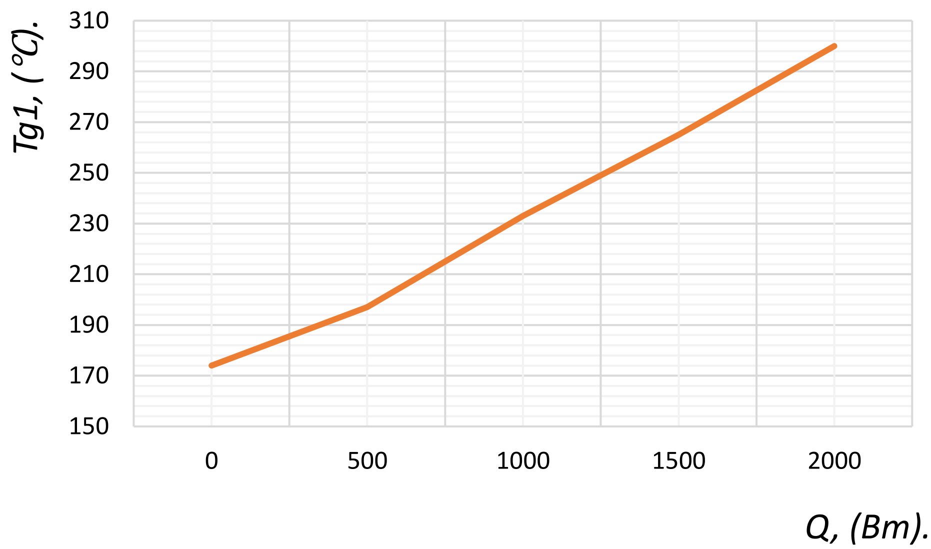


Figure 4. The dependence of the temperature of exhaust gases from the engine (Tg1) on the load (N) applied to the engine.

As can be seen from the graph above, when the engine is running without load, the flue gas temperature is 174 °C, at a load of 500 W - 197 °C, and with an increase in load by 500 W, the flue gas temperature increases by an average of 35 °C.

In order to determine the efficiency of the heat recovery device for the internal combustion engine of the developed drilling equipment, a comparison was made of the equipment efficiency with and without the use of a heat recovery device.

The efficiency of the diesel power plant of the drilling equipment is determined.

$$\eta = \frac{N}{Q}; \quad (4)$$

where, N is the load of the generator (kW), Q is the heat flow released as a result of fuel combustion (kW).

The heat flow released as a result of fuel combustion depends on fuel consumption and its combustion heat.

$$Q = \frac{Q_p^H D}{3600}; \quad (5)$$

where, Q_p^H - lower combustion heat of fuel, (for gasoline $Q_p^H = 44500$ kJ/kg).

When using the device for useful disposal of the heat of the internal combustion engine of the developed drilling equipment, the useful work coefficient is determined.

$$\eta = \frac{N+R+Q_{ut}}{Q}; \qquad (6)$$

where, Q_{ut}- utilized heat flow (kVt), R – the power of the electric current generated in the thermoelectric generator. (kVt).

The heat flow of the exhaust gases of the engine in the heat exchanger is determined as follows

$$Q_{ut} = G_g \cdot C_g(T_{g2} - T_{g3}), \text{kVt}; \qquad (7)$$

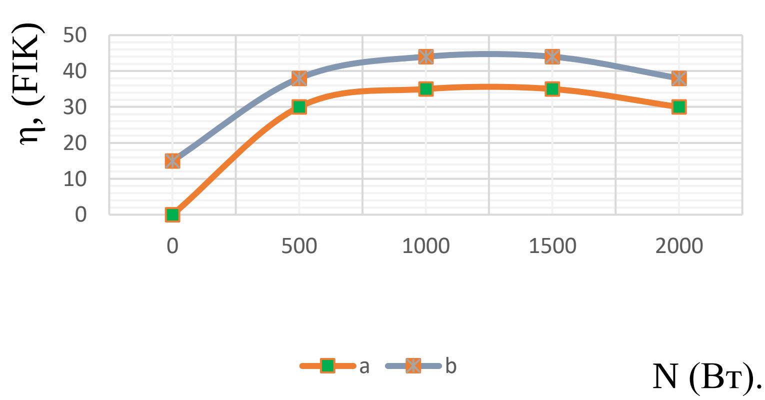
where, C_g- heat capacity of flue gases (kJ/kg·°C), T_{g2} and T_{g3} – temperature of flue gases at the inlet and outlet of the heat exchanger (°C).

The useful efficiency of diesel power plants is determined by the part of the thermal energy generated in their engines that is converted into useful mechanical energy, and then into electrical energy.

For example, when the engine was loaded with 1000 Watts during the experiments, the power consumption was 0.72 kg/h, the heat flow from the engine was 30.24 MJ/kg, and only 35% was used to get electricity through the generator, and the rest is released into the atmosphere.

When using a heat recovery device connected to the engine, at a load of 1000 Watts, the fuel consumption was 0.78 kg/h, (the increase in fuel consumption is explained by the resistance in the flue gas pipe), and the heat flow separated from the engine was 32.76 MJ/kg, 44% of this released heat is usefully recovered.

Figure 10 shows the dependence of the efficiency (η) of the diesel power plant of the drilling equipment on the load (R) applied to the engine.



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a - when heat is not utilized, b - when heat is utilized.

Figure 5. Graph of the dependence of the efficiency (η) of the diesel power plant of drilling equipment on the load (N) applied to the engine.

An analysis of the results of experimental work shows that the efficiency of the internal combustion engine of a diesel power plant of drilling equipment is actually 30-35% (Fig. 5). It has been established that this figure can be increased to 44% when using the proposed heat recovery device.

The efficiency of the engine is increased by recovering secondary energy resources in the form of heat released into the atmosphere.

In the graph shown in Figure 5, curve b shows the change in engine efficiency when using a heat recovery device. As can be seen from the graph, the load efficiency (H) increases from 0 to 1000 watts, we can observe a decrease at loads of 1500 and a maximum of 2000 watts. This situation can be explained as follows: at high loads, the flow and consumption of flue gases increase, but the heat exchange process in the heat exchanger does not have time to fully utilize this heat, which leads to energy losses. In addition, the reason is also the low efficiency of thermoelectric generators used in the proposed device.

Thus, it has been established that our proposed device for the useful recovery of heat from a diesel power plant of drilling equipment will have a high efficiency when using an engine with a load in the range of 50-75%.

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