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Reserves for Improving the Perfection of the Organization of the Combustion Process in Marine Boilers

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ABSTRACT

The energy efficiency of marine boilers largely depends on the quality of the organization of the combustion process, which is provided on modern boilers with the help of aggregated combustion devices. Imperfect organization of the fuel combustion process, as a rule, leads to a decrease in the efficiency of the boiler due to significant heat losses and, accordingly, to an increase in fuel consumption, as well as to the harmful effect of the formed products, mostly incomplete combustion, on the environment. Therefore, they mainly determine the efficiency of the boiler. Solving the problem of reducing these losses by increasing the efficiency of the furnace process organization is an urgent task, which is the main goal of the work being performed. Its novelty is the substantiation of reserves for increasing the perfection of the organization of the furnace process.

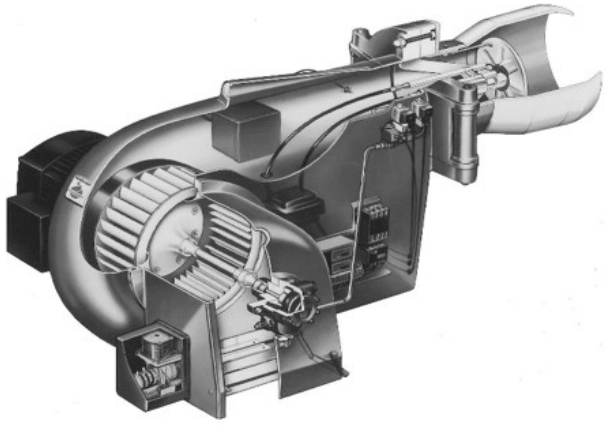
1. Introduction.

Increasing the energy efficiency of ship power plants is one of the main issues of the modern day, which is constantly receiving considerable attention. The reasons for this are the high share of petroleum fuel consumption by the transport fleet, which is about 6% of the total volume of petroleum fuel [1]. The high cost of energy carriers constantly prompts the search for ways of its efficient use in order to minimize heat loss and prevent the harmful effects of the generated combustion products on the environment. Along with internal combustion engines, marine boilers are also among the largest consumers of oil fuel on a marine vessel [2].

2. Relevance of research.

The energy efficiency of marine boilers largely depends on the quality of the organization of the combustion process, which is provided on modern boilers with the help of aggregated combustion devices (Fig. 1).

Figure 1: «Weishaupt Monarch» aggregate combustion device model.



Source: Weishaupt monarch burners.

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These devices combine elements of various marine boiler systems in their design, namely:

- the fuel system, which is responsible for the preparation of fuel and its direct supply to the boiler furnace;
- air supply and flue gas removal systems, which ensure air injection into the boiler furnace;
- automatic regulation and signaling system, which implements both protective functions to ensure trouble-free operation of the marine boiler, as well as functions of automatic control and regulation of work processes occurring during operation, both directly of the combustion device and the boiler as a whole.

Imperfect organization of the fuel combustion process, as a rule, leads to a decrease in the efficiency of the boiler due to significant heat losses and, accordingly, to an increase in fuel consumption, as well as to the harmful effect of the products formed, mostly incomplete combustion, on the environment.

Therefore, they mainly determine the efficiency of the boiler. Solving the problem of reducing these losses by increasing the efficiency of the furnace process organization is an urgent task, which is the main goal of the work being performed. Its novelty is the substantiation of reserves for increasing the perfection of the organization of the furnace process.

3. Presentation of the main material.

The main factors that can cause an imperfect combustion process or failure of the aggregate combustion device include the following:

1. Unsatisfactory atomization of fuel;
2. Malfunctions in the operation of the automatic regulation and signaling system (ARS);
3. Unsatisfactory air supply;
4. Pulsations, hissing and breakdowns of the fuel torch;
5. Stopping the electric motor of the combustion device;
6. Human factor.

We will analyze all the factors identified by us that can be the causes of an imperfect combustion process or failure of the aggregate combustion device, we will highlight the subfactors related to them and classify them.

1. The following subfactors may be the causes of unsatisfactory fuel atomization:
   1.1 Low fuel heating temperature;
   1.2 Low fuel pressure;
   1.3 Unsatisfactory cleanliness of the fuel injector holes;
   1.4 Worn spray nozzles, coked heads;
   1.5 Unsatisfactory mixing of fuel with air;
   1.6 Fuel leakage.
2. Among the causes of malfunctions in the operation of the automatic regulation and signaling system (ARS), we will highlight the following subfactors:
   2.1 Malfunction of the combustion control unit;
   2.2 Pollution / moisture of the ignition electrodes;
   2.3 Defect of ignition electrodes;
   2.4 Malfunction of the ignition transformer;
   2.5 Malfunction of electromagnetic valves;
   2.6 No signal from the flame sensor to the combustion control unit.
3. The factor of unsatisfactory air supply can include the following reasons (subfactors):
   3.1 Malfunction or stoppage of the fan wheel;
   3.2 Leaks in the air ducts;
   3.3 Improper position of the diffuser and flaps of air-directing devices;
   3.4 Low air pressure;
   3.5 Excessive air pressure
4. The causes (subfactors) of pulsation, hissing, and breakdowns of the fuel torch can be:
   4.1 Excessive water content in fuel;
   4.2 Excessive content of mechanical impurities in fuel;
   4.3 Fuel pressure fluctuations;
   4.4 Contaminated nozzle;
   4.5 Too weak flame signal;
   4.6 Inappropriate fuel temperature;
   4.7 Inadequate proportion of air for fuel combustion.
5. Problems with stopping the electric motor of the combustion device may occur due to:
   5.1 Lack of voltage;
   5.2 Malfunction of the motor contactor;
   5.3 Activation of the current protection relay;
   5.4 Falling water level in the boiler.
6. The human factor includes the following subfactors:
   6.1 Low (insufficient) qualification of personnel;
   6.2 Insufficiency (absence) of relevant experience in performing this type of tasks;
   6.3 Negligence;
   6.4 Low culture of labor organization.

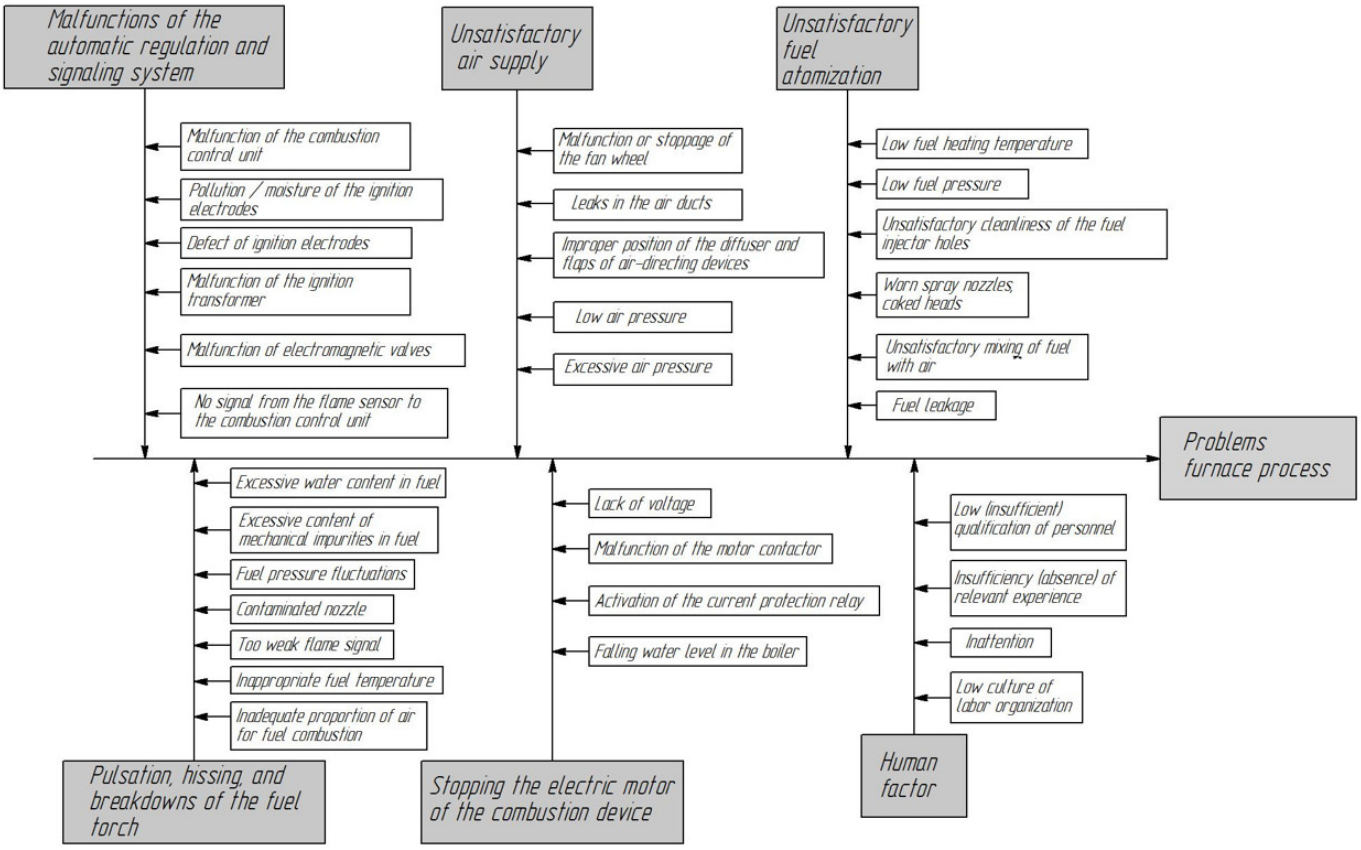
The set of factors affecting the perfection of the organization of the furnace process can be presented in the form of an Ishikawa diagram (Fig. 2).

To rank the identified factors that may be the cause of the imperfection of the combustion process organization, we will use the method of expert evaluations based on the number of points scored, using the information provided by the Weishaupt Monarch manufacturer of combustion devices [3]. The obtained results of factor ranking in percentages are entered in the Table 1. in descending order from more significant to less significant.

According to the Table 1, we build a Pareto diagram (Fig. 3), the principle of which is that, analyzing the factors that characterize the causes of the imperfection of the fuel combustion process, we can state that their small number represents great significance, while the large number that remains has low significance [4].

A cumulative broken line is also constructed, which shows the total contribution of several imperfection factors to the common causes of imperfections (failures). From fig. 3 shows that the first three factors account for 75.1% of the reasons for the imperfect organization of the fuel combustion process. The

Figure 2: Ishikawa diagram (causes and consequences) for determining factors of imperfection in the fuel combustion process.



Source: Authors.

elimination of these factors and their consequences should be dealt with first.

As part of the development of a work plan to eliminate the negative impact of these factors on the perfection of the organization of the fuel combustion process, it should be noted that companies producing combustion devices, as a rule, provide recommendations on the algorithm of actions in the event of a particular malfunction. However, it is worth noting that these recommendations are mostly typical for unscheduled (forced) maintenance, which leads to the shutdown of the combustion device and the removal of the marine boiler from work, and as a result, to a decrease in energy efficiency. Regulated maintenance of the combustion device is also not as perfect as possible and does not take into account all factors of possible failures.

Therefore, within the framework of improving the organization of the fuel combustion process on marine boilers, it is necessary to provide maintenance according to the condition, when both the frequency and the scope of maintenance work are established based on the results of continuous monitoring and forecasting of the technical condition of the elements of the combustion device, which is achieved only when using automated systems of technical diagnostics. Also, on the basis of statistical data and modern mathematical modeling tools, the development of mathematical models for maintenance planning should be foreseen.

Table 1: Failure factors of the combustion device [3].

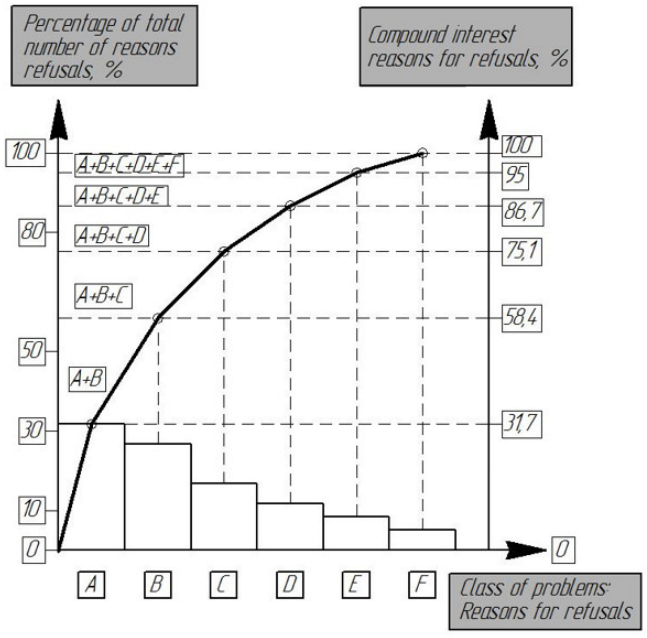
Factor code	Factor	Significance, %
A	Malfunctions of the automatic regulation and signaling system	31,7
B	Unsatisfactory fuel atomization	26,7
C	Pulsation, hissing, and breakdowns of the fuel torch	16,7
D	Unsatisfactory air supply	11,6
E	Stopping the electric motor of the combustion device	8,3
F	Human factor	5,0

Source: Authors.

Conclusions.

1. The analysis of the main factors that may be the cause of an imperfect combustion process or failure of the aggregate combustion device is summarized.
2. The most influential factors on the perfection of the organization of the fuel combustion process have been determined, which may constitute reserves for improving the

Figure 3: Pareto diagram of the reasons for the imperfection of the fuel combustion process.



Source: Authors.

quality of the organization of the fuel combustion process.

3. It is proposed to introduce maintenance of the combustion device according to the condition based on the results of continuous monitoring and forecasting of the technical condition of its elements when using automated technical diagnostic systems.
4. On the basis of statistical data and modern mathematical modeling tools, it is necessary to provide for the development of mathematical models for maintenance planning.

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