Conclusion:

Thus, automating the transition from one type of fuel to another makes it possible to speed up the transition process, achieve its smoothness through constant monitoring, abandon the costly installation of a scrubber and solve the problem of the human factor at this stage of work.

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REDUCING EMISSIONS TO THE ATMOSPHERE BY INSTALLATING OF ADDITIONAL PURIFICATION EQUIPMENT IN THE EXHAUST PIPING LINE OF THE MAIN ENGINE

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The growth and development of the fleet have a negative impact on the global environmental situation, and in order to reduce harmful emissions, the International Maritime Organization had made a decision according to which, from January 1, 2020, all maritime transport switched to low-sulphur fuel. The exceptions were ships

equipped with systems for cleaning the exhaust gases of ship power plants from chemical compounds (NOx, SOx, soot, CO), as well as research ships engaged in the development of ship exhaust gas cleaning systems. This article discusses various methods for cleaning exhaust gases from harmful substances used on ships and shore enterprises - a scrubber, a catalytic filter and an electrostatic filter. There are the design features, advantages, disadvantages and cleaning capacity of each unit below. The purpose of this work is to consider the prospects for the introduction of electrostatic filters on marine vessels. Calculations of harmful substances amount were made from the ship m/v "Khord", as well as the calculation of the amount of harmful substances neutralized by the types of treatment plants. The comparative analysis demonstrates a visual comparison and helps to draw conclusions regarding the further use of the scrubber and catalytic filter on ships. The conclusion of this research work is the focus on the integration of electrostatic filters in the exhaust gas purification system.
Keywords: electrostatic filter, exhaust gas, exhaust gas treatment, scrubber, environmental protection, marine power plants

УМЕНЬШЕНИЕ ВЫБРОСОВ В АТМОСФЕРУ ПУТЕМ УСТАНОВКИ ДОПОЛНИТЕЛЬНОГО ОЧИСТНОГО ОБОРУДОВАНИЯ В ВЫХЛОПНОМ ТРАКТЕ ГЛАВНОГО СУДОВОГО ДВИГАТЕЛЯ

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Рост и развитие флота негативно влияют на глобальную экологическую обстановку, и для уменьшения вредных выбросов Международной морской организацией было принято решение, согласно которому с 1 января 2020 г. весь морской транспорт перешел на низкосернистое топливо. Исключение составили суда, оборудованные системами очистки отработавших газов судовых энергетических установок от химических соединений (NOx, SOx, сажа, CO), а также научно-исследовательские суда, занимающиеся разработкой судовых установок очистки выхлопных газов.
В данной статье рассмотрены различные методы очистки отработавших газов от вредных веществ, использующиеся на судах и на наземных предприятиях – это скруббер, каталитический фильтр и электростатический фильтр. Ниже приведены конструктивные особенности, преимущества, недостатки и очищающая способность каждой установки. Целью данной работы является рассмотрение перспектив внедрения электростатических фильтров на морских судах. Произведены расчеты количества выбросов вредных веществ с судна т/х «Хорд», а также расчет количества вредных веществ, нейтрализованных видами очистных установок. Сравнительный анализ демонстрирует наглядное сравнение и помогает сделать выводы относительно дальнейшего применения скруббера и каталитического фильтра на судах. Заключением данной научно-исследовательской работы является направленность на интеграцию электростатических фильтров в систему очистки выхлопных газов.
Ключевые слова: электростатический фильтр, выхлопные газы, очистка отработавших газов, скруббер, защита окружающей среды, морские энергетические установки

Introduction

The relevance of maritime transport is undeniable. For a long time there was a development of ships and vessels, and now we have a high-tech and multifunctional fleet. However, over time, the environmental problem has grown, mainly related to exhaust emissions into the atmosphere, because the predominant type of power plant in maritime transport is internal combustion engine. Since the fleet is only becoming more numerous and the aggravation of the unfavorable environmental situation is inevitable, at the moment various restrictions and requirements have already been adopted, primarily related to the quality of fuel and the equipment of ships with cleaning plants [1, 12, 14].

To begin with, consider the existing classification of exhaust gas cleaning methods:

1) Methods of internal suppression of emissions (water supply to the cylinders of the engine, regulation of fuel supply, exhaust gas recirculation and selection of a certain mode of operation);

2) Methods of external suppression of emissions (use of particulate and thermal filters, liquid and catalytic converters, use of additives and ultrasonic coagulation of soot) [18];

3) Organizational measures (optimization of schedules of passenger ships, reduction of work in parking lots, limitation of the number of maneuvers during approaches and waste to berths, transfer to low-sulfur fuel);

4) Use of alternative fuels – liquefied petroleum gas, methanol, alcohol, compressed natural gas, hydrogen [2, 15].

Having analyzed these options, we can generally say that organizational measures require the reorganization of driving maneuvers, the use of alternative fuel requires special equipment for storing and supplying gases to the cylinder, and methods of internal emission suppression are associated with limiting the power of the DG. Therefore, we will study in more detail only one option, which, in our opinion, is more affordable [7, 13, 17].

Consider some variants of filters and installations from the method of external suppression of emissions, drawing a parallel with analogues used on the shore [16].

Catalyst

Catalytic filters have found great application in the purification of exhaust gases in industry, as well as in the purification of exhaust gases of internal combustion engines. They showed a high degree of purification from soot and from contaminating impurities of the acid type: NO_x, SO_x, CO. At industrial enterprises, the cleaning capacity of catalytic filters reaches about 95-98%. This is due to the introduction of new technologies, an increase in the mass-dimensional indicators of installations and the use of more effective catalytic substances.

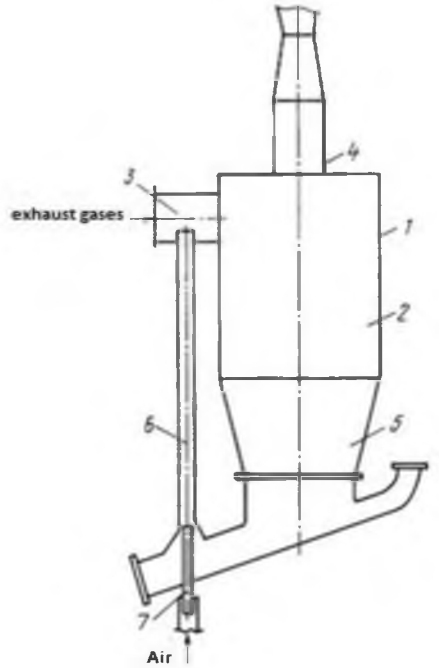

Fig.1.– Catalytic filters scheme. 1-housing, 2-sedimentation part,3-inlet pipe,4-outlet pipe,5-soot collector,6-bypass pipe,7-ejector

However, the regular need to replace the reagent raises doubts about the further development of this method and its use on merchant ships. But still, catalytic filters continue to be used on some ships. Let's give an example of the scheme of operation of a catalytic filter of centrifugal type (Fig.1) [3].

The soot collector 5 contains alkaline reagents: NaOH, KOH .The installation includes a separator consisting of a housing 1 with a sedimentation part 2. On the body 1 there is an inlet pipe 3 and an axial outlet pipe 4. The separator is communicated at the inlet with a branch pipe 3 with a soot collector. The installation has an ejector 7 that supplies the gas flow to the separator body through the gas bypass pipe 6. Exhaust gases containing harmful substances and solid impurities enter through the inlet pipe into the body of the centrifugal separator and settle down. The ejector creates a vacuum zone in the cage housing communicated with the pipeline through the inlet nipple. The gas stream, having passed through the sedimentary part, enters the soot collection, filled with an alkaline earth oxidizing reagent. Exhaust gases, in contact with the reagent, are neutralized, there is a complete purification from sulfur oxides, nitrogen oxides and carbon monoxide. After passing catalytic filtration, the gas stream enters the atmosphere through the outlet pipe. The part of this flow containing the alkaline reagent again passes through the sedimentary part of the separator and enters the soot collector. The catalytic cleaning cycle is repeated. Experiments have shown that this method of purification allows to reduce the amount of harmful substances: NOx - by 78-83%, SOx - by 75-80%, CO - by 80-82%, soot - by 60-70%.

The advantages of this cleaning system include high cleaning capacity, as well as ease of operation. The main disadvantages of catalytic filters are high mass-dimensional indicators, high cost of reagents, and also problems in storing them on the ship.

Scrubber

Among the treatment plants, the scrubber occupies an important place. This is the predominant technology on ships at the moment. The patented technology for cleaning exhaust gases from various contaminants is a flexible and relatively compact system that can be installed without much difficulty (Fig. 2). Supplied in three configurations – open loop, closed loop and hybrid – these scrubbers help to enter the framework for sulfur content in exhaust gases for both 0.1% for ECA and 0.5% for conventional areas without the use of expensive low-sulfur fuels. For the global sulphur content cap introduced in 2020, these decisions represent the most convenient option for complying with accepted international norms. Scrubbers reduce SOx to 90%, NOx to 10% and particulate matter to 60–90% of the original exhaust content. [5]

The main advantages of scrubbers over other types of filters are the high efficiency of air purification from dust, the absence of the need for regeneration (filters are self-cleaning), as well as the ability to process extremely hot, toxic, chemically active, explosive and flammable dust streams.

Many industrial dust and gas collectors are used on the shore. These include the Venturi scrubber, movable/stationary scrubbers, plate scrubber, etc.

Their diversity is justified mainly by use in various spheres of industry, starting from the rationality of application - metallurgy, agro-industry, energy and others. Unlike the ship analogue, scrubbers are used to capture other chemical pollutants - hydrogen chloride, hydrogen sulfide, ammonia, hydrogen bromide, aldehydes, acidic and alkaline vapors, metal oxides, halogens and halides, alcohols, esters, alkanes and much more [6].

A complete comparison of onshore and ship installations by the degree of purification is impractical, since the volumes of gases to be cleaned and their chemical composition vary greatly.

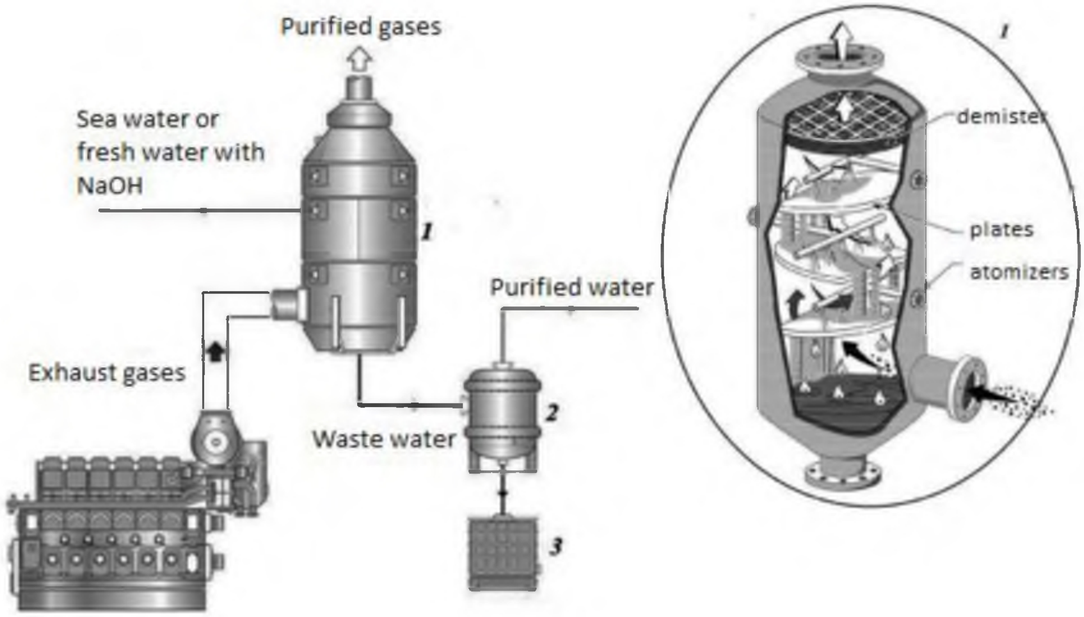

Fig 2. – Principled diagram of the ship's scrubber operation:
1 – gas cleaning housing, 2 – waste water treatment unit, soot collecting tank

It is also worth mentioning that in coastal conditions, these treatment plants are in no way limited in weight and volume, which cannot be said about ship performance. But the volume is directly related to the surface area of the liquid, which determines the effectiveness of filtration. Plus, part of the spent water in the scrubber (approximately 20%) is discharged back into the sea, which does not have a very positive effect on the overall environmental friendliness of the installation.

The heavy weight and volume of the scrubber, the need for a tank for the collection and storage of cleaning waste, and the need to eject the waste salt solution overboard are significant disadvantages of using an exhaust gas neutralization system using scrubbers.

Electrostatic filter

Existing exhaust gas treatment options have been discussed above. Now we will try to theoretically assess the effectiveness and feasibility of using the type of filtration, which is widespread in terrestrial industrial complexes (Fig. 3), but this method is not used in the design of ships.

Fig. 3 – Large-sized electrostatic filter

We are talking about electrostatic filters. They are a rather complex and technically demanding type of dust collection installations. The principle of operation of these filters is based on giving a negative charge to neutral polluting particles in the electrostatic field of the corona discharge, and then capturing these particles on electrode plates that are positively charged [8].

In coastal use, these filters have shown their high efficiency in capturing finely dispersed mechanical impurities. Among the minuses, because of which these installations have not received widespread use, it can be noted:

1.Low efficiency in the treatment of wet dust, as well as danger when working with flammable substances;

2.Powerful high-voltage DC equipment is needed, including transformers and even a local substation, hence the high consumption of electricity;

3.In economic terms, it is rational to use electrostatic precipitators only when treating medium and large volumes of medium;

4.Efficiency is guaranteed only for ultra-low dispersion particles that are formed during pyrolysis, combustion and other thermal and chemical processes.

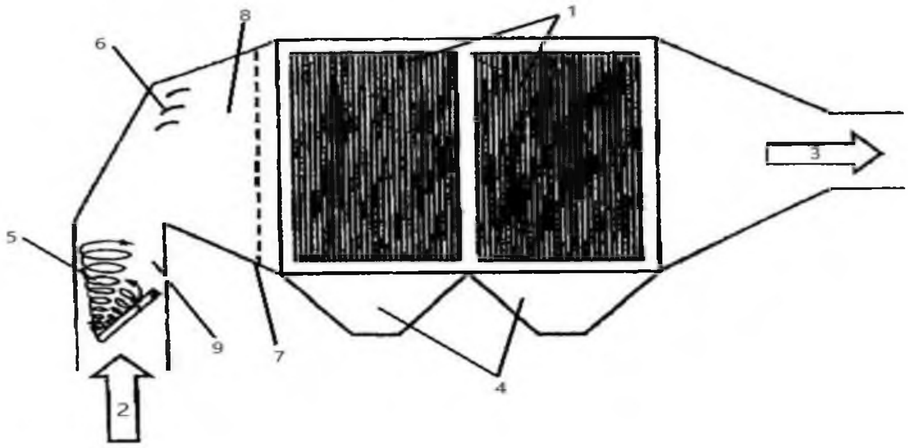

Fig. 4 – Electrostatic filter diagram: 1 - electrostatic filters, 2 - inlet gas, 3 - outlet gas, 4 - storage tank, 5 - vortex-forming device, 6 - reflective dampers, 7 - flow distributor,8 - expansion cap, 9 - vertical channel

As we can see, all the shortcomings have almost nothing to do with the ship's conditions. The installation of this filter is supposed to be in the exhaust tract of the main engine after the utilization boiler, which means that its dimensions will correspond only to some part of the exhaust pipe. These dimensions are significantly inferior to the coastal ones, hence the fact that electricity consumption will not be so overestimated.

With regard to vessels, the design in a generalized form will look like this (Fig. 4): in the exhaust tract, a vertical channel (9) is made for the incoming gas flow with a constant cross-sectional area, after which the channel is located gradually expanding towards the electrostatic filter (1) gas cap (8). A flow distributor (7) located in the extended area of the gas receiving cap is also provided. In addition, there is a vortex-forming device (5), which serves to mix the gas and temperature medium. Reflective flaps (6) help direct the flow of gases after vortex to the plates of the electrostatic filter. Under the filter there is a storage tank (4), which receives dirt and dust that have settled on the filter elements [9].

To automate the process of cleaning electric plates, you can borrow the technology from coastal installations - when starting, a servo motor or a gear mechanism rotates the shaft, on which a set of hammers is installed, hitting the ends of the plates with sufficient force to create vibrations (Fig. 5).

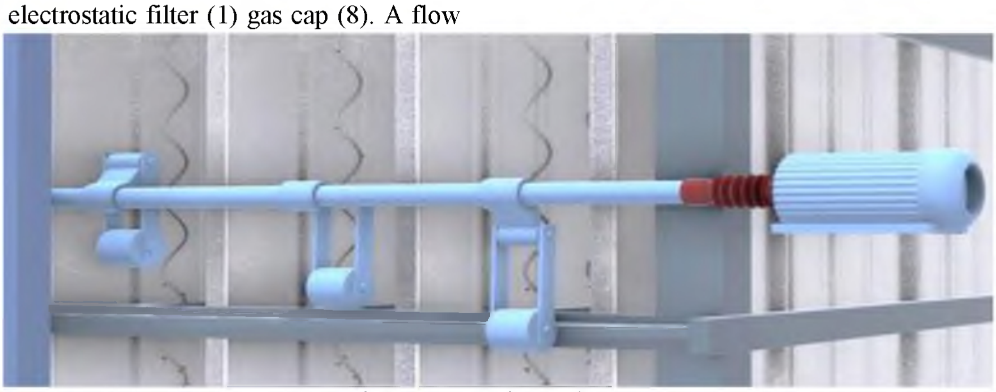
Fig.5 – Automatic soot bumper

The vortex-forming device in conjunction with the flow distributor allows the electrostatic filter to purify the gas with greater efficiency, as it ensures the uniformity of the moving medium. When a non-optimal flow filter enters the filter, there will be a heterogeneous distribution of dust, temperature or velocity in the gas flow, as a result of which dust deposits can very easily form, which gradually lead to a decrease in the flow-through section available for passing the flow through the electrostatic filter and to a corresponding decrease in its efficiency. It is worth noting that these are all only theoretical assumptions, and changes will be made during practical tests. However, the electrostatic filter is a promising installation with the possibility of modification - adding additional vortex-forming devices and flow distributors, or using a mixing device to supply special reagents to the gas before installation to increase the electrical conductivity of the medium.

Inference

All the above-mentioned methods of cleaning exhaust gases on ships are very effective, and in the case of an electrostatic filter, promising. However, for clarity, it is necessary to analyze and compare all installations. For example, let's take the report made by LUKOIL-BUNKER LLC on the amount of emissions of harmful substances from the vessel m/v "Khord". The vessel does not have exhaust gas cleaning devices, which in turn facilitates our further calculations [4].

Based on the calculations made in this document, the following results were obtained (Fig. 6).

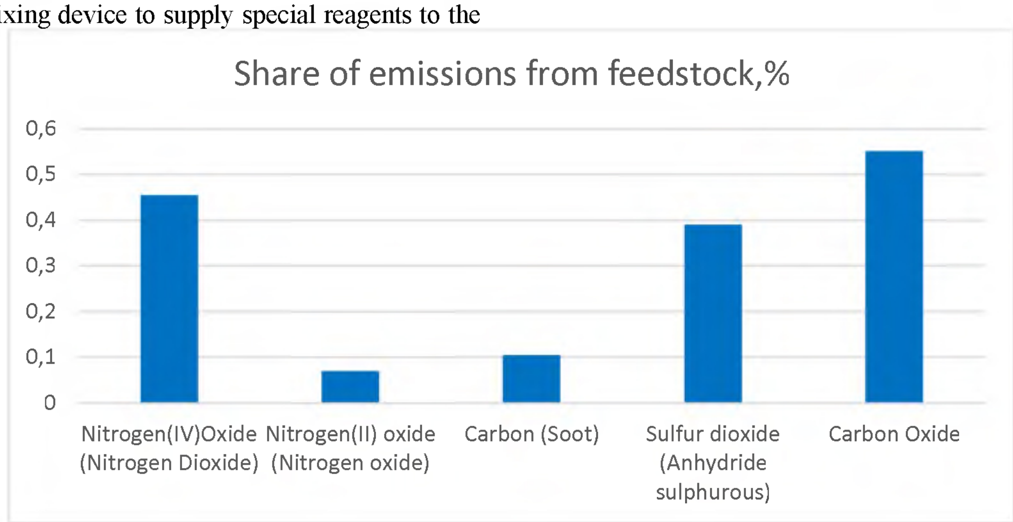

Fig.6 – Percentage of harmful substances in fuel combustion

Let's compare the amount of emissions into the atmosphere when this vessel implements the cleaning systems mentioned in our article. For convenience, let's take the average values of the cleaning efficiency of the plants. We will assume that the cleaning capacity of the systems from nitrogen oxide and nitrogen dioxide will be the same, and we will present this in the table (Table 1).

Table 1

	Degree of purification from NOx, %	Degree of purification from SOx, %	Degree of purification from soot, %	Degree of purification from CO, %
Scrubber	10	85	90	0
Catalytic filter	88	83	65	82
Electrostatic filter	73	79	96	63

By adding correction factors to the calculation formulas given in the report, we get a visual representation of the effectiveness of each cleaning scheme:

This histogram (Fig.7) clearly shows the efficiency of exhaust gas cleaning by different methods. According to it, we can conclude that the optimal choice will be catalytic filters. However, it should be borne in mind that their service life is significantly lower compared to competitors. In this regard, the next step for us will be to compare the service life of each device under the condition of trouble-free operation. So, the service life of the scrubber before overhaul is 8-10 years and this is due to corrosion of the body and its parts. Catalytic filter maintenance mainly consists of replacing segments containing finely dispersed reagents with alkaline properties every 9-12 months. The service life of the electrostatic filter of the proposed scheme is 5-6 years and this is due to the replacement of the high-voltage transformer.

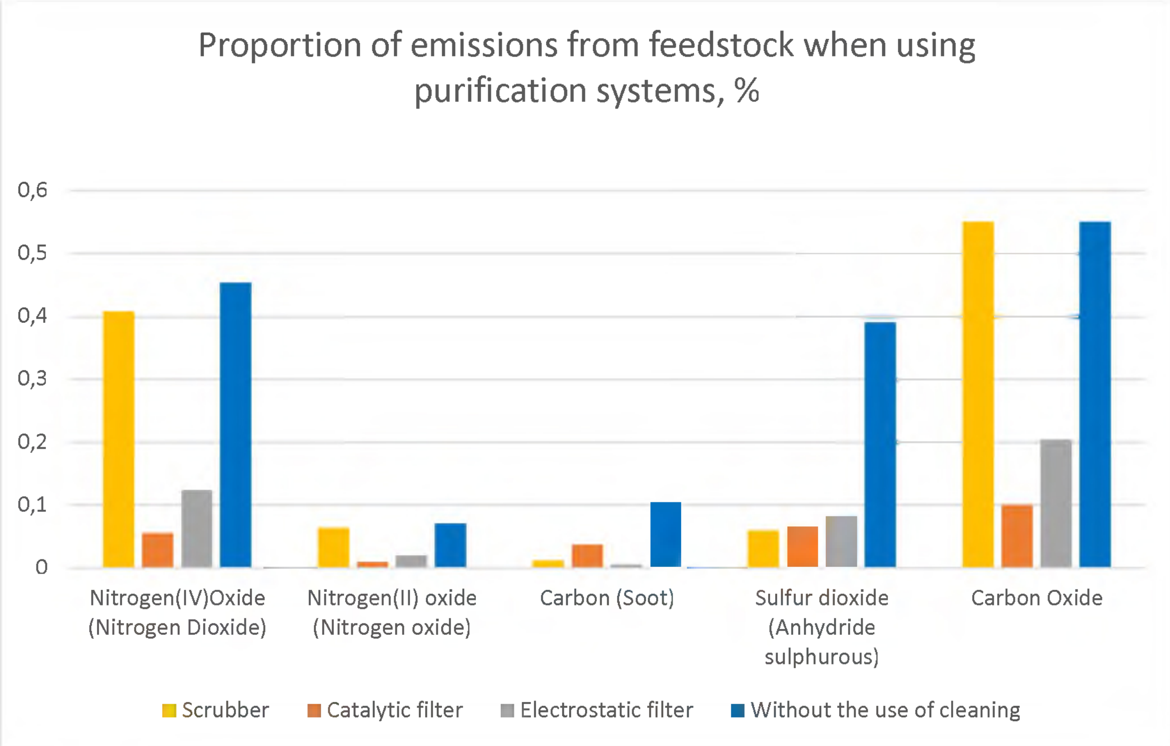

Fig.7 – Proportion of emissions from feedstock when using different purification systems

From an economic point of view, the most profitable option is a scrubber, since its operation requires a small amount of electricity. Catalytic filters are the least cheap to maintain and this is due to the high cost of segments and the problem of their storage on ships. An electrostatic filter is a large consumer of electricity to create the necessary electrostatic charge between the plates, and, as a result, occupies an intermediate position between the scrubber and the catalytic filter in terms of efficiency [19].

Based on all of the above, we can draw some conclusions on the rationality of the choice of an installation for cleaning exhaust gases on a vessel. Focusing on improving the environmental friendliness of the vessel, the right decision for the shipowner will be the choice of catalytic filters. But, in addition, there is a problem in the storage of reagents on the ship and in the high costs of their purchase. A scrubber is currently a good choice for exhaust gas cleaning. It meets the requirements of international environmental codes. However, at present there is a tendency to tighten control over the emission of harmful substances into the atmosphere from ships. There is a risk of scrubbers disappearing from ships due to their insufficient cleaning capacity. A promising solution to this problem, in our opinion, is the introduction of electrostatic filters on ships, and, moreover, this treatment plant does not exclude the use of others - it can be used in conjunction with a scrubber or catalytic filter to level the shortcomings of each of the installations.

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DIAGNOSTICS AND INTERPRETATION OF SIGNALS OF A COMPLEX DYNAMIC SYSTEM OF A SHIP POWER PLANT BASED ON FRACTAL ANALYSIS

Ionut Cristian SCURTU, A. I. Epikhin, Octavian Andrei BREZEAN

The article is devoted to the analysis of the features of the diagnostics and interpretation of the signals of a complex dynamic system of a ship power plant (SPP) based on fractal analysis. During the analysis, the Hurst exponent was calculated and the wavelet decomposition of the signals being analyzed was carried out. The proposed approach is universal and can be used to diagnose the technical condition of different types of power plants.
Keywords: fractal analysis, ship power plant, wavelet decomposition, signal, vibration.

ДИАГНОСТИКА И ИНТЕРПРЕТАЦИЯ СИГНАЛОВ СЛОЖНОЙ ДИНАМИЧЕСКОЙ СИСТЕМЫ СУДОВОЙ ЭНЕРГЕТИЧЕСКОЙ УСТАНОВКИ НА ОСНОВЕ ФРАКТАЛЬНОГО АНАЛИЗА

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Статья посвящена анализу особенностей проведения диагностики и интерпретации сигналов сложной динамической системы судовой энергетической установки (СЭУ) на основе фрактального анализа. В процессе проведения анализа был рассчитан показатель Херста и осуществлено вейвлет-разложение сигналов, которые анализируются. Предложенный подход является универсальным и может использоваться для диагностики технического состояния СЭУ разных типов.
Ключевые слова: фрактальный анализ, судовая энергетическая установка, вейвлет-разложение, сигнал, вибрация.