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AUTOMATISATION OF THE SHIP SYSTEM FOR EXHAUST GASES CLEANING

The problem of exhaust gases cleaning while diesel engine works as a unit of ship power plant was considered. For the ship technological exhaust gases outlet line there has been offered to use automatic cleaning system. By means of automatic switching on/off between purifying lines there could be achieved the discharge of spoiled water, exhaust gases temperature control on the outlet line of the ship's power plant and providing the answering to all legal norms for burned products discharge to the environment. Structural scheme and algorithm have been developed for the work of automatic control system. For automating process control of exhaust gases cleaning have been formulated a list of software, devices and sensors.

***Keywords**: diesel engine, ship power plant, exhaust gases, gases discharge line, exhaust gases composition, impurities, water cassette, cleaning production, structural scheme, controlling algorithm, automatic control, system software SCADA, industrial protocol HART, temperature and flow-rate measuring units, diapason of the change in main parameters, control of temperature, flow- rate, impurity level, filtration level, leakage*

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АВТОМАТИЗАЦИЯ СУДОВОЙ СИСТЕМЫ ОЧИСТКИ ДЫМОВЫХ ГАЗОВ

Рассмотрена проблема очистки дымовых газов при работе дизельного двигателя в составе судовой энергетической установки. Для судовой технологической линии отвода дымовых газов предложено использовать автоматизированную систему очистки. За счет использования автоматического переключения между линиями очистки достигается своевременный отвод загрязненной воды, управление температурой дымовых газов на выходе из судовой энергетической установки и обеспечение требований по нормативным выбросам продуктов горения в окружающую среду. Разработаны структурная схема и алгоритм работы системы автоматического управления. Для автоматизированного управления процессом очистки дымовых газов приведен перечень программного обеспечения, оборудования и датчиков.

***Ключевые слова**: дизельный двигатель, судовая энергетическая установка, дымовые газы, линия отвода газов, состав дымовых газов, примеси, водяная кассета, производительность по очистке, структурная схема, алгоритм управления, автоматическое управление, программное обеспечение системы SCADA, промышленный протокол HART, датчики температуры и расхода, диапазон изменения основных параметров, контроль температуры, расхода, степени загрязнения, уровня фильтрации и утечки*

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АВТОМАТИЗАЦІЯ СУДНОВОЇ СИСТЕМИ ОЧИСТКИ ДИМОВИХ ГАЗІВ

Розглянуто проблему очистки димових газів під час роботи дизельного двигуна у складі суднової енергетичної установки. Для суднової технологічної лінії відводу димових газів запропоновано використовувати автоматизовану систему очистки. Завдяки використанню автоматичного перемикання між лініями очищення досягається своєчасний відвод забрудненої води, управління температурою димових газів на виході з суднової енергетичної установки і забезпечення вимог щодо нормативних викидів продуктів згорання в навколишнє середовище. Розроблені структурна схема і алгоритм роботи системи автоматичного керування. Для автоматизованого управління процесом очищення димових газів наведено перелік програмного забезпечення, обладнання і датчиків

***Ключові слова:** дизельний двигун, суднова енергетична установка, димові гази, лінія відводу газів, склад димових газів, домішки, водяна касета, продуктивність очищення, структурна схема, алгоритм управління, автоматичне керування, програмне забезпеченя системи SCADA, промисловий протокол HART, датчики температури і витрати, діапазон зміни загальних параметрів, контроль температури, витрати, степені забруднення, рівня фільтрації і витоку*

I. Introduction

At present time, diesel engines in the ship power plants most widely used because they are about 90 % of the world fleet. The world's leading producers of ship diesel power plants are: "Mitsubishi Heavy Industries Ltd.", (Japan) – 10 % of the world; "Wartsila Switzerland Ltd." (Switzerland) - 25% of the world production;«Burmeister and Wain» (Denmark), MAN (Germany); «Doksford» (United Kingdom); «Stork» (The Netherlands); «Geta-verken» (Sweden); «Fiat» (Italy); «Pillstick» (France) [2-3]. Diesels, produced by these manufactures differ both in design and in performance parameters.

In the classification of diesel engines, depending on the speed of the piston they are differing as:

– low-speed (speed of piston equals up to 7 m/s);

– average speed (speed of piston differs from7 to 10 m/s);

– high-speed (the speed of piston is more than 10 m/s).

The performance of any diesel plant is characterized by regimes of nominal, maximal and minimal loading mode. To determine the maneuvering capabilities of the ship are used an additional regime of a minimally stable shaft speed. In this mode of operation an energetic resources of the vessel use about 3–4 % of nominal capacity and about 30 % of the rated speed of the diesel shaft [4]. As the operational power of diesel engine is accepted average power of diesel engine under the planned load and speed of the vessel. For cargo ships, it is about 85–90 % of rated power and for towing – 90–95 %. Exactly the very power mode determines economic performance of the vessel and gives ability to rate fuel costs [2].

The principle of the diesel engine operation is based on the use of the chemical energy of fuel combustion process resulting in the flue gases appearance. In this case, it can be stated, that regardless on the diesel engine design and its main performance indicators exist unsolved problem of flue gases cleaning.

According to the requirements of regulating documents a concentration of contaminants due to the release to the environment must be determined individually for each component [6–7]. The most toxic compounds are oxides of nitrogen [5] and their concentration in the exhaust gases depends on the design of a diesel engine.

Permissible limits for emissions of the main components of exhaust gases, which are produced during operation of the ship’s diesel should be less than: NO_2 – for low-speed diesel up to 20 g/kW•h, medium-speed – 10 g/kW•h; N0 - 75 g/kW•h, O_2 – 12,3 g/kW•h; CO_2 – 5,6 g/kW•h, inert gases – 0,9 g/kW•h, H_2O vapor – 6 g/kW•h; SO_2 – 12 g/kW•h; CO – 0,6 g/kW•h; CH – 0,4 g/kW•h, carbon black – 0.05 g/kW•h [6]. During the work of ship diesel harmless or neutral ($C0_2$) substances in the total amount are up to 99 % of the total volume of exhaust gases. Others include oxides of nitrogen ($N0_2$), sulfur ($S0_2$), carbon monoxide (CO), hydrocarbons (C_2H_4) and particles (carbon black, cinder) [1,7].

II. Materials of research

Common functional scheme of the ship's power plant is shown in Fig. 1.

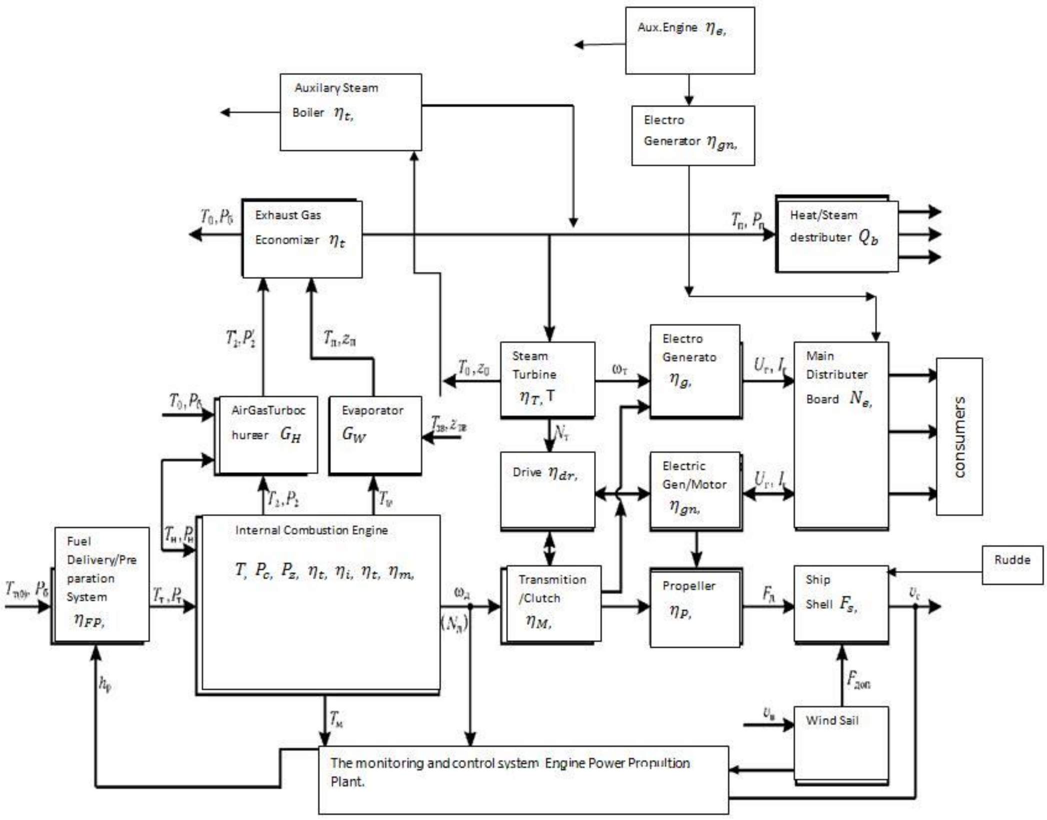

Fig. 1. General functional scheme of the ship’s power plant

Its analysis shows that at the exit from the recycling boiler and heat distributor any additional equipment for exhaust gases treatment is not provided. This fact is very big disadvantage and because of this reason during investigation works there have been developed a new technological scheme for exhaust gases cleaning. It is shown in Fig. 2 and the principle of its work had been based on the use of water as a filtering material [5].

The exhaust gases from the discharge vent channel 1 through two lines enter water cassettes 4. Their flow-rate is controlled by means of automatic non-return valves 3. Inside the cassettes, by means of the directing rigid plates 5 out-flowing exhaust gases obtain complex movement and during the lifting up process the particles of impurities contact with water molecules, and then deposit on the plates 5. Fully cleaned exhaust gases through lines 6 pass the outlet non-return valves 7 and then are emitted into the surrounding space. The quantity of water in the filtering cassettes is under constant monitoring. Its supply is carried out with lines 8 usage and drainage respectively goes at lines 10. These branches are equipped with automatically controlled valves 9, 11.

To achieve maximal effectiveness of the process of treatment and purification of exhaust gases under the ship’s conditions there is necessary to fulfill constant monitoring of a number of important technological parameters. To these parameters belongs:

– exhaust gases temperature at the enter and the outlet of water filtration cassettes;

– the temperature of water in filter cassettes;

– partial and total flow-rate of exhaust gases;

– water level in the filter cassettes;

– the degree of water contamination in the filtering cassettes.

The numerical values of the stated parameters determine the way and order to manage the process of purification. To ensure the operational continuity of the ship's systems for treatment and purification of exhaust gases technological scheme implies the use of primary and reserve water cassettes. The degree of contamination for main cassettes determines automatically and then happens flow redirecting of the treated exhaust gases to reserve cassettes. By means of such technical solution the automatic control system for the process of exhaust gases cleaning can significantly improve the efficiency and reliability of the operation of the ship's power plant.

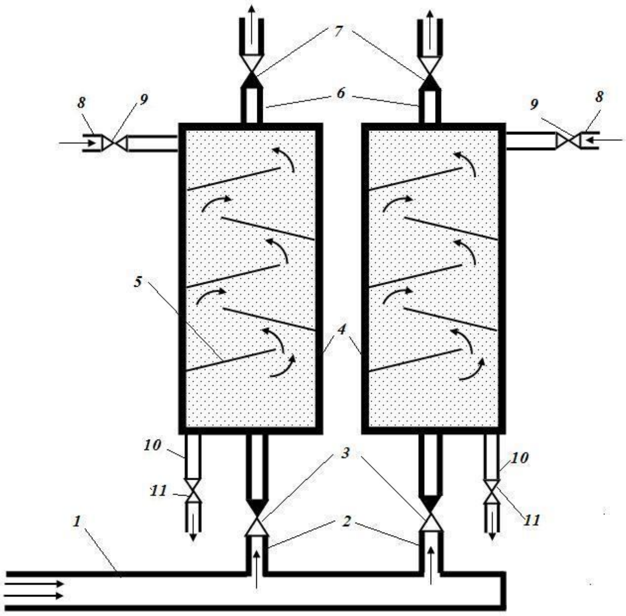

Fig. 2. Technological scheme for exhaust gas cleaning:
1 – exhaust vent channel; 2 – line for partial selection of exhaust gases; 3 – automatic non-return valve; 4 – body of water cassette; 5 – directing plates; 6 – line for cleaned gases discharge; 7 – automatic non-return discharge valve; 8 – water supply line; 9, 11 – automatically controlled valves; 10 – waste water discharge line

Ensuring of the stated above working parameters can be achieved by means of use of the most advanced methods for control and technological process monitoring, control and measuring equipment and actuators. They should be used in combination with advanced information industrial technologies. The most fully to these requirements answers the equipment of Emerson’s company. Technological solutions of the company allow to create highly reliable and high-effective systems for technological processes control in the wide range of change for such parameters like: the temperature of the working process, the pressure in hydraulic systems, the level of vibration. They also can operate at a high electrical and electromagnetic interference [8].

During its operation process control system for exhaust gas cleaning automates fulfillment of:

– exhaust gases temperature and flow-rate controlling;

– control of temperature, the degree of contamination and the level of filtering water;

– control of leakage in the exhaust system of ship energy plant;

– management of the main and reserve filtering cassettes;

– water supply and drainage to/from filtration cassettes;

– display of all operating parameters of the process in real time;

– system alarm mode indication.

Fig. 3 shows a developed structural scheme of the system of automatic management for the ship's exhaust gas cleaning equipment.

To manage the process of exhaust gas cleaning the system uses a PC with installed software by SCADA system, allowing visualization of management procedures, data of sensors and status of the components [9]. The check up of the system's sensors provided by means of industrial protocol HART [10].

It makes possible to provide reliability, simplicity of setup and installation of the initial and boundary parameters of the sensors. The HART protocol also provides high interference immunity needed under working conditions of the ship. All system's sensors have a built-in HART-interface. To ensure the conversion of information signals from sensors into digital form suitable for processing on a PC have been used HART-modem, connected to the network of sensors with two-wire line and to the PC via RS-232 interface. For sensors and PC combining in the single information network can be used wireless technologies also [11].

The management of four filtration cassettes (two working and two reserves) provided by electromagnetic valves controller (EMK1-4) on internal multiplexed bus. The governing information goes to the controller from PC via wired Ethernet network. Each filtration cassette is controlled by three electromagnetic valves: working one – for supply of exhaust gases, inletting one – for water supply to the filter, draining one – for filter cleaning in case of water contamination level exceeding.

To monitor the changes in the main parameters of the exhaust gases cleaning process were stated following ranges in the change of key values:

– exhaust gas temperature at the entrance to the system of filtration cassettes: t_1 = 120-600 ° C;

– temperature of the exhaust gases at the exit from filtration cassettes: t_2 = 60 – 90 ° C.

Descending below the lowest value of temperature t_1 indicates on possible depressurization and leakage of exhaust gases in the exhaust line of the ship's power plant.

The exit temperature t_2 is used as a control parameter to identify the necessary quantity of filtering cassettes working at the same time. While its value is small it possible to include in the processing circuit one cassette only, but while the values are prolonged and high it possible to introduce at the same time all four cassettes.

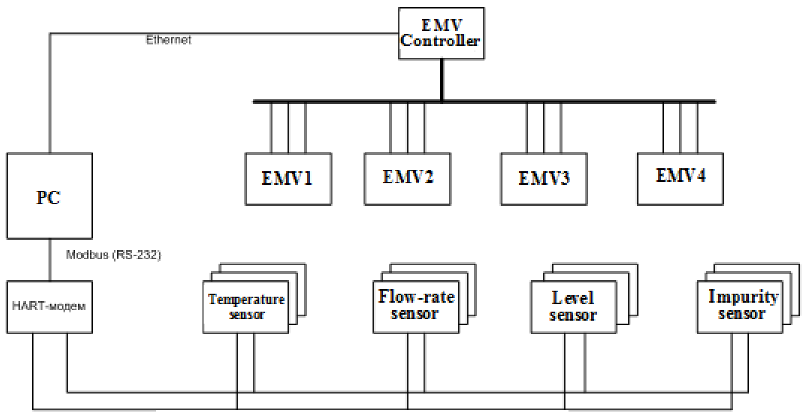

Fig. 3. Structural scheme of the automatic management system for the ship's exhaust gas cleaning equipment

The values for permissible levels of exhaust gases flow-rate, the volume of water in the filters and its level of contamination are variable parameters that depend on the degree of technical condition of ship's power plant. These values must be determined individually for each vessel during pre-commissioning works and configuring of automation management system.

The developed algorithm for the work of ship's management system of the exhaust gases cleaning process is shown in Fig. 4.

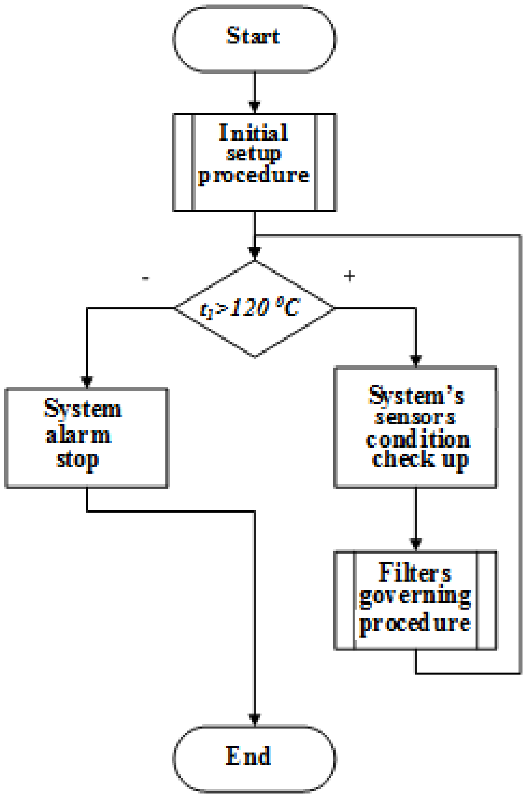

Fig. 4. The scheme of the control system work algorithm

The initial setup procedure includes checking of the working ability of all units of the governing system of management and selection for water filters the working initial conditions. The filter governing procedure is described by a complex empirical dependence function in the form: $F=f(x_i,t_1,Q_1,t_2,l_i)$. This dependence relationship uses the following values: x_i – state of the filtration cassettes working valves (i = 1 .. 4); t_1 – exhaust gases temperature at the entrance to the filtration system; Q_1 – flow-rate of supplied to the processing gases; t_2 – exhaust gases temperature at the outlet of the filtration system; l_i – water level in the i-th filter.

To correct the above stated dependence it is recommended to conduct test trials under specific exploitation conditions of the exhaust gas cleaning system. The obtained values of the parameters and factors can be stored in a database of the SCADA management program for further use in the vessel's real operating conditions.

The change in the technological contour configuration, which includes primary and reserve filters, can be done in the following cases:

1. Exceeding of the permissible level of the exhaust gases temperature at the exit of the filtration system – introducing additional filtering contours from the reserve ones.

2. Excess of water temperature in the active filter circuits – introducing additional filtering contours from the reserve ones.

3. The excess of the allowable level of contamination in the filtering water (from 20 %) – there provides switching off and cleaning of active filter by means of polluted water drainage and clean water supplying to the level stated by sensor.

In case when during the work of all four filtration circuits the system parameters go out the stated limits the system switches to emergency mode or manual mode.

The advantages of the described system for exhaust gas cleaning in comparison with known analogues [2–4] are full automation of cleaning process and simplicity of construction. In contrast to all known technologies it has no mechanical filtering elements because the filter is usual water. Reliability of the operation is assured by approach never applied previously on the automating of working process parameters for performance management and capacity regulation of the purifying plant.

III. Conclusions

1. Regardless of the design of the diesel engine and its key performance indicators there still exist an unsolved problem of exhaust gases cleaning.

2. As a solution of the exhaust gas cleaning problem may be considered a new automated technological scheme, the working principle of which is based on the use of water filtration cassettes.

3. The offered variant of automated governing of the ship's exhaust gas cleaning process concerns the usage of PC, the SCADA system software, Industrial Protocol HART, primary sensors with integrated HART-interface, HART-modem connected to PC via RS-232 interface, electromagnetic valves controller governing via internal multiplexed bus.

4. For sensors and PC combination in a single information network can be used two-wire lines or wireless technologies.

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