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EVALUATION OF FUEL CELL TECHNOLOGY EFFICIENCY FOR SHIP ENERGY SYSTEM

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Abstract. The work is devoted to the analysis of the thermodynamic efficiency of the cycle of the ship's hybrid energy system with fuel cells and a gas turbine with a capacity of 2500 kW. The performed calculations proved an increase in the efficiency of the thermal scheme of the installation with the utilization of the heat of the waste gases of the fuel cells in the gas turbine circuit with the injection of steam into the combustion chamber. This allows us to assert the prospects of such an energy system for power generation in ship conditions.

Keywords: energy system; heat engine; fuel cell; gas turbine.

Introduction. Power plants with solid oxide fuel cells (SOFC) are considered for use on marine vessels as auxiliary equipment, as a ship power plant, and also as main engines, since they can convert chemical energy into electrical energy with high efficiency, with practically no harmful emissions, such as NO_x, SO_x, etc. [1-6]. It is also noted that fuel cell systems have good characteristics when working at partial load modes, low maintenance costs, and low noise and vibration [7]. One of the advantages of SOFC should be noted is their fuel flexibility, which means the possibility of direct use of different types of fuel, or their use after certain stages of processing [1].

Today, in existing commercial SOFC systems, as well as in research projects, hydrogen, methane, or natural gas are primarily considered as fuel. Several alternative marine fuels have also been claimed, the possibilities of which have also been evaluated for SOFC.

Main part. With the use of data [8], this paper developed a mathematical model of a hybrid power plant with a capacity of 2500 kW. This model has two independent submodels: a SOFC stack and a contact gas turbine unit (CGTU) with a gas turbine engine (GTE) operating with over-expansion.

For the solid oxide fuel cell-gas turbine (SOFC-GT) complex under consideration, a complex scheme of the gas turbine part is adopted, in which the CGTU cycle operating with over-expansion is implemented. Such a CGTU scheme, as shown below, allows you to reduce the pressure in the SOFC stack casing to acceptable values and significantly increase the efficiency of the hybrid power plant.

The mathematical model of CGTU is written for 1 kg/s of air entering the GTE compressor, to find the specific power parameters of turbomachines, as well as the steam productivity of the steam generator of the heat utilization circuit. After finding the specific parameters in the mathematical model, the transition is made to the formulas that describe the mass and energy parameters in the final

form, taking into account the air flow required for the operation of one SOFC stack at the rated power of the installation.

To determine the indicators of the SOFC-GT scheme in a wide range of determining parameters, its optimization calculations were performed for the range of values of the pressure increase in the gas turbine compressor π_c from 4 to 18. Fig. 1 shows the dependence of the efficiency of the SOFC-GT hybrid scheme on the rate of pressure increase in the compressor, and Fig. 2 shows the change in the capacity of the gas turbine part of the hybrid scheme, which is accounted for by one SOFC stack, in the specified range of π_c.

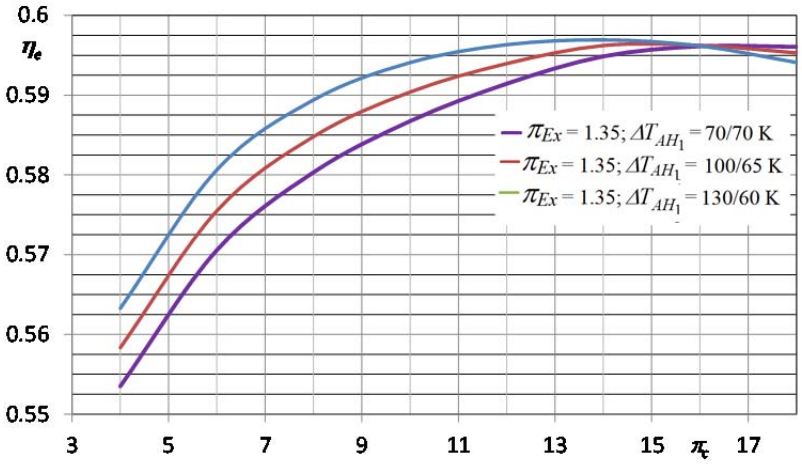

Figure 1 – Dependencies of the efficiency of the SOFC-GT hybrid system on the rate of pressure increase in the compressor

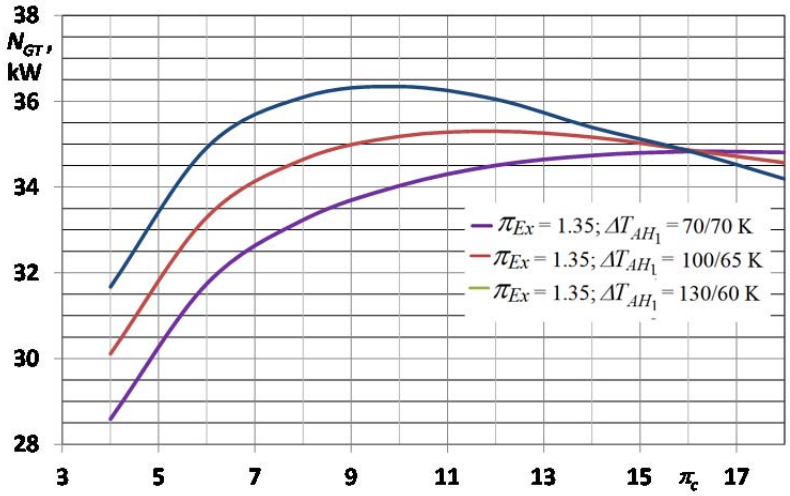

Figure 2 – Power change of the gas turbine part of the SOFC-GT system per one stack

Of interest are the changes in the initial characteristics of the gas turbine part of the SOFC-GT hybrid power plant with a capacity of 2500 kW when the pressure increase in the compressor π_c changes from 5 to 10 and the pressure increase in the exhauster π_{Ex} varies from 1.2 to 1.5.

Fig. 3 shows the change in the generated power of the gas turbine part, and Fig. 4 shows the change in air flow rate through the gas turbine compressor.

The calculated parameters of the ship's hybrid energy system: GTE capacity is 524.2 kW; SOFC stack power is 150.9 kW; stack battery power is 2112.5 kW; the total capacity of the power plant is 2636.6 kW; the efficiency of the power plant is 59.4%.

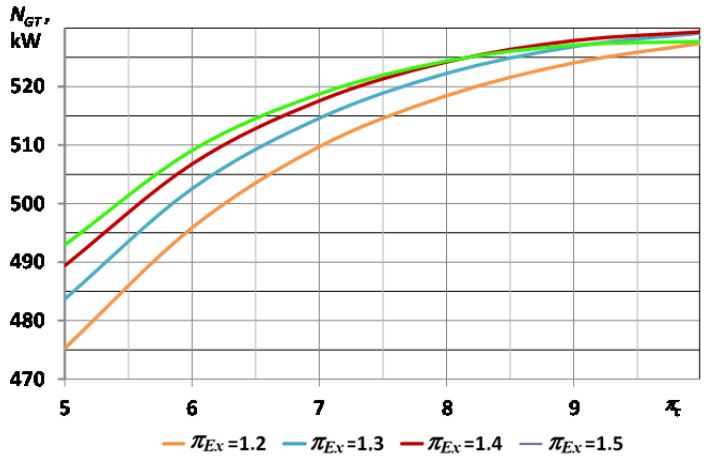

Figure 3 – Power change of the gas turbine part of the hybrid power plant

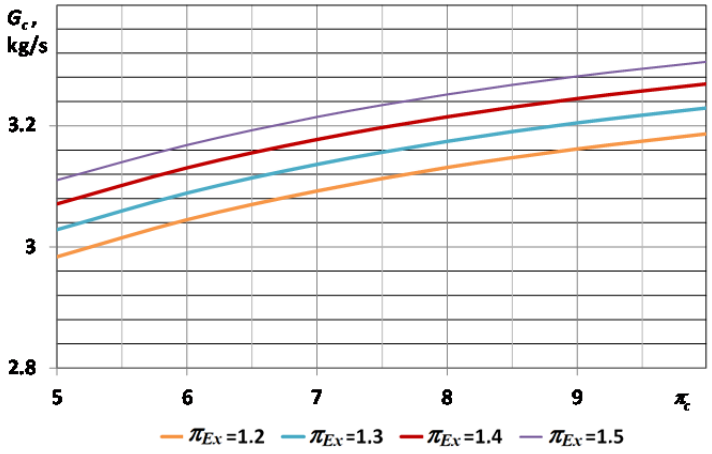

Figure 4 – Change in air flow rate through the gas turbine compressor of the hybrid power plant

Conclusions. 1. The scheme of a promising SOFC-GT ship power plant, which uses stacks of solid oxide fuel cells, as well as a contact gas turbine unit operating with over-expansion, has been developed.

2. A mathematical model of the SOFC-GT hybrid scheme was developed, which allows optimizing the thermodynamic parameters of its gas turbine part.

3. It is shown that the use of a contact gas turbine unit with an over-expansion turbine allows achieving the overall efficiency of the complex of 59.4% at the SOFC operating temperature of 1190 K and its efficiency of 46.24%.

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Оцінка ефективності технології паливних елементів для енергетичної системи судна

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Роботу присвячено аналізу термодинамічної ефективності циклу суднової гібридної енергетичної системи з паливними елементами та газовою турбіною потужністю 2500 кВт. Проведені розрахунки доказали підвищення ефективності теплової схеми установки з утилізацією теплоти відхідних газів паливних елементів в газотурбінному контурі з впорскуванням водяної пари в камеру згоряння. Це дозволяє стверджувати про перспективність подібної енергетичної системи для генерації електроенергії в суднових умовах.

Ключові слова: енергетична система; тепловий двигун; паливний елемент; газова турбіна.

УДК 629.123.066

ПРО ПІДВИЩЕННЯ ЕНЕРГЕТИЧНОЇ ЕФЕКТИВНОСТІ ТА ЕКОЛОГІЧНОЇ БЕЗПЕКИ СУДНОВИХ КОТЕЛЬНИХ УСТАНОВОК

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