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ENERGY SAVING ENERGETIC SYSTEMS FOR COASTAL FISHING CUTTERS

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Abstract. The maritime environment protection is increasingly reflected in legal regulations regarding, inter alia, the harmful exhaust gas components emitted by marine combustion engines. The provisions imposing the emission limits for SO_x, NO_x and CO_2 are included in MARPOL 73/78 ANNEX VI adopted by the International Maritime Organization (IMO). However, as of today, these provisions are not applicable to fishing cutters. One of the methods, both to decrease emissions' volume and also to reduce the operating costs of ships, is to lower fuel consumption of marine energetic systems. The paper presents a proposition of energy-efficient and environmentally friendly energetic systems for coastal fishing cutters. It also demonstrates the importance of the said systems and includes the elaboration regarding the impact of fuel type, renewable energy sources and energy conversion methods on the hazards to the environment caused by the emission of harmful exhaust gas components. The presented solutions refer to fishing cutters of the length of 15-30 m and are categorized into two groups. The division criterion applied is an access to technologies currently available and future technologies enabling the use of alternative energy sources.

Keywords: fishing cutters, energetic systems structure, alternative fuels and energy source, exhaust gas emission

INTRODUCTION

Sea fishing industry is a significant food supplier. This task has been performed by fishing fleets of particular European states. For example, the Polish fishing fleet, operating at the Baltic Sea, consists of 650 vessels, while the Danish one is made up of 950 vessels (annual report, 2015, Behrendt, 2013) operating at the Baltic Sea and the North Sea.

The implemented provisions of MARPOL 73/78 Annex VI are intended to reduce the volume of the harmful exhaust gas components emitted by ships. Under the said Convention, the special areas were designated and named ECAs (the Emission Control Areas) which, in Europe, cover the Baltic Sea and the North Sea. It is also planned to include the Mediterranean Sea area to the ECAs (Hongisto, 2012, Johansson et al., 2017). The ships operated in these areas are subject to the established SO_x limits and should be equipped with combustion engines complying with the standards on NO_x emission, included in Tier II and Tier III provisions. In order to reduce CO_2 emissions, the IMO has introduced the obligation for new ships to meet the requirements in terms of the Energy Efficiency Design Index (EEDI), and for the already operated ships – to meet the requirements in terms of the Energy Efficiency Operational Index (EEOI). Moreover, all ships, both being in operation and the new ones, are subject to the Ship Energy Efficiency Management Plan (SEEMP), which ensures optimal ship operation from the point of view of power consumption and hazards to the environment. The obligation refers to ships over 400 GT and to the following types of vessels: bulk carriers, gas carriers, tankers, container ships, general freight carriers, refrigerated freight ships and combination carriers [IMO, 2015]. Both the EEDI and the EEOI consider the CO_2 emission in relation to the fuel type used at ships. They are also necessary for the SEEMP to be drawn up (Szczepanek and Kamiński, 2013, Tourret and Pinon, 2008).

As of today, the abovementioned limitations are not applicable to fishing cutters. However, given the large number of fishing vessels operating at waters around Europe, including the

ECAs, it should be expected that they will be established and implemented also for this group of ships.
The volume of the harmful exhaust gas components emitted by combustion engines may be reduced by discontinuance to use common petroleum fuel for gas fuel.
An example of an LNG fuel system, that may be installed at fishing cutters (longer than 15 m), is presented in Figure 1.

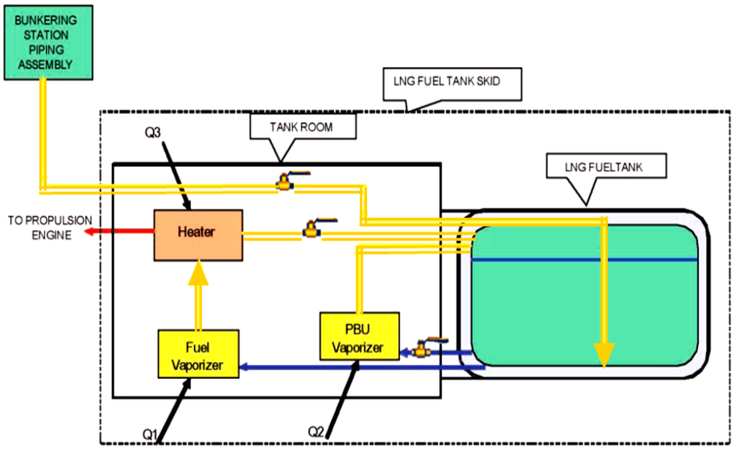

Fig. 1. Idea of the LNG fuel system for small ships

Source: Hamwhorty (2016)

During the analysis of Figure 1, one may see that the system requires additional elements to be installed: liquefied gas tank, heat exchangers, pumps, pipelines, valves, automation system and gas detection system. This implies the need to organise space on the deck or in the hull for the system. This would result in the reduced working area on the deck and cargo/industrial space in the hull. It would be also essential to install an engine adjusted to the gas fuel. However, due to shifting from petroleum fuel into the gas one, the CO_2 emission would be reduced by 15% (Behrendt red., 2009).
The reduction of the energy consumption of the fishing cutters' energetic system, which has a decisive impact on fuel consumption, and thus also on the exhaust emissions, may be obtained through a comprehensive approach to the problem. This approach involves developing a design of a system and its implementation, selecting energy-efficient and environmentally friendly machines and devices, drawing up and adopting energy management procedures.
When designing the future energetic systems for fishing cutters, it should be considered to include the option of using alternative fuels or renewable energy sources.
Such an approach to designing is also compliant with the sustainable growth principle, which is strongly promoted and recommended in the European Union states. The principle refers to the integration of ecological, economic and social goals, the IMO requirements on environment protection and the FAO Code of Conduct for Responsible Fisheries (Green Growth, 2012).
The paper presents concepts of energetic systems developed for fishing cutters of the length less than 30 m. It also includes both the designs in which modern technologies of energy production and conversion have been applied and the future designs taking into account the use of future technologies.

ENERGETIC SYSTEMS USING MODERN TECHNOLOGIES

On fishing cutters, there are complex energetic systems with a large number of technological devices with a significant demand for mechanical, electrical energy and heat. Therefore, proper design of an energetic system is particularly important in the aspect of fuel consumption. In terms of energetic systems for fishing cutters, a large number of construction options, ensuring high performance, is available.

The first proposed system consists of two main engines. The system, presented in Figure 2, is characterized by high power capacity in a wide range of variable operational conditions. An open issue, here, is the share of power of each engine. One should answer the question whether the design should include two engines of the same power or of various ones. Due to two main engines, the design provides main propulsion system redundancy.

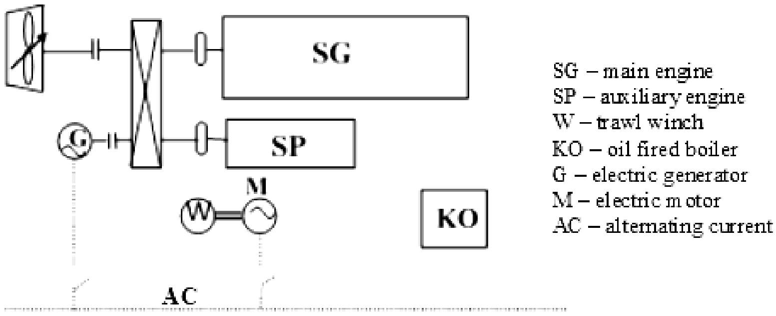

Fig. 2. Diagram of energetic system with two combustion engines for the main propulsion system
Source: Authors' elaboration

An alternative to the above option may consist of the energetic system (Figure 3) that needs less space in the engine room. The system is equipped with a shaft generator which also may work as an electric motor for the main propulsion powered by an auxiliary power generator set. Due to the above, the main propulsion system may be assisted by the electric motor cooperating with combustion engines or by emergency propulsion system in case of the main engine failure or damage. The final decision should be made based on the engine room dimensions and the operational requirements. These systems usually consist of a water boiler which generates heat. Mention must also be made of the recommended use, for the heating purposes, waste heat energy in water cooling the combustion engine.

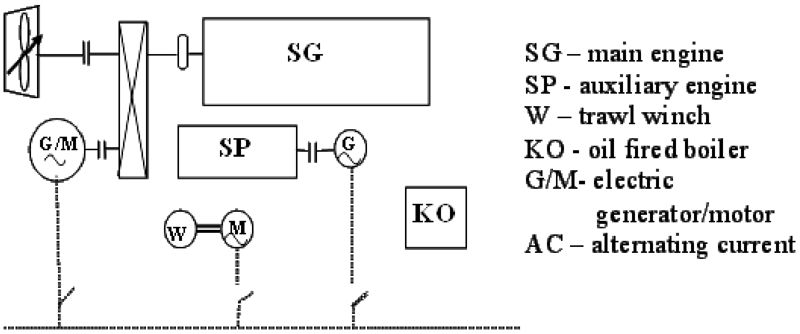

Fig. 3. Diagram of energetic system with a combustion engine and a shaft generator/electric motor
Source: Authors' elaboration

A highly recommended solution of energetic system is a system corresponding to the all-electric ship concept (Ackerman, 2004). This option is presented in Figure 4.

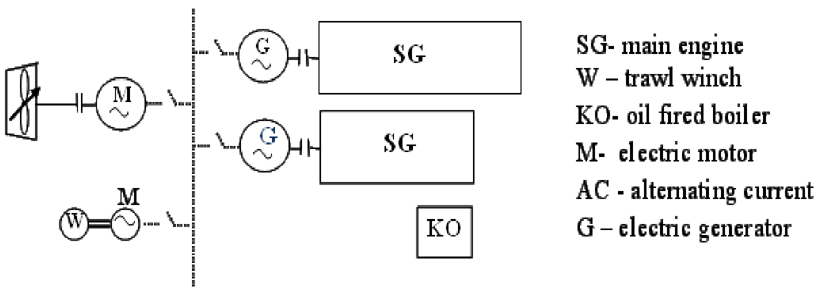

Fig. 4. Diagram of energetic system on all-electric ship
Source: Authors' elaboration

Employing, as per Figure 4, two combustion engines of various powers enables the higher efficiency of mechanical energy conversion into the electrical one required depending on the operational states of the fishing cutter.
In the presented energy systems, it is possible to use a hydraulic winch drive instead of the proposed electrical drive. However, hydraulic systems are of lower efficiency.

FUTURE ENERGETIC SYSTEMS

Future energetic systems for fishing cutters require taking into consideration the mitigation of hazards to the environment. The hazards result from the use of liquid petroleum fuels and the mitigation of same is related to the use of non-conventional fuels. In the short term, natural gas will become the more common fuel, while in the long-term perspective, non-conventional fuels such as biofuels, synthetic fuels or hydrogen will be considered as same (Tourret and Pinon, 2008, European Fisheries Technology Platform, 2012, Aberhethy and Trebilcock, 2010, Rajewski et al. ,2013).
Temporary, it may be appropriate to use of hybrid energetic systems, based on conventional energetic systems in relation to non-conventional systems.
A temporary, hybrid system is presented in Figure 5. The system, apart from the combustion engine, is composed of an electric motor powered by batteries charged by a photovoltaic cell or onshore power system.

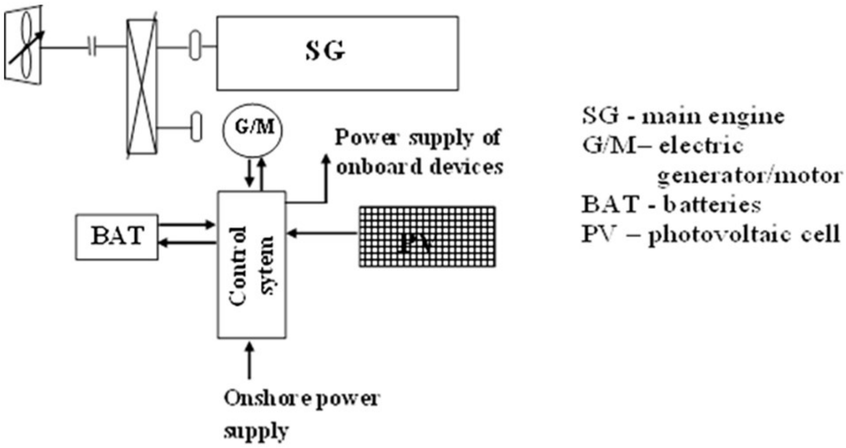

Fig. 5. Hybrid energetic system with photovoltaic cell
Source: Authors' elaboration

Batteries may be charged by the combustion engine when the electric device works as power generator. The power may be fed to the propeller by the combustion engine or by the electric motor separately or jointly. Using an electric motor for the voyage purposes, in addition to the limitation of harmful exhaust gas components' emission, has one further advantage, namely it does not emit noise.
The hybrid system, presented in Figure 5, is especially intended for small fishing cutters with low power requirements.
Using hydrogen as the fuel is associated with the storage-related problems due to its large specific volume. Therefore, the hydrogen tanks should be of large capacity. In the case of a fishing cutter, with autonomy limited to 3-4 days, the problem becomes less significant. Hydrogen, as the fuel, may be used both to feed combustion engines and photovoltaic cells being the electricity source.
For small vessels such as coastal fishing cutters, low-temperature fuel cells may be particularly useful. This refers specifically to the PEMFC (the Proton Exchange Membrane Fuel Cells) which are the considered as the most promising ones (Zeńczak, 2006). They are characterized by low work temperature, not exceeding 100°C, high density of generated current, short start-up time measured in seconds, and by the possibility to make load adjustments or changes rapidly. The efficiency of the said systems is at the level of 40%-50%

and is higher than combustion engines efficiency of low power. This advantage is even more evident at partial loads with the power at which the combustion engines run with much lower efficiency than at nominal loads. While the efficiency of the cells is constant in the entire range of power loads. Except for the undoubted advantages provided above, we should also mention the relatively long lifetime of this type of cells and the lack of competition in the field of ecology due to the lack of exhaust gas emission. A by-product of the reaction i.e. hydrogen cold-combustion in the cell is water.

The energetic system in which a fuel cell was used, apart from the cell itself as an electricity source, one may find an inverter converting the obtained direct current into the alternating current as well as batteries and electric motors.

There is also an option to use waste heat from the cell cooling system.

In the near future, however, the most realistic appears to be the use of cells as an emergency source of electricity or to feed the propulsion system during travelling at low speed in ports or at ECAs. Fuel cells may also replace combustion power generator sets. Their engagement, in that case, will come down to generating electricity only for a limited time, e.g. during maneuvers or stay at a port.

The energetic system with a fuel cell as an auxiliary electricity source is presented in Figure 6.

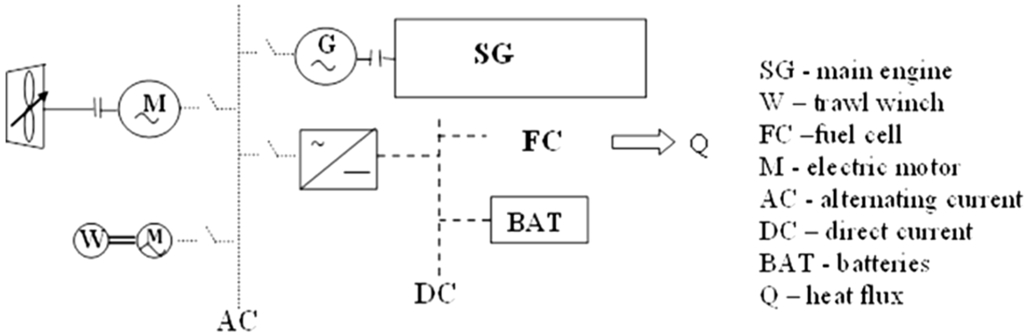

Fig. 6. Energetic system with a fuel cell as an auxiliary electricity source
Source: Authors' elaboration

While Figure 7 shows a system entirely based on same and should be considered as the most distant perspective for implementation.

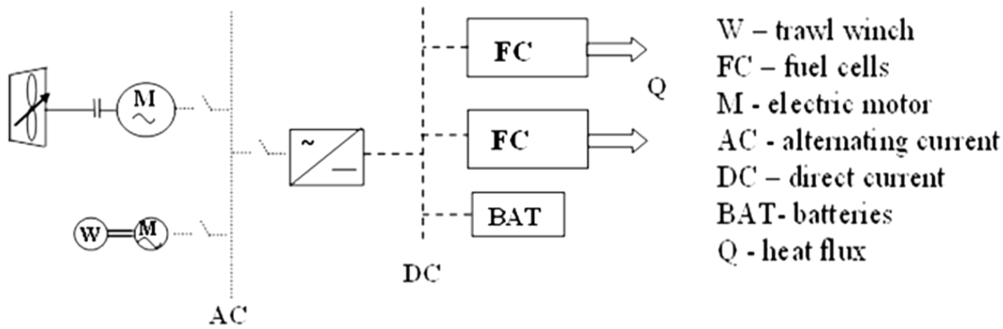

Fig. 7. Energetic system entirely based on a fuel cell
Source: Authors' elaboration

SUMMARY

The solutions and options presented in the above paper are the concepts considering contemporary and future technologies which may be used in the shipbuilding, ensuring lower energy consumption and degree of environmental impact of harmful exhaust gas components. In order to make the system selection, the energy efficiency of the system installed at the particular vessel should be established as well as the demand for electricity, heat energy based on energy efficiency audit. Machines and devices should also be chosen. The volume of required energy is significantly affected by the resistance of the hull and depends on its shape, fishing type and trawl devices used. These matters have not been mentioned in the paper as they do not impact on the energetic systems.

It is highly encouraged in the EU states to use renewable sources of energy. However, it should be remembered that not every onshore technology is applicable to ships. A physical parameter specific for the energy renewable sources is low density when compared with the conventional one. For example, solar radiation power density is lower than 1.33 kW/m^2, wind energy's one is lower than 3 kW/m^2, while for the coal combusted conventionally it equals to 500 kW/m^2 (Zeńczak, 2006, Behrendt red., 2009). This parameter of renewable energy means that its use on ships, especially on small ones, is difficult due to the limited available space for assembly of devices. However, in the case of larger cutters, the use of photovoltaic panels located on the roof and walls of the superstructure is worth considering. Hydrogen, the wider use of which is also postulated in shipbuilding, is an excellent fuel in ecological terms since the product of its combustion is water. In nature, hydrogen in a free-form occurs in a small amount as it easily enters into relationships with other chemical elements. Its resources are considered to be practically inexhaustible as it is a component of water and circulates with it in a closed cycle in nature. However, it requires energy to generate it, which is less attractive for use due to the current level of conventional fuel prices. At present, the majority of hydrogen is derived from the decomposition of hydrogen-rich compounds, including hydrocarbon fossil fuels, which also involves CO_2 emissions. If hydrogen is to replace liquid petroleum fuels, its production must be related to the use of energy from renewable sources. Only with such a production method hydrogen may be considered as a pure fuel. Although the costs of building energy systems based on fuel cells are much higher than energy systems with combustion engines, it should be remembered that these systems have great development potential. A significant price reduction should be expected when the production of high-volume cells for motor vehicles is commenced.

During the observation of the development of the energy systems' construction for modernized and being designed fishing cutters, it can be concluded that no significant progress is currently being made in that field. The main reasons for this state of affairs are the exclusion of cutters from the requirements contained in MARPOL 73/78 Annex VI and high costs of such projects.

Prior activities, in most cases, are focused on modernizing the hull shape, installing energy-efficient combustion engines, improving techniques for fishing and storing catch (shipping efficiency, 2016, IMO, 2015).

The concepts presented above should be considered as guidelines for further works related to the modernization of coastal fishing fleet.

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