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Factors affecting the energy efficiency of fishing vessels

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Abstract
The paper presents guidelines for the factors affecting the energy efficiency of fishing vessels. A main classification covers operational and structural factors. This classification is due to circumstances under which an opportunity to make decisions affecting the final energy consumption level arises. Under this approach one may distinguish operational and structural methods for energy efficiency management of fishing vessels.

Introduction

According to Art. 3, par. 1 of the Act of 15th April 2011 (Journal of Laws No. 94, item. 551 with amendments) on energy efficiency, "energy efficiency is a ratio of the obtained volume of useful effect for a particular object, technical device or system, in typical conditions of their use or operation, to the amount of energy consumed by the object, technical device or system, necessary to obtain such result" (Sawicka & Szczepanek, 2013).

The limitation and elimination of ineffective use of energy constitute one of the main goals of the European Union. Energy efficiency improvement will be decisive for competitiveness, ensuring supply safety and meeting the requirements regarding the climate changes adopted within the Kyoto protocol.

In the case of fishing vessels, a basis power source, provided and used in the conversion processes, is the chemical energy of petroleum fuels. The energy, in the ship power system, is converted into mechanical energy in the self-ignition internal combustion engine and used for propelling a vessel, or transformed into electrical energy in diesel generators for generator sets and shaft generators. Heat is generated in oil fired boilers and, in the case of small vessels, in major cases, water is a heat medium. Generated mechanical and electrical energy are used in particular systems and installations of the ship.

The increasing prices of energy sources and regulations on the environment protection provide higher requirements to the fisheries sector. Numerous fishing vessels are structures that were built many years ago, of obsolete technical solutions, often re-constructed and modernized by shipowners. The vessels are usually operated in low-efficient manner when taking into consideration the relation of the amount of energy consumed during operation to useful effect in the form of catch volume. The assessment and improvement of energy efficiency for the fleet has become a necessity having regard to the changing requirements for environment protection as well as the market, which has become more competitive (Sawicka & Szczepanek, 2013).

Energy efficiency management

Factors affecting energy consumed by fishing vessels may be classified according to a number of criteria. A main classification covers operational and structural factors. This classification is due to circumstances under which an opportunity arises to make decisions affecting final energy consumption. Under this approach, one may distinguish operational and structural methods for energy efficiency management of fishing vessels. The operational methods include (IMO, 2009a):

- the speed optimization of a vessel;
- fuel consumption control on current basis;
- the reduction of electricity consumption by machinery;
- scheduled technical services of main propulsion system and auxiliary machinery;
- the control of the hull and the propeller;
- the optimization of the draft and trim;
- the optimization of trip planning;
- verification of fishing operations.

The structural methods of energy management include:

- the optimization of the main propulsion system;
- the optimization of propeller selection;
- the selection of anti-heeling systems;
- hull shape optimization;
- limitation of additional hull resistance;
- the optimization of the fishing gear.

There are a number of methods to improve the energy efficiency of fishing vessels. However, not every solution discussed in the literature has a practical application in a fishing fleet. A number of solutions are subject to assessment under operational conditions, while others cannot be assessed individually due to physical connections with other methods for the reduction of energy consumption. Areas on which efforts aimed at the energy efficiency improvement of fishing fleets are focused include:

- hull shape;
- propulsion system together with electricity supply system;
- engine modernization;
- fishing devices and methods;
- fishing gear;
- fishery management strategy.

Opportunities to improve fuel efficiency during operation are mainly related to the transformation of chemical energy contained in the fuel to the useful effect as the main propulsion system, generation of electricity and heat. Main engines, due to their power and size, are devices with the highest energy consumption of all devices used for fishing vessels. The main possibilities to improve the energy efficiency of the main propulsion system include the limitation of energy losses arising from the following factors (Rajewski & Behrendt, 2013):

- exhaust gases;
- radiation and heat convection;
- cylinders' cooling;
- spring bearings and shaft glands;
- main propulsion system gear;
- hull resistance: wave resistance, water friction.

Energy consumption in the fisheries sector

Usually four-stroke self-ignition engines are used in a ship propulsion system. They are relatively low effective energy machines. Their efficiency does not exceed 45%. Due to a number of losses occurring in the entire propulsion system, only 10–15% of chemical energy provided in fuel is transferred into useful energy for vessel propulsion. The remaining energy is lost in the engine, gear, shaft line, hull and propeller. Due to the specific structures of propulsion systems for fishing vessels, certain losses may be omitted in the process of energy efficiency assessment because of their small share in total losses, while high investment costs are essential in order to their further reduction. The fisheries sector accounts for about 1.2% of the total fuel consumption in the world (Tydmer, 2004). Simultaneously, the Food and Agriculture Organization (FAO) estimates that income of the fisheries sector equals 25% of the total income of agricultural activity in the world. The FAO data on fuel costs indicates a growing share of fuel in general operational costs of fishing vessels. According to the Organization for Economic Co-operation and Development (OECD), data from member states on fuel costs in fishing fleet operations are higher when active fishing gear is used then when passive methods are used. Under to the same estimates the share of fuel costs in general operational costs increases along with the distance to a fishery. The range of fuel costs share in the general operational costs of fishing vessels may reach from 3%, for offshore vessels using passive fishing gear, to 78% for deep-sea vessels using active fishing gear (OECD, 2013). Despite high fuel costs, fishing is an effective way to obtain food supplies compared to other sectors of the agricultural industry. An indicator of the energy intensity in the fisheries sector is found in the relationship of energy contained in fuel to the energy of proteins in food obtained due to its use. This value is about 12.5 for the fisheries sector.

Energy losses

Fishing vessels with a propulsion system together with a self-combustion engine and a propeller shaft are characterized by a limited indicator of energy transformation contained in the fuel. During operation, an average of about 35–37% of energy provided to the main engine in the form of fuel is forwarded to the drive of the propeller shaft gear.

The remaining 63–65% represents losses from exhaust gases, energy transferred to the cooling system of working media, and energy discharged to the environment as radiation and convection. The energy transferred from the gear to the propeller shaft is decreased by the losses of gear friction that equals on average 1–3% of input fuel energy (Sawicka & Szczepanek, 2013). The friction losses are transferred to the water cooling oil and to the air as a result of radiation and convection. The energy of rotational movement of the propeller is lower that the output energy of the gear by the friction losses in bearings and propeller shaft gland which constitute around 1–2% of the input fuel energy. The frictional losses are transferred to lubricating oil or the water cooling bearings and propeller shaft gland, and dispersed to the air surrounding the elements of the propeller shaft. Only 10–14% of the energy contained in the fuel is used directly for propelling a vessel, i.e., providing the vessel with kinetic energy (Figure 1). The remaining share of energy is lost due to a physical phenomenon related to the difference of pressure arising from hull movement on the interface of two mediums and water and air friction.

One of the basic structural methods to reduce wave resistance is to lengthen the hull. In case of fishing vessels, such a modification usually results from the extension of the room necessary to store fish caught in the midships area, not from the desire to reduce wave resistance. An increase of the vessel energy efficiency arises from an improvement of the relation of buoyancy to the length of the water line, while the remaining hull parameters constant (Szczepanek & Kamiński, 2013).

Issues subject to energy efficiency assessment

The energy efficiency improvement of fishing vessels is based on operational experience. The energy efficiency management methods are usually grouped in the manner representing the opportunities to save energy while in operation. Fuel and energy savings may be classified according to a number of criteria, subject to adopted energy efficiency measures. The most general classification covers the following (Behrendt, 2013):

- the reduction of unit fuel consumption – this directly related with the fuel consumed by the main engine, which allows for a main engine operational efficiency to be improved as well as its systems;
- the reduction of general and relative fuel consumption by the main engine per unit of distance traveled – this is related to the amount of energy absorbed by the main propulsion system, power provided to the propeller, and general hull resistance;
- the reduction of total fuel consumption – this specifies fuel consumption by all engines and boiler burners, and is related to the general energy efficiency of vessel equipment, the operational customs of the crew, and general fuel costs while in operation.

The management measures for sea vessel energy efficiency may be also classified according to the circumstances of operation, or the type of technical measures for its improvement. Considering such criteria, the following may be distinguished (IMO, 2009b):

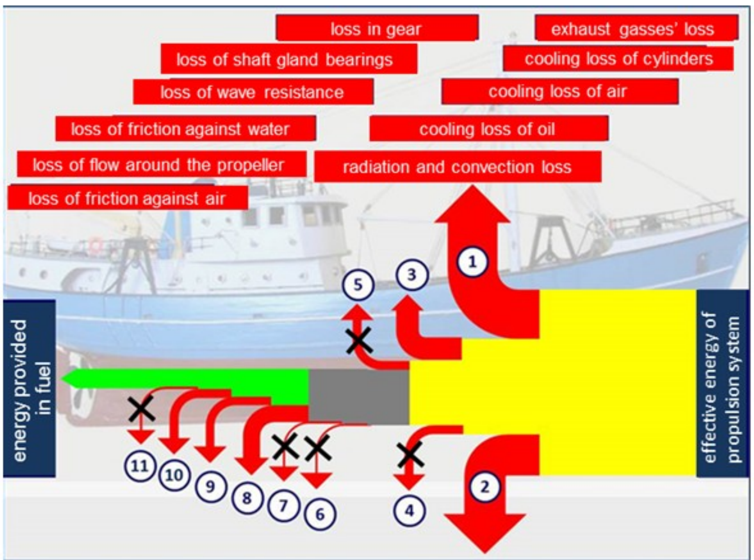

Figure 1. Elements of propulsion system losses presented in the Sankey diagram indicated for use in modernized energy audit sheets (Kidacki, 2014)

- the optimization of hull shape – this includes a selection of the basic hull dimensions, the reduction of its resistance by the optimization of the underwater parts' shapes and submerged elements, and by the estimation of movement resistance. This group of measures generally relates to new-built ships, although certain parameters may be modified during a vessel's reconstruction or modernization processes;
- machinery used for saving energy – this includes devices used for the improvement of the propeller efficiency, the reduction of the hull resistance and for the application of alternative energy sources;
- the reduction of hull weight by the optimization of structure and materials – this includes the use of steel of increased mechanical properties. These measures may be used only for new-built ships, and are not subject to analysis during energy audits;
- the improvement of systems and machinery efficiency – this includes an improvement of the systems and machinery efficiency of an engine room, and the improvement of their operational methods. This is the fundamental group of measures to improve the energy efficiency of a vessel. It covers not only the machinery using fuel directly, but also elements applying other forms of energy, including electricity, heat and hydraulic energy, and the methods of waste energy application;
- the increase of fuel operational efficiency of a vessel – this includes measures for the reduction of fuel consumption while the vessel is in operation. They consist of trip planning management, the condition of the hull and the propeller, and maintaining the technical condition of machinery and systems.

A comprehensive approach to the energy efficiency assessment issue for fishing vessels requires an accounting of all elements comprising the whole considered as an "energy object". It consists not only of the vessel itself, with its technical equipment, but also its crew and their operational methods.

The basic methods to reduce the energy consumption of an energy object include:

- the improvement of efficiency and technical condition of the main engine;
- the limitation of the losses of the propulsion system, which consists of the gear, the main engine shafting, and the propeller;
- the reduction of wave resistance related to operational speed;
- the reduction of other hull resistance which is a sum of friction resistance and local resistance;
- the reduction of energy demand that is not related to the main propulsion system, consumed by machinery and auxiliary systems and the social needs of the crew;
- the reduction of distance traveled by a vessel while in operation.

Conclusions

The energy efficiency is listed on the first place of the Energy Policy priorities until 2030, adopted by the government in 2009. Since the fishery remains one of the fundamental elements of the Polish marine economy, an implementation of energy efficiency management methods for the Polish fishing fleet is a very significant activity that may affect the improvement of the energy efficiency indicators in that sector. The presented methods (upon having carried out energy audits) allow for the reduction of power consumption and for an improvement of financial results of the Polish fishing fleet.

Research on the energy efficiency in maritime transport and fisheries sector are a relatively new discipline. A decisive factor here is an application of audit processes developed for onshore industrial objects. The onshore procedures are difficult to be directly adapted due to their adaptation to other types of objects and the lack of significant issues related to the vessels operation. Therefore, there is a need for their adjustment and extension in order to meet maritime transport requirements.

Apart from an identification of potential fuel saving areas, an energy audit allows for quantification of the results of energy efficiency assessment by the means of properly selected indicators such as the amount of energy needed to obtain and provide to the shore a specified useful effect in the form of fish caught or fuel cost in relation to profit gained due to the fish sold. Initially, the energy efficiency indicators are used as models allowing for a comparison of different fishing vessels or different areas of sea operation and its resources. Afterwards, the same indicators may be used for progress monitoring and assessment in the scope of energy efficiency improvement in regard to fisheries activities (IMO, 2009a).

The methodology of energy research for fishing vessels should be based on a compilation of the methods applied in the maritime transport and the audit models applied in onshore industrial and construction objects. In such an approach the energy audit is a system approach the aim of which is to establish methods and practices related with the energy use in the object subject to research commencing from the purchase until the final use.

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References

1. Behrendt, C. (2013) Analysis of fishing cutters of the Polish fishing fleet and structure of their power systems. *Conference DEMaT'13*. Rostock, Germany. Conference materials. pp. 253–261.
2. IMO (2009a) *Consideration of the Energy Efficiency Design Index for new ships*. GHG-WG 2/2/17, London,
3. IMO (2009b) *Guidance for the development of a Ship Efficiency Management Plan*. MEPC.1/Circ. 683, London.
4. Kidacki, G. (2014) Wybór metody oceny efektywności energetycznej. Materiały projektu *Przeprowadzenie audytów energetycznych dla grup statków rybackich celem przygotowania systemu zarządzania eksploatacją w sposób przyjazny środowisku* realizowanego w Akademii Morskiej w Szczecinie finansowanego z Programu Operacyjnego RYBY 2017–2013 działanie 3.1 Szczecin.
5. OECD (2013) *Green Growth and Energy Use in Fisheries and Agriculture*. Organisation for Economic Co-operation and Development. TAD/FI(2012)2/FINAL.
6. Rajewski, P. & Behrendt, C. (2013) Possibilities of increasing energy efficiency of small fishing vessels. *DEMaT'13 Conference*. Rostock, Germany. Conference materials. pp. 297–304,
7. Sawicka, M. & Szczepanek, M. (2013) Legal conditions regarding the energy efficiency of fishing vessel. *Scientific Journals Maritime University of Szczecin*. 36 (108) z. 2. pp. 166–170.
8. Szczepanek, M. & Kamiński, W. (2013) Test methodology assumptions for energy test of fishing fleet cutters. *Conference DEMaT'13*. Rostock, Germany. Conference materials. pp. 263–270,
9. Tydmer, P. (2004) *Encyclopedia of Energy. Vol. 2. Fisheries and Energy Use*. Elsever.