Scientific Journals
Maritime University of Szczecin

Zeszyty Naukowe
Akademia Morska w Szczecinie

2012, 30(102) pp. 115–120

2012, 30(102) s. 115–120

The impact of the fuel supply to the safe operation of Polish fishing vessels

Oddziaływanie zasilania paliwem na bezpieczeństwo eksploatacji polskich jednostek rybackich

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Key words: fishing vessels, fuel assessment, failures in fishing vessels

Abstract
A significant number of failures and accidents of Polish fishing vessels operating in the Baltic Sea was the impetus to examine their sources. It was found that one of the important factors causing the failure is poor condition of the fuel systems and inappropriate fishing vessels to be operated. Typical fuel installations operated on Polish fishing vessels were discussed. The methodology of sampling and testing of samples of fuel from fishing vessels to assess its fuel quality has been presented, as well as tests results.

Słowa kluczowe: statki rybackie, testy paliw okrętowych, awarie jednostek rybackich

Abstrakt
Znacząca liczba awarii i wypadków polskich jednostek rybackich eksploatowanych na Bałtyku była impulsem do zbadania ich źródeł. Stwierdzono, iż jednym z istotnych czynników powodujących awarie jest zły stan techniczny układów paliwowych jednostek rybackich i niewłaściwa ich eksploatacja. W artykule omówiono typowe instalacje paliwowe polskich jednostek rybackich, przebadano pobrane z jednostek rybackich próbki paliwa celem oceny jego jakości i omówiono uzyskane wyniki.

Introduction

There are 881 Polish fishing vessels operating from Polish ports located along Polish sea coast, registered as actively engaged in fishing. The craft vary in age, size and technical condition of the structure, machinery and equipment.

The collected data [1] show that more than 50% of Polish fishing vessels exceed 25 years of age, and nearly 38% of them are more than 30 years old. The safety of the craft to a large extent depends on the following factors:

- technical condition,
- operating conditions,
- crew qualifications.

The number of fishing vessels operating in areas where the traffic intensity of merchant ships is high.

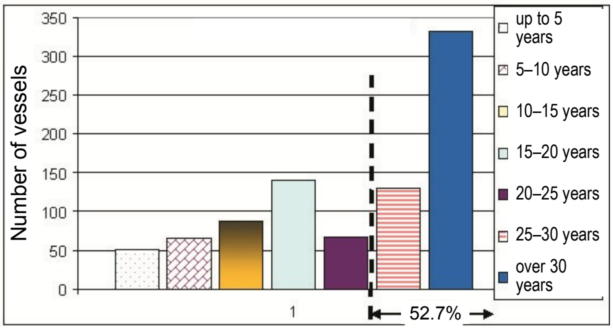

Fig. 1. Age structure of Polish fishing vessels operating from Polish ports
Rys. 1. Struktura wiekowa polskich statków rybackich operujących z polskich portów

The accident rate of fishing vessels in Baltic is significantly affected by weather conditions during fishing operations [2]. Notably, fishing intensity is the highest in autumn and winter months when the weather conditions are the most difficult. Due to large groups of fishing craft operating in small and shallow areas, the factor that creates a risk to fishing vessels and the marine environment is that these vessels have to manoeuvre in bad weather conditions, additionally burdened with fishing gear. Damage of the fishing vessels propulsions are the largest group among the collected 152 accident cases [2]. Second largest factor influencing the number of failures of fishing vessels concerned with damage to the fuel supply main propulsion engines [2]. Testing of selected properties fuel sampled from fishing vessels is subject to the work of the Institute for Sustainable Power Marine University of Szczecin to confirm or exclude the impact of fuel quality on injection equipment damage.

Engine fuels used in fishing vessels

The European Union requires that by 2020 the share of liquid biofuels used in transport should be increased to 10%. Apart from the positive ecological aspect, addition of biocomponents considerably changes physical and chemical properties of the base fuel. Additives of “biological oils” – fatty acid esters to fuel oils significantly improve the viscosity and lubricity of fuels, which enhances the working conditions of injection equipment. Biofuels, however, also have properties that hinder their use at sea. One disadvantage of biofuels is their higher hygroscopicity. The design of fuel installation system and adverse sailing conditions make the risk of moisture absorption a difficult issue for the use of biofuels in fishing vessels, as water in fuel systems is undesired. At the same time the European Union, in Annex VI, introduced regulations restricting SO_x emission by ships flying an EU member state flag or flags of other countries and entering an EU port. Legal restrictions were introduced in the Directive 2009/30/EC, which provides that from 1st January 2010 the content of sulphur in marine fuels used on ships calling at in EU ports should not be higher than 0.1%.

Table 1 presents maximum limits of sulphur in marine fuels, provided by IMO regulations. The table specifies limits for the Emission Control Area and other areas not covered by the regulations.

Table 1. Limits of sulphur content in fuel [3]
Tabela 1. Limity zawartości siarki w paliwie [3]

Limit in force from:	Limit of sulphur in fuel	
	SO_x ECA	Total
05.2005	1.5%	4.5%
07.2010	1.0%	
01.2012		3.5%
01.2015	1.0%	
01.2020		0.5%

Water in fuel can cause damage to elements of fuel installation. If water does not convert into an emulsion with droplets smaller than 5 µm in diameter, it may cause an accelerated wear, even the seizure of engine fuel installation components. Besides, sea water contains metal salts, e.g. containing sodium (Na), that have a major influence on the range of high-temperature corrosion related with the presence of vanadium in fuel. Ester fuels are particularly sensitive to the presence of water, because in even slightly water-containing environment they are strongly liable to microbiological decomposition, caused by intensive growth of microorganisms. Water also causes the formation of free fatty acids that have corrosive properties. Fatty acid esters in contact with water are liable to polymerization. As a result, precipitated polymers may cause seizures in the discharge parts of injection pumps or injectors. Fishing vessels operate in conditions facilitating water condensation, and water vapour penetrating into tank spaces through air vents on deck may result in considerable amounts of water collecting in them. Sea water shipped on deck may get in through untight air vents. Trace amounts of water may be present in the bunkered fuel. The ISO 8217 standard specifies the maximum level of 0.3% of water in distillate fuel (for DMB), while the standard for biodiesel fuel is even stricter (PN – EN 14214), i.e. not more than 0.05%.

Overview of fuel installations in fishing vessels

The simplest fuel installation used in small fishing vessels and boats is shown in figure 2. Fuel tanks of fishing boats are rather small (about 100 litres), and the yearly quantity of fuel consumption ranges between 1 and 2 tons per boat. The fuel tank is located above the level of fuel pumps, so that fuel flows down gravitationally. Installations of this type are used with low power engines. Diesel oil from the service tank passes through a filter to injection equipment, and overflows are transferred back to the tank. The air vent and fuel inlet are mounted in the upper part of the tank. Such installation should have drain valves additionally fitted in the tank bottom, for removal of water and particulate matter. This fuel installation system works very well in fishing boats. Operated for about nine months a year, the boats are placed in hangars for the winter. Then small fuel tanks are dismantled and thoroughly cleaned. The only method to get rid of water from this simple installation is its periodi-

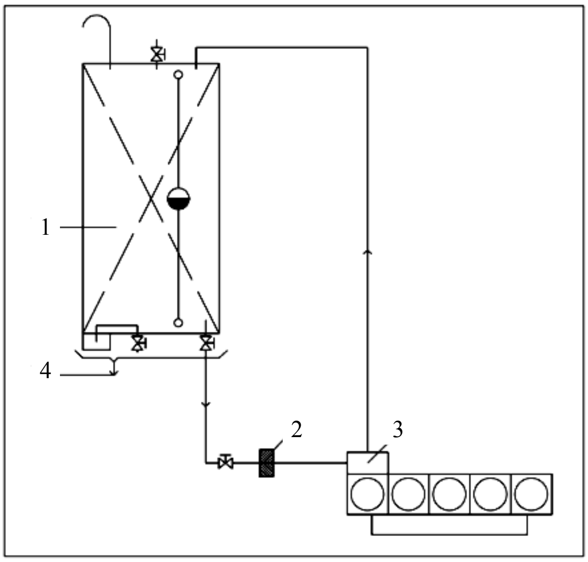

Fig. 2. A diagram of gravitational fuel installation: 1 – tank, 2 – double filter, 3 – injection equipment, 4 – outlet to a sludge tank
Rys. 2. Schemat grawitacyjnej instalacji paliwowej: 1 – zbiornik, 2 – podwójny filtr, 3 – wyposażenie wtryskowe, 4 – odpływ do zbiornika odpadowego

cal removal by opening the drain valves, as the fuel filter effectively stops only particulate matter.

Fishing vessels are commonly equipped with two service tanks. The tank not in use functions as a settling tank for the sedimentation of contaminants. The tanks are connected to each other by a pipeline, and the discharge pump allows to transfer fuel from one tank to the other.

Another common solution of fuel installation (Fig. 3) is one with a storage tank that is usually much larger than the service tank. The storage tank containing a relatively large amount of fuel performs the function of a settling tank, and is used for preliminary fuel preparation before it is transported to the service tank. Most of these tanks have a flat bottom, which hampers the total removal of water collected in the lower part of the tank. Even when the sea is moderate waves cause the bunkered fuel to mix with water.

The fuel installation with an additional storage tank may also be equipped with a strainer capturing larger solid particles carried with fuel to the service tank, which is an extra safeguard for the transport pump. The system with a strainer (Fig. 4.) allows to stop particles lighter than water that cannot be removed by tank dewatering. The only way to remove water from the above installations is periodical tank dewatering through drain valves if they are installed.

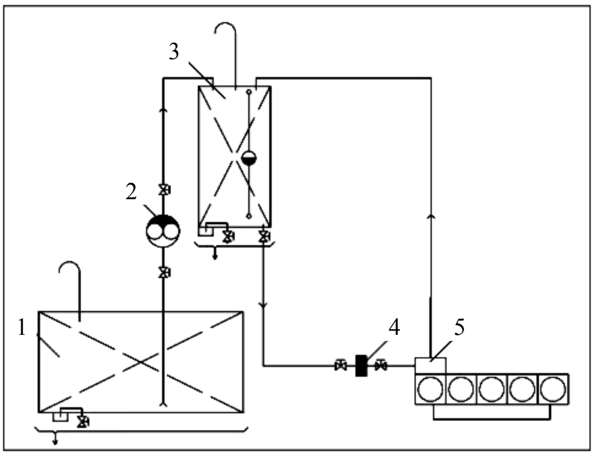

Fig. 3. A diagram of fuel installation with a storage tank: 1 – storage tank, 2 – transport pump, 3 – service tank, 4 – double filter, 5 – injection equipment
Rys. 3. Schemat instalacji paliwowej ze zbiornikiem magazynowym: 1 – zbiornik magazynowy, 2 – pompa transportująca, 3 – zbiornik serwisowy, 4 – podwójny filtr, 5 – wyposażenie wtryskowe

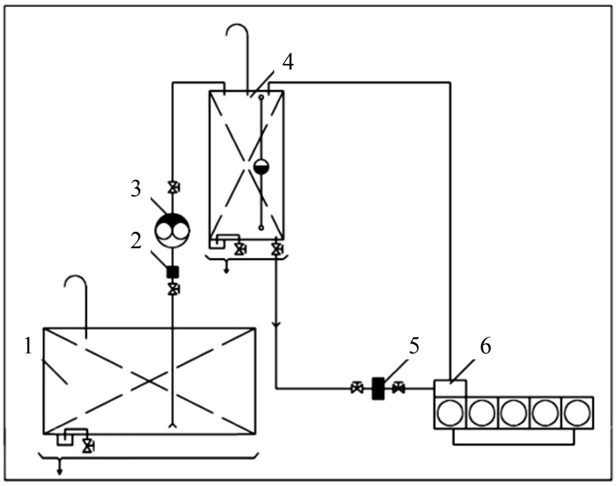

Fig. 4. A diagram of fuel installation with a settling tank and an additional coarse filter – strainer: 1 – storage tank, 2 – strainer, 3 – transport pump, 4 – service tank, 5 – duplex filter, 6 – injection equipment
Rys. 4. Schemat instalacji paliwowej ze zbiornikiem osadowym i dodatkowym grubym filtrem siatkowym: 1 – zbiornik magazynowy, 2 – filtr siatkowy, 3 – pompa transportująca, 4 – zbiornik serwisowy, 5 – podwójny filtr, 6 – wyposażenie wtryskowe

Technologically more advanced installations may be fitted with dewatering filters (Fig. 5). Dewatering filters can function in two ways: as a single filter or in combination with a duplex filter. It is generally a filter with a paper cartridge. The filter chamber may be fitted with water sensor that signals the presence of water by an alarm. The flowing water settles on the bottom where a valve for water removal is fitted. Some types of filter separators may be automated. When water apppears or the pressure increases due to the contamination of the cartridge, the flow is automatically directed to the other chamber.

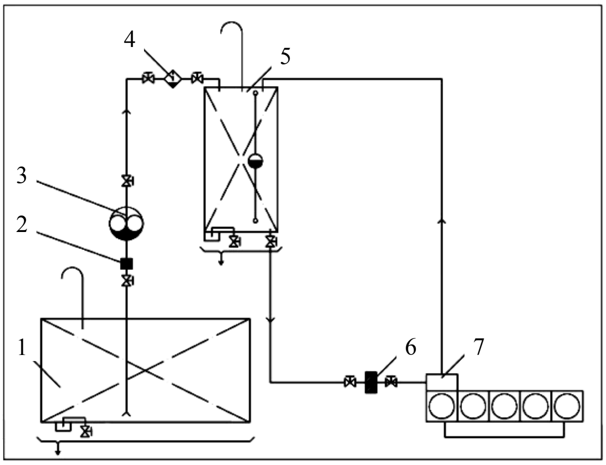

Fig. 5. A diagram of fuel installation with a dewatering filter: 1 – storage tank, 2 – strainer, 3 – transport pump, 4 – dewatering filter, 5 – service tank, 6 – duplex filter, 7 – injection equipment
Rys. 5. Schemat instalacji paliwowej z filtrem odwadniającym: 1 – zbiornik magazynowy, 2 – filtr siatkowy, 3 – pompa transportująca, 4 – filtr odwadniający, 5 – zbiornik serwisowy, 6 – podwójny filtr, 7 – wyposażenie wtryskowe

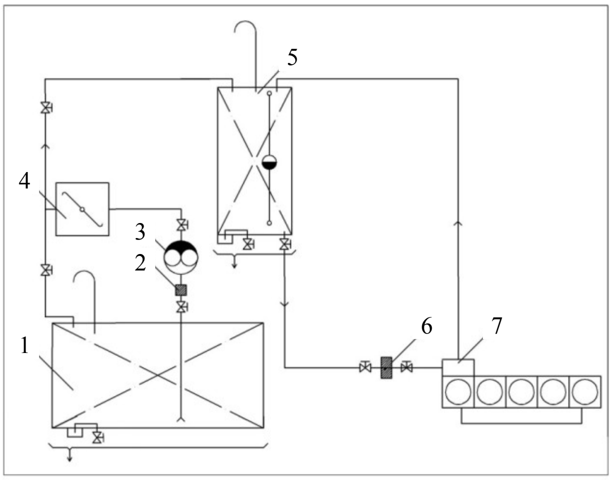

Fig. 7. A diagram of fuel installation with a fuel centrifuge: 1 – storage tank, 2 – strainer, 3 – transport pump, 4 – centrifuge, 5 – service tank, 6 – duplex filter, 7 – injection equipment
Rys. 7. Schemat instalacji paliwowej z centryfugą paliwową: 1 – zbiornik magazynowy, 2 – filtr siatkowy, 3 – pompa transportująca, 4 – centryfuga, 5 – zbiornik serwisowy, 6 – podwójny filtr, 7 – wyposażenie wtryskowe

The best fuel purification effect is obtained by using a centrifuge that purifies fuel from water and particulate contamination. A diagram of fuel installation including a fuel cetrifuge is shown in figure 7.

Such solutions are sporadically used in bigger vessels.

Testing of water level in fuels and fuel lubricity stored in fuel tanks in Polish fishing vessels

In order to determine the water level in fuel stored in fishing vessel tanks, a representative sample was collected from such vessels. Two methods were used to take samples. One method consisted in sampling fuel from the tank bottom through drain valves after previous removal of the settled water. Then the volume of water removed from the tank was determined and its amount compared to the whole quantity of fuel in the tank. The method does not allow to estimate the content of water solved in fuel, nor the water-fuel emulsion that has not settled on the bottom. In the other method, fuel samples were also taken through the drain valves, but before taking fuel samples the water settled on the bottom was removed. Therefore, the obtained sample represented water content in fuel in the whole volume of the tank, including water solved in fuel.

There are fuel tanks without drain valves, therefore, it was necessary to design a sampling probe

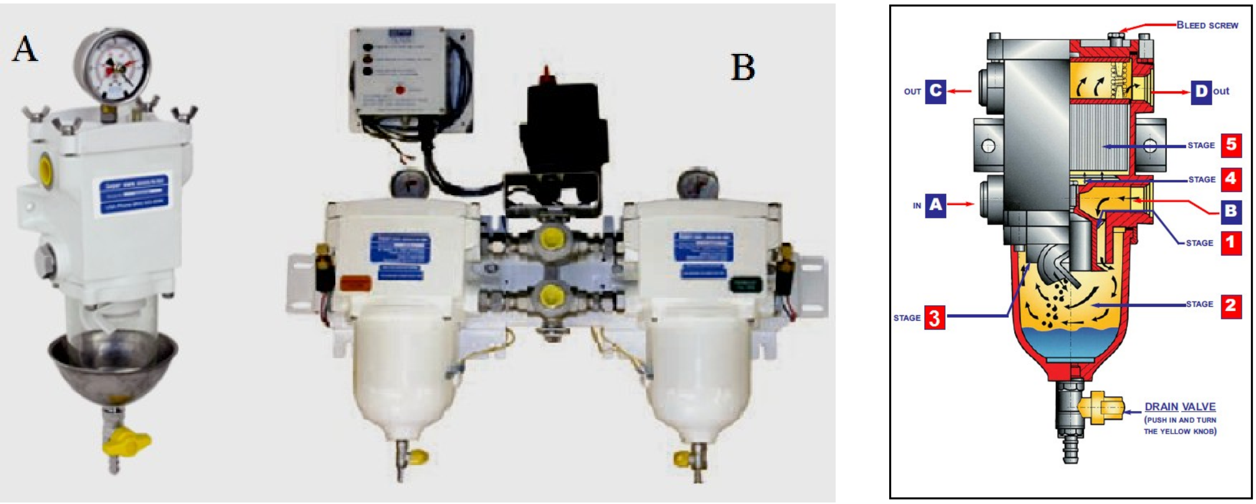

Fig. 6. Separ-made dewatering filters: A – single, B – duplex automatic and dewatering filter cross-section displaying the liquid flow
Fig. 6. Filtry odwadniające: A – pojedynczy, B – podwójny automatyczny oraz filtr odwadniający w przekroju, obrazujący przepływ cieczy [10]

(Fig. 8) enabling taking a sample of fuel through the sounding pipe of the fuel tank.

Fig. 8. The sampling probe used for taking fuel samples
Rys. 8. Sonda służąca do pobierania próbek paliwa

The flexible tube allows to reach the tank bottom despite the irregular shape of the sounding pipe. The probe end includes a head (Fig. 9) with a piston opening and closing the sample space. The piston is moved by an armoured string and its position is controlled by a handle placed on the other side of the string.

Fig. 9. The probe head and its components
Rys. 9. Górna część sondy i jej elementy

The sample taken by a sampling probe represents the fuel spectrum found across the whole volume of the tank. However, sampling the water settled on the tank bottom is difficult as it makes up a layer less than a centimeter thin. The water content in samples taken from fishing vessel tanks was determined by the Karl Fischer titration method. The method, adopted for the determination of water content in standardized fuels, both distillate and biodiesels, is described by the PN-EN ISO 12937 standard. The water level was determined using a coulometer 831 KF from Metrohm. The measuring equipment allows to determine water level ranging from 10 µg ÷ 200 mg, and its accuracy is 3 ppm. Laboratory tests included titration of 32 fuel samples. The water level in fuels taken from fishing vessels was checked at the IESO lab. The samples were put into one-litre containers. Before the tests, each fuel sample was placed in a shaker for about 30 minutes to create a homogenous mixture. The water level in tested fuel samples from fishing vessels is presented in the chart (Fig. 10).

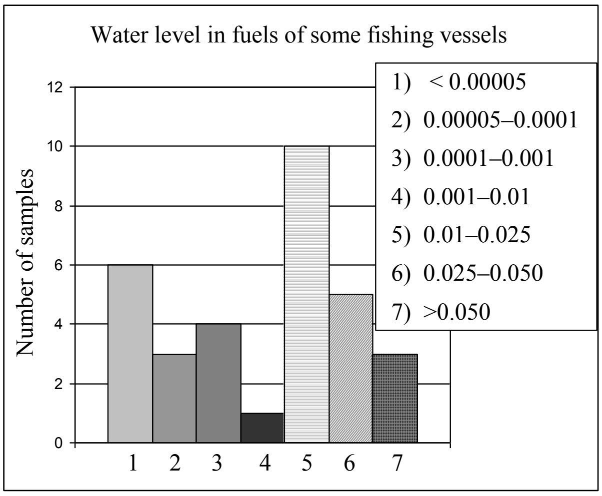

Fig. 10. Water level in the tested fuel from fishing vessels (1, 2, 3, 4 – samples taken through drain valves; 5, 6, 7 – samples taken from the tank bottom after dewatering and by a sampling probe)
Rys. 10. Poziom wody w testowanych paliwach ze statków rybackich (1, 2, 3, 4 – próbki pobrane poprzez zawory spustowe; 5, 6, 7 – próbki pobrane z dna zbiornika po odwodnieniu i poprzez sondę)

Apart from slight deviations, the same results were obtained for samples taken through drain valves and samples taken by a probe from the whole fuel tank cross-section.

To sum up, it can be stated that the level of water contaminating fuel sampled from fishing vessels ranges from 0.011 to 0.059%. The figures for samples taken by a probe oscillate between 0.012 and 0.045%, while in samples taken through a drain valve the range is 0.011÷0.059%. The water level above 0.059% (3 samples taken through drain valves) can be regarded as an effect of water accumulated in the pipe connecting the drain valve to the tank bottom. That water, due to limited contact, did not react with fuel. The distribution of water levels in tested fuel samples is presented in figure 11. The tests have indicated that water in fuel of the fishing vessels under consideration shows a very small level and forms an unsaturated solution, without a precipitation of the separate water phase.

The exclusion of exccess water in fuel allows to obtain correct evaluation of lubricating properties. The HFRR test delivered information whether the fuel had lubricating properties that meet agreed international requirements provided in the Worldwide Fuel Charter IV Edition [4]. The number of

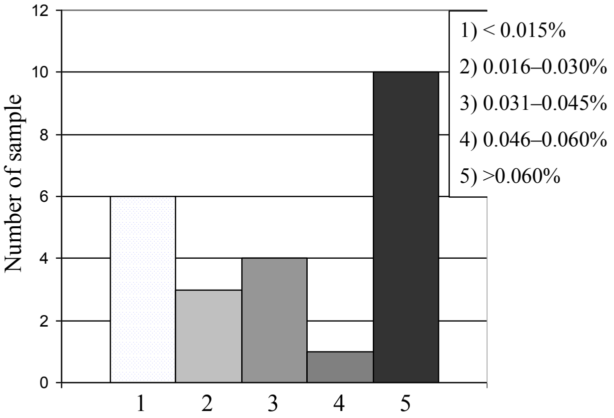

Fig. 11. Water level in the tested fuel samples
Rys. 11. Poziom wody w testowanych próbkach paliwa

fuel samples was restricted to ten due to cost and research duration limitations. It was assumed that the research was of preliminary nature and would bring material for further studies in this direction. The diagram in figure 12 shows mean wear scar values obtained during the tests.

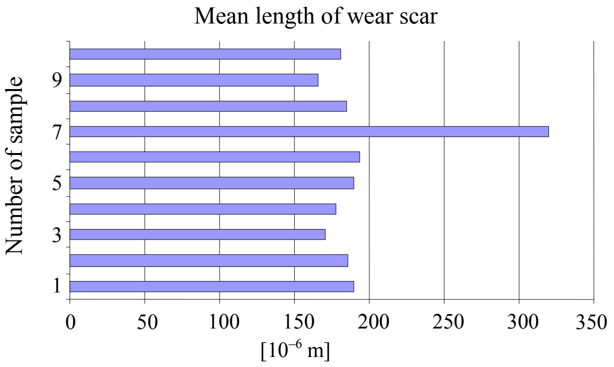

Fig. 12. HFRR test results
Rys. 12. Wyniki testu HFRR

The analysis of results

It follows from the test results that wear scars obtained during the HFRR test for all samples ranged in the 165 μm – 317 μm interval, which satisfied the requirements of the mentioned standard. The values determined as boundary for scars formed during the standard test at 25 and 60°C were, respecively, 400 and 460 μm. None of the samples tested did not cause excessive wear. It was assumed that all samples had correct lubricity.

Conclusions

The lab tests lead to an observation that excessive water level in fuel of Polish fishing vessels is rather an occasional phenomenon. The tests have shown that the water level in examined samples is low. Even old exploited power plants of fishing vessels are capable of running on fuel with very small amounts of water without causing engine failure. Nevertheless, due to organic additives used in fuels, shipowners should be encouraged to modernize the existing fuel installations, mainly tank air vents, and to add filtration devices. At a relatively low cost fuel tanks can be fitted with drain valves and fuel filtering devices for separating water from fuel. It can be expected that high costs and large dimensions may discourage shipowners from installing fuel centrifugal purifiers. The basic filter satisfying the requirements for fishing vessels costs about 1000 PLN. Low costs of fitting, small size and high efficiency (c. 99.9%) make it available for small fishing vessel, or boat operators.

The data gathered allowed to determine the fuel properties to a satisfactory extent. Taking into account the content of water and solid particles, we found out that the fuels were of good quality, stored in proper conditions. Seeking a correlation between water content, solid particles content and lubricity was regarded as irrelevant for the examined set of samples.

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