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Analysis of energetic system failures of Polish fishing fleet vessels and their impact on the environment

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Abstract

An analysis of the failures occurring in the energetic systems of Polish fishing cutters, covering the years 1999–2012, is presented in this paper.The structural age, size and number of Polish fishing cutters is also indicated herein. The effect of the failures on the marine environment has been assessed, taking into consideration a presumed fuel spillage depending on fish catch volume and an analysis of the biodegradability of various fuels. The subject of the analysis also includes the damage impact of transponders cooperating with a vessel monitoring system (VMS) on an increase of the risk of collisions between other offshore industry objects and fishing vessels.

Introduction

According to officially used terminology, the term ‘fishing vessel’ includes all fishing vesselsregardless of their size. This analysis maintains the former classification of fishing vessels into open and closed-deck fishing boats and fishing cutters. Fishing boats include vessels with anoverall length up to 15 meters, while fishing cutters are craft over 15 meters in length.

Following implementation of the European Union directives, the Polish Baltic fishing fleet has been subject to constant reduction.

Accession of Poland to the European Union in 2004 decisively affected Polish Baltic sea fisheries. The fishing fleets belonging to the EU Member States are too large compared with the available stock of fish. Therefore, ways to reduce the size of a fleet, and also to establish time-limits for when fishing vessels may catch specific fish species have been sought. Implementing the European Union directives, the Polish Baltic fishing fleet has been subject to constant reduction.

A particularly large number of fishing cutters of the Polish fishing fleet have been reduced, that is vessels whose length exceeds 15 m. Figure 1 presents the number of fishing cutters since the accession of Poland to the European Union divided into

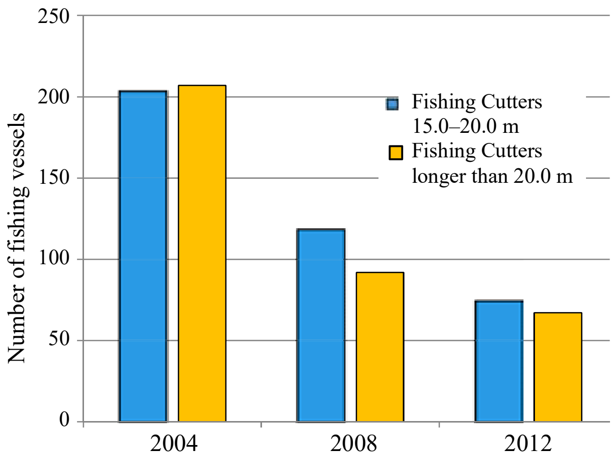

Figure 1. Number of fishing cutters of the Polish Baltic fishing fleet from 2004 to 2012 (Rajewski & Behrendt, 2008; Behrendt, 2013)

two groups according to the length of theship's hull: fishing cutters of length from 15 to 20 m and those exceeding 20 m.

The changes in the number of fishing cutters, without any division of the ship's hull length, for the analyzed period 2004–2012 are shown in Figure 2.

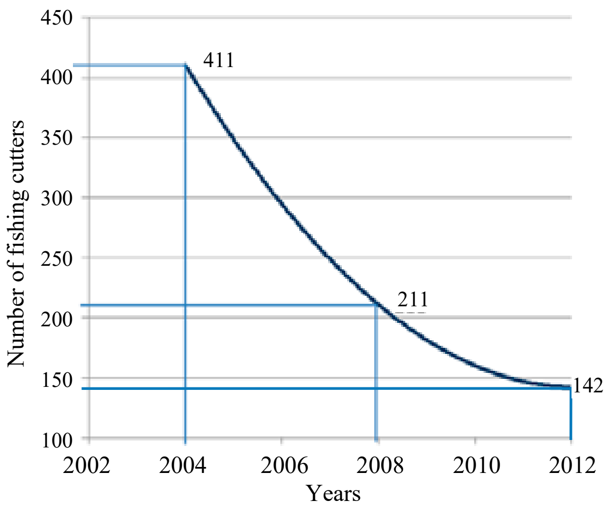

Figure 2. Total number of fishing cutters of the Polish Baltic fishing fleet in 2004–2012

As it appears from the analysis carried out using the results presented in Figures 1 and 2, major reductions in the number of fishing cutters occurred in the segment with length exceeding 20 m. Out of the fishing cutters group, the length of which equals from 15 to 20 m, 95% were constructed in 1955–1970. The newest vessels in the amount of 3 units were constructed in 1991–1992 in Odra Shipyard in Szczecin (Rajewski & Behrendt, 2008; Behrendt, 2013). The situation is slightly better in the case of fishing cutters of length exceeding 20 m. Having analyzed the fleet size in 2012, in that group of the fishing cutters, 50% of the vessels have been in operation for more than 25 years (Rajewski & Behrendt, 2008; Behrendt, 2013).

Owners of fishing vessels also purchase fishing cutters operated by other countries' fleets, such as Germany, Denmark, Holland and Russia. However, these are individual cases, and the age of the purchased fishing cutters ranges from 20 to 30 years. The age structure of the Polish fishing cutters, as of 2012, whose length exceeds 15 m, is presented in Figure 3.

Vessel age can affect the number of failures. Damage to machines and equipment comprising the energy systems of fishing cutters may cause the release of petroleum products (fuels, lubricating and hydraulic oils) to the water environment, creating

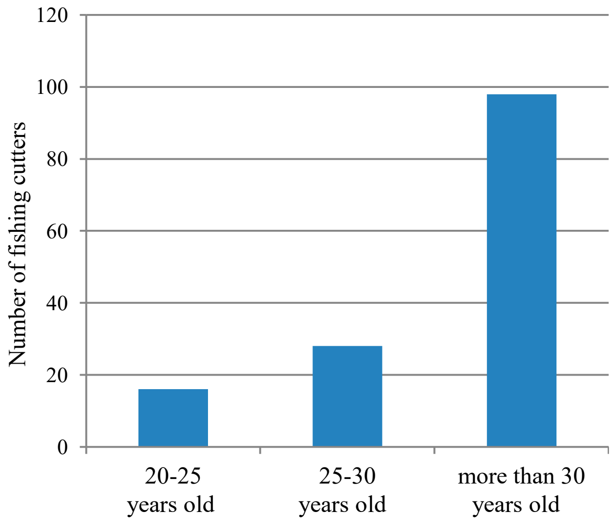

Figure 3. Structural age of the Polish fishing fleet

a risk to biological life. Failures which result in the sinking of a ship are extremely dangerous.

Failures that occurred in the years 1999–2012 have been considered. Energetic system failures are divided into the following types: main engine, auxiliary systems and machinery, main engine shafting and propeller, and finally, propeller fouled by fishing gear. Source materials used in the analysis included documents from the Maritime Court of Appeal in Gdynia, Maritime Court units operating at the Regional Courts in Gdańsk, Gdynia and Szczecin, materials from the insurance company TUiR Warta SA – its branches in Szczecin Świnoujście, Koszalin, Kołobrzeg, Darłowo, Kamień Pomorski and Dziwnów, and from the Maritime Office in Słupsk.

Failures of fishing cutters

The list of failures of fishing cutter energetic systems divided by the year 2012 and type of failure is presented in Table 1.

Among the fishing cutters, the greatest number of failures occurred to the main engine counted together with auxiliary systems and machinery serving the main engine. These two types of failure combined made up over 48% of all failures reported by fishing cutters in the years 1999–2012. Propeller fouling by fishing gear – nets and lines – was most significant in this class of fishing vessels. In total, 81 failures corresponded to nearly 32% of all failures in that period.

The figures in Table 1 are illustrated in the bar chart below (Figure 4).

Table 1. Energetic systems failures in fishing cutters (Materials of TUiR Warta SA; Materials of the Marine Court of Appeal in Gdynia; Materials of the Maritime Court at the Regional Courts in Gdańsk; Materials of the Polish Register of Shipping; Materials of the Maritime Office in Słupsk)

Year	Type of energetic system failure				Total
	Main engine	Auxiliary systems and machinery	Shafting and propeller	Propeller fouled by fishing gear	
1999	6	4	6	6	**22**
2000	6	3	–	8	**17**
2001	–	5	2	8	**15**
2002	5	8	7	2	**22**
2003	9	12	7	10	**38**
2004	6	2	5	8	**21**
2005	8	2	4	8	**22**
2006	5	3	3	9	**20**
2007	2	3	2	5	**12**
2008	3	4	3	4	**14**
2009	2	5	3	5	**15**
2010	4	4	2	3	**13**
2011	3	5	3	3	**14**
2012	2	3	3	2	**10**
Total	**61**	**63**	**50**	**81**	**255**

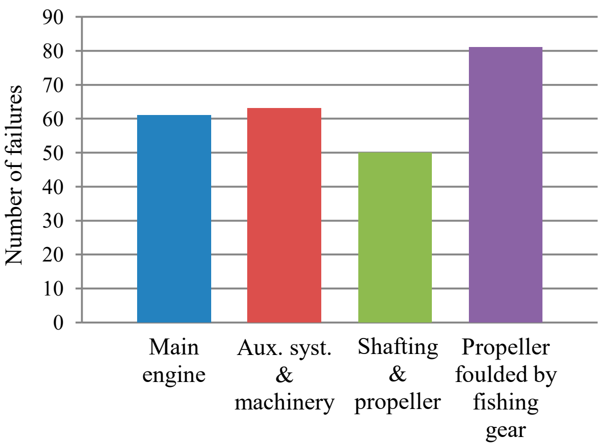

Figure 4. Number of energetic system failures in fishing cutters

Failures of VMS transponders

VTS is a satellite system for monitoring fishing vessels. Fishing vessels must be equipped with transponders. Satellite data is monitored and stored by the Polish Fisheries Monitoring Centre. Under the agreement signed with the Boarder Guard on the exchange of information regarding ships staying in Polish maritimeareas, the data is provided to the Automated Radar Surveillance System of Polish Maritime Areas.

Although the VMS system serves to monitor fisheries, precise data on vessel position was used to carry out rescue operations in the case of fishing vessel energy system failures and collisions with other cutters or offshore industry objects (mainly commercial vessels).

A mathematical model was developed by the Maritime University of Szczecin, which allows assessment of the number of collisions and damages to the fishing vessels (Gucma et al., 2008).

Simulation tests with the use of the developed model were conducted using the stochastic model of navigational risk assessment based on the Monte Carlo method. Simulation time may be accelerated, which allows us to obtain statistically stable results. As far as the statistics of accidents are concerned, most of the damage is caused by the collision of vessels. Therefore, it was decided to simulate situations covering these types of accidents.

The tests were conducted in two stages:

- firstly, excessive close-ups were computed (less than 0.1 Mm) between fishing vessels and commercial vessels; an average number of such situations equaled to 1800;
- the second stage referred to the calculation of collision feasibility; the calculation was basedon the grounds of the number of identified collisions and excessive close-ups between fishing vessels; the result is $3.2 \cdot 10^{-3}$.

At the following stage a simulation was carried out. The result of which are provide a number of collisions within a year and a volume of petroleum products spilled. In order to obtain statistically stable conditions, it was assumed that the simulation period was 70 years.

As a result of the simulation, an average number of simulated incidents was obtained which amounted to 5.73 collisions/year.

Vessel collisions may result from incorrect own or external navigation. They may happen in ports, at roadsteads and in fisheries. In the case of fishing vessels, the collisions may happen due to the loss of vessel maneuverability as a result of winding fishing gear, lost and remaining in the depths, on the propeller or propeller shaft. Also, a large number of vessels simultaneously being at the fishery and catching fish limits their maneuverability and is the reason for higher collision feasibility.

Figure 5 presents the number of transponder failures noted and reported by the Polish Fisheries Monitoring Centre to fishing vessels owners between 2011 and 2014 (Materials of The Center of The Monitoring of Fishery in Gdynia).

As it may be noted in Figure 5, the number of damages in the analyzed period (2011–2014) varied in the range of 75 to 103. The transponders are installed on around 480 vessels (Rajewski & Behrendt, 2008; Behrendt, 2013).

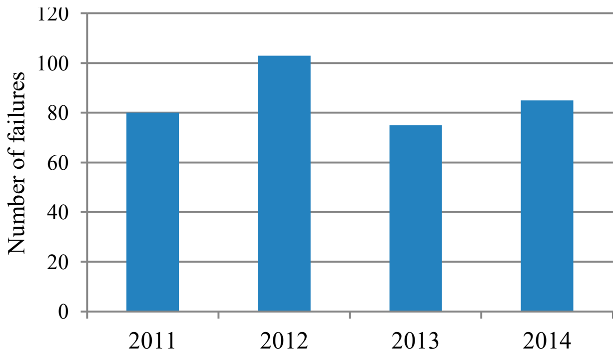

Figure 5. Number of transponder failures installed on fishing vessels

Environmental pollution due to fishing cutter failures

Failures inthe energetic systems of the fishing fleet are a potential source of marine environment pollution due to spills of oil products, such as fuels, lubricants and hydraulic oils. Environment pollution is most likely to happen in the case of the propeller being fouled by ropes or nets. As a result, the stern tube becomes unsealed and lubricating oil is released into the sea; when the controllable pitch propeller is thus affected – the sealing between the blades and the hub is damaged and consequently, hydraulic oil is spilled (Materials of TUiR Warta SA; Materials of the Marine Court of Appeal in Gdynia; Materials of the Maritime Court at the Regional Courts in Gdańsk; Materials of the Polish Register of Shipping; Materials of the Maritime Office in Słupsk).

There were 11 spills noted within the examined period caused by fishing gear that fouled the propeller. One boat sinking in a harbor was reported. Its reason for sinking was the unsealing of the stern tube through which water flooded into the unmanned boat in the night.

Similarly, the marine environment may be threatened by failures of the main engine or its auxiliary systems or machinery. A failure of boat propulsion makes the craft unable to bemaneuvered. This in turn, in specific operating conditions, such as heavy traffic of the ship's maneuvering in a restricted area and fishing in the vicinity of shallow waters, may result in collisions.

Immediate actions which occur after a collision results in a damaged hull, include discharging oily water into the sea. In extreme cases the ship involved in the collision may sink which often leads to fuel oil and lubricant spills from the wreck. In the examined period, six collisions and one sinking were recorded, all resulting from main engine or auxiliary system/machinery failures.

A spillage area is assessed on the basis of vessel fuel tank volume. An analysis of real objects allowed the development of a formula for fuel amount in the tanks of fishing vessels depending on the length of the vessel (Gucma et al., 2008):

$$M_p = 0.2026\ e^{0.1938\,L}\ \text{[tons]} \qquad (1)$$

where: L – vessel length [m].

Spilled fuels are subject to biodegradability, referred to as degradability caused by biological activity, in particular by enzymatic reactions leading to the change of the fuels chemical structure. In the case of fishing vessels, petroleum fuels are commonly used. Due to increasingly stricter regulations on air protection against the emission of harmful exhaust components, creating a special zone on the Baltic Sea and the EU regulations on alternative fuels, there is ongoing research regarding the use of biofuels for combustion engines of fishing vessels (Report, 2012; Klyus, Behrendt & Rajewski, 2013).

Biofuels are characterized by significantly higher biodegradability than petroleum fuels. Biodegradability efficiency in water is tested upon 28 days, as a percentage of fuel decomposition.

Table 2 presents the results of the laboratory tests of the selected petroleum fuels.

Table 2. Biodegradability of selected petroleum fuels (Zhang & Peterson, 1998; Speidel & Lightner, 2000)

Fuel	Biodegradability [%]
Gasoline (91 octanes)	28
Residual fuel (Bunker C)	11
Refined rapeseed fuel	78
Refined soya fuel	76
Rapeseed methyl ester	88
Sunflower methyl ester	90

As it may be noted during the analysis of the data in Table 2, petroleum fuels are characterized by low biodegradability – between 10 and 30% upon 28 days. The biodegradability of the methyl esters of plant oils is 3–9 times higher within the range 15–90%. Plant oils have slightly lower biodegradability than methyl esters.

Cyto Culture Inc. conducted the research aimed at demonstrating the impact of methyl esters from plants on aquatic organisms. A basic parameter allowing for the results interpretation is the so called LC50, namely the compound concentration causing

50% mortality of the population. The results of the ecotoxicological tests are presented in Table 3 (Zhang & Peterson, 1998).

Table 3. Ecotoxicological tests results (LC50)

Species tested	Fuel	Result
Larval stage of fish Menidia Beryllina	Biodiesel 80 diesel	578 ppm 27 ppm
Larval stage of shrimp Mysidopsis Bahia	Biodiesel 80 diesel	122 ppm 3 ppm

The ecotoxicological tests were carried out on larval forms of fish and shrimp due to their higher sensitivity to ambient conditions as compared to adult forms.

It may be stated on the basis of the data in Table 2 that although biodiesel is not completely harmless to fish and shellfish larvae, it is 20 to 40 times less harmful than petroleum fuels.

Taking into consideration the biodegradability, the reduced emission of harmful exhaust components and the results of the ecotoxicological testing, it is advisable to use biofuels for fishing vessels combustion engines, in particular due to their operation in a special zone such as the Baltic Sea.

Conclusions

In the years 1999–2012 there were reports on as many as 255 failures in fishing cutters operating in the Baltic Sea from Polish ports. Among the four examined types, or groups, of failures relating to the energetic systems of fishing cutters, the fouling of the propeller by fishing gear is the most frequent reason. Figure 6 presents an example of the damage to the propulsion system of a fishing vessel which limitsoperation of the vessel. The damage was caused by a rope wound on a line of shafts.

Figure 6. Therope wound on a line of shafts

The damage presented in Figure 6 resulted in the need to haul the vessel to a port by a second cutter fishing nearby. A fishing line screwed into the stern tube seal of the fishing vessel is presented in Figure 7. Oil spillage was a result of the situation.

Figure 7. Nylon fishing line of a fishing net line screwed into the stern tube seal

A total of 81 such failures make up over 32% of all failures. 11 cases of marine environment pollution were reported to have been caused by oil spillage. The direct reason was either a leak of the stern tube or due tothe controllable pitch propeller blades mounted to the hub, line or net fouling the propeller. The two fishing craftsinking incidents reported also caused oil spills. The substantial share of failures caused due to a propeller fouled by lines or nets results from the specific character of fishing cutter operation connected with running out and hauling in fishing gear while sailing at slow speed or a drift, often at high seas.

Notably, in the case of 124 failures of the main engine or its auxiliary systems and machinery, 48% of all the examined cases, the age of cutters was a significant factor. More than 87% of the failures occurred to cutters built more than 25 years ago.

Failures of the main engine or its auxiliary systems and machinery caused six collisions and one sinking. The advisability forusing biofuels has been shown in relation to the supply of fishing vessel engines due to their high biodegradability (3–9 times higher than petroleum fuels) and due to 20–40 times lower toxic effect on live organisms than petroleum fuels. As far as the implementation of a new satellite control system, VMS, is concerned, its possibilities and functions in relation to preventing collisions and its application during rescue operations has been presented. An average number of simulated collisions of fishing vessels was determined at the level of 5.73 collision/year for the Polish fishing fleet.

Acknowledgments

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References

1. Behrendt, C. (2013) *Analysis of fishing cutters of the Polish fishing fleet and structure of their power systems*. Contributions on the Theory of Fishing Gears and Related Marine Systems. University of Rostock vol. 8. pp. 253–262.
2. Gucma, L. et al. (2008) Ocena ryzyka zanieczyszczenia w polskiej strefie Bałtyku południowego w tym kolizji łodzi i kutrów rybackich, opracowanie w ramach projektu nr OR16-61535-OR1600006/06, Szczecin.
3. Klyus, O., Behrendt, C. & Rajewski, P. (2013) *Reduction of Nitrogen Oxides Emission and Fuel Consumption in Fishing Cutter Engines*. DEMaT'13 Conference, Rostock. pp. 293–300.
4. Materials of The Center of The Monitoring of Fishery in Gdynia.
5. Materials of the Marine Court of Appeal in Gdynia.
6. Materials of the Maritime Court at the Regional Courts in Gdańsk, Gdynia and Szczecin.
7. Materials of the Maritime Office in Słupsk.
8. Materials of the Polish Register of Shipping.
9. Materials of TUiR Warta SA, an insurance company, from its branches in Szczecin, Świnoujście, Koszalin, Kołobrzeg, Darłowo, Kamień Pomorski and Dziwnów.
10. Rajewski, P. & Behrendt, C. (2008) The Distribution Structure of Polish Fishing Vessels Operating from Polish Ports. *Problemy Eksploatacji* 2 (69), Radom. pp. 205–213.
11. Report (2012) *Key Challenges to Promote the Energy Efficiency in Fisheries From a Research and Innovation Perspective*. Report from workshop about energy efficiency organized by the European Fisheries Technology Platform, Madrid.
12. Speidel, H. & Lightner, R.L. (2000) Biodegradability of new engineered fuels. *Biochem, Biotechnology* 3. pp. 84–86.
13. Zhang, X. & Peterson, C. (1998) Biodegradability of biodiesel in aquatic environment. Trans ASAE 41.