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RESEARCH OF REFRIGERATION SYSTEMS FAILURES IN POLISH FISHING VESSELS

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Abstract:
Temperature is a basic climatic parameter deciding about the quality change of fishing products. Time, after which qualitative changes of caught fish don't exceed established, acceptable range, is above all the temperature function. Temperature reduction by refrigeration system of the cargo hold is a basic technical method, which allows extend transport time. Failures of refrigeration systems in fishing vessels have a negative impact on the environment in relation to harmful refrigerants emission. The paper presents the statistical analysis of failures occurred in the refrigeration systems of Polish fishing vessels in 2007-2011 years. Analysis results described in the paper can be a base to draw up guidelines, both for designers as well as operators of the marine refrigeration systems.

Key words: *failures, fishing vessels, refrigeration systems*

INTRODUCTION

Reaching the competitive productions effectiveness level in our times is firmly associated with keeping of the appropriate machines maintenance level. At present a main problems to solve the problem in operational field are better production quality, greater reliability and production systems readiness, costs optimization, appropriate strategy selection of both maintenance and repairs. An additional aspect is harmful effects reduction on the natural environment as well as costs associated with it.

It also regards to fishing units of the Polish coastal fleet, on which focused in the paper. At Maritime University in Szczecin it has been implemented a few EU projects associated with the fishing unit modernizations and reduction their negative impact on the environment. Their aim is among others database development as well as to collect as many measurement data enabling to estimate propulsion characteristics and appoint mathematical equations credible describing functional relations of the fishing vessels energy systems. Collected measurement data during the normal units operation will allow to describe emission of exhaust gases, refrigerating medium leaks, etc.

Large number and diversity of fishing units requires designation of vessels, which propulsion system is the most common in Polish coastal fleet. Of course it is assumed to perform measurements on the largest possible population of researched objects. For every designated unit the devices and the measurement equipment are prepared in order to carry the measuring cycle.

Due to wide range of conducted studies, for the article purposes the analysis is limited only to refrigeration systems failures in fishing vessels. This failures are very often connected with harmful factors emission. It is necessary to remember that temperature is a basic climatic parameter deciding about the quality change of fishing products. Time, after which qualitative changes of caught fish don't exceed established, acceptable range, is above all the temperature function. Apart from storing in containers sprinkled with flake ice additional technical measures are applied for transport time extension. Temperature reduction by refrigeration system of the cargo hold is a basic mean.

Refrigeration systems of fishing vessels have a similar impact on the natural environment as refrigeration devices applied in remaining economy sectors. Adopting a principle of estimating equipment costs in the entire operation period, it must be stated that environment impact appears in all installation lifetime stages, from its elements production moment, through assembly, startup, operation, repairs, shutdown and liquidation. Fundamental elements of the environmental impact are impoverishing ozone layer in the ionosphere, gas emission, smog production in the lowest atmospheric layers, soil and waters acidity change as well as natural water reservoirs eutrophication.

As a result of international actions the refrigeration industry tries to limit its harmful impact on natural environment by introduction of new refrigerant and design solutions of refrigeration installations. An integrated approach to the issue includes:

- installation design choice and refrigerant selection;
- procedures choice, responsible for safe refrigerant operation;
- introduction of technology reducing leaks and increasing installation efficiency;
- promotion of the latest knowledge and staff training, responsible for designing and operation;
- predicting and estimating possible refrigeration systems elements failures for prevention and repair purposes.

These issues remain in the interest of centers responsible for implementation of environment-friendly solutions in the refrigeration.

LOCALIZATION AND DIVISION OF FISHING UNITS IN POLAND

Polish fishing boats, fishing based on ports located on Polish sea waters constitute a large group of 914 registered units as active fishing vessels. These are units of varied age, different sizes and different technical solutions. Also a location of these units is uneven along Polish coast. In Table 1 numbers of fishing boats registered in the biggest Polish fishing ports were compared.

Table 1
Number of fishing boats in the biggest Polish fishing ports (data from 2007) [3]

No	Port	Number of boats
1	Ustka	86
2	Władysławowo	80
3	Kołobrzeg	65
4	Jastarnia	53
5	Darłowo	44
6	Łeba	37
7	Trzebież Szczecińska	36
8	Świnoujście	34
9	Dziwnów	28
10	Kuźnica Morska	30
11	Piaski	27

In view of operation specificity of particular fishing unit types a division due to these objects size is commonly used. As a basis assessment of the unit size adopted its total length.

Following groups were assigned based on vessels total length:

1) vessels about total length up to 7 m,
2) vessels about total length 7-9 m,
3) vessels about total length 9-10 m,
4) vessels about total length 10-15 m,
5) vessels about total length 16-20 m,
6) vessels about total length 20-30 m,
7) vessels about total length above 30 m.

In accordance with applicable naming the name of "fishing vessel" includes all fishing units, regardless of their size. However, a former division into fishing boats of opened and closed-deck as well as fishing **cutters** is also saved. Vessels about the total length not-exceeding 15 meters are included to the first group. Larger fishing units on the Baltic Sea are determined as cutters. 1 to 4 vessels groups constitute fishing boats, operating in close distance from the shore and using mainly passive fishing devices. These vessels won't be considered in this work due to smaller saturation degree of the technical devices. Vessels gathered in remaining groups operate on fishing grounds applying passive and active fishing devices.

OPERATING DATA ABOUT REFRIGERATION SYSTEM FAILURES OF FISHING VESSELS

For research purposes, data were collected during chosen vessels operation. Two main sources were used to collect them.

The first source constitutes information obtained from ship-owners, vessels operators as well as repair companies in the questionnaire forms and interviews for vessels designated in individual years (projects carried out at the Maritime University). This way based on "register cards" a database was created as part of the project: *Development of Guidelines for the Modernization of Fishing Vessels in Terms of Energy Expenditure and Reduction of Environmental Impact.* Information in the base were added in next projects: *Use of Fuels of Vegetable Origin in Fishing Vessels and Reduction in Fuel Consumption and Exhaust Gas Engines Toxicity of Fishing Vessels*, as well as during numerous meetings with ship-owners, ship operators and information from repair companies. It was used to create descriptive statistics and matrix diagrams at determining the probability of refrigeration systems elements failures appearance in fishing vessels.

Operating documentation of every designated unit, including information about periodical inspections, overhauls and running repairs in 2007-2011 years constitutes the second source. From the operating documentation was singled out documentation concerning exclusively refrigeration systems elements of fishing vessels and saved in the form of test sheets with the division for years. These sheets were used to draw up reliable mathematical relations describing refrigeration systems failures.

ANALYSIS OF OPERATING DATA AND QUANTITATIVE DESCRIPTION OF REFRIGERATION SYSTEMS FAILURES IN FISHING VESSELS

Application of devices, installation, accessories intended for refrigeration requires experience and abilities of operation. Proper refrigeration devices operation with the minimum breakdown number provides qualified service as well as use of appropriate quality materials and equipment accessories. However, in spite of steady increase of refrigeration systems reliability it is impossible to prevent all failures [6, 7]. So it is necessary to appropriately predict their occurrence in order to avoid situations, in which their failure will affect the stoppage of entire object work.

Based on data collected during research (2007-2011 years) it was stated that the most frequent refrigeration system failures are:

1) refrigerant installation leaks and associated with it refrigerant leakages,
2) refrigerating compressors failures,
3) heat exchangers failures (condensers and evaporators),
4) control systems failures,
5) fans failures,
6) failures of water pumps, brine pumps and oil pumps,
7) defrosting systems failures.

Examples of refrigeration systems elements failures were shown on Fig. 1.

Failures were divided on seven main categories (according to the above system). 235 refrigeration systems failures of 25 cutters of the fishing fleet located in the west, middle and eastern polish coast ports were collected and analyzed. Two fishing cutters types were analyzed, taking into account kind of refrigerant as an division criterion (Table 2):

1) cutters marked in the paper as **X** – constitute vessels, in which it is used as refrigerant the old type of refrigerating medium from hydrochlorofluorocarbons (HCFC) group,
2) cutters marked as **Y** – cutters, in which refrigeration devices were modernized (or are originally adapted) to use refrigerants alterable for hydrochlorofluorocarbons (HCFC) and chlorofluorocarbons (CFC).

Fig. 1 Examples of refrigeration systems elements failures

Table 2
Data concerning refrigeration systems elements failures with the division into seven categories for cutters of X and Y type in 2007-2011 years

X	2007	2008	2009	2010	2011
1	6	6	7	10	10
2	3	4	6	8	8
3	3	3	3	3	3
4	5	2	4	5	7
5	2	1	3	3	2
6	0	1	2	1	0
7	0	1	1	0	0
Y	**2007**	**2008**	**2009**	**2010**	**2011**
1	3	1	1	2	2
2	6	5	5	6	7
3	3	4	4	2	5
4	8	8	6	7	7
5	2	4	2	3	2
6	0	2	1	0	1
7	0	1	1	1	0

DESCRIPTIVE CHARACTERISTICS FOR THE FREQUENCY OF REFRIGERATION SYSTEMS FAILURES ON FISHING CUTTERS IN 2007-2011 YEARS

For statistical analysis of refrigeration systems failures in fishing vessels in 2007-2011 years the following variables were determined [1, 2, 4, 5]:

dependent:
- number of refrigeration systems failures in fishing vessels,
- refrigeration systems failures frequency in fishing vessels, which is a quotient of the failures number to fishing cutters quantity.

independent:
- 2007-2011 years,
- category of refrigeration systems elements failures in fishing vessels, 7 indicated categories were accepted with the next natural numbers,
- fishing units type – two types of cutters were determined X (16 cutters) and Y (9 cutters).

For variables: number of the refrigeration systems failures and refrigeration systems failures frequency in fishing vessels histograms were drawn up, presented on Fig. 2 and 3.

It can be seen from them that for variable number of the refrigeration systems failures the most observations were with a failure number from 0 to 3, and the least with 9-10 failures. If we will take refrigeration systems failures frequency into consideration, the most observations were for the frequency from range 0 to 0.2, however the least from 0.8 to 1. It means that there was most often a small number of refrigeration systems failures in fishing vessels with a rather small failures frequency.

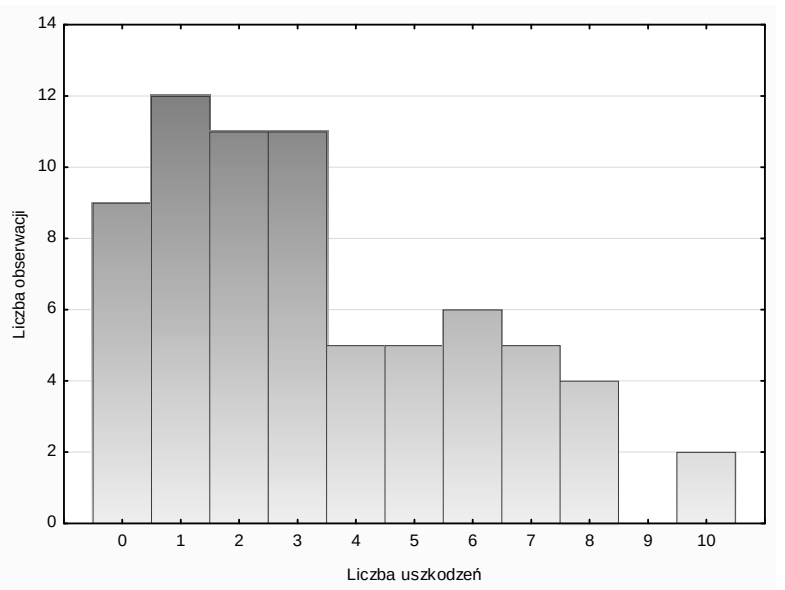

Fig. 2 Histogram of refrigeration systems failures number in 2007-2011 years

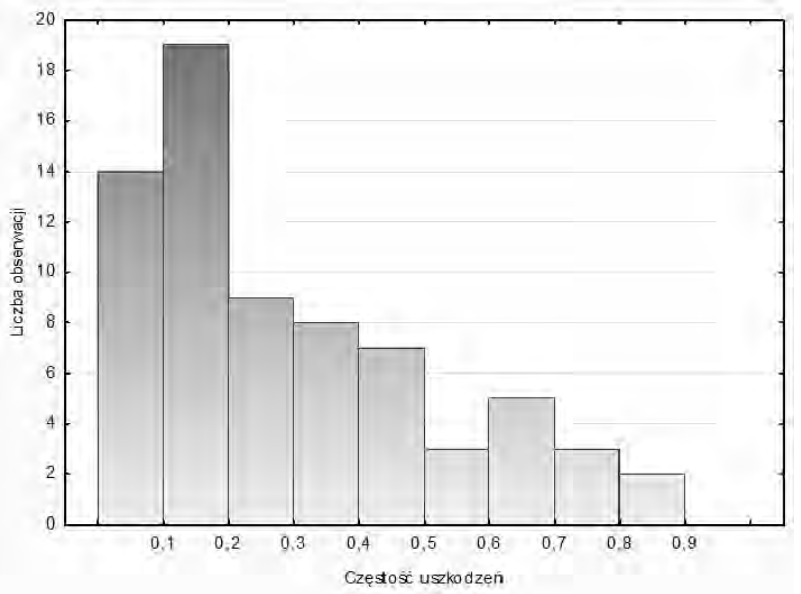

Fig. 3 Histogram of refrigeration systems failures frequency in 2007-2011 years

Table 3
Descriptive statistics for particular variables concerning refrigeration systems failures in fishing vessels

Specification	Mean	Median	Mode	Modal value	Min.	Max.	Standard deviation	Coefficient of variation
Failures number	3.36	3	1	12	0	10	2.66	80%
Failures frequency	0.29	0.22	0	9	0	0.89	0.24	84%

Descriptive statistics parameters were next calculated: arithmetic mean, median, mode, modal value, minimum, maximum, standard deviation and coefficient of variation for these variables. They were presented in Table 3.

Variable number of the refrigeration systems failures assumes values from 0 to 10, with the mean more than 3, but with great standard deviation 2.66, what determines 80% of variation coefficient. Most often (12 times) failures number is 1, however middle value (median) is similar to the mean and amounts 3.

However, variable refrigeration systems failures frequency assumes values from 0 to 0.89, with the mean 0.29, and standard deviation is also large 0.24, what constitutes 84% of the mean. Most often (9 times) failures frequency is 0, however middle value (median) is smaller than arithmetic mean and amounts 0.22.

SUMMARY AND CONCLUSIONS

Implemented changes concerning environmental requirements also include fishing vessels, due to the atmosphere impact resulting from their operation. Failures appears in fishing vessels, particularly failures of their refrigeration systems. Therefore, failures analysis is very important for prevention purposes, among others by statistical analysis, which enables to determine the probability of their occurrence. Due to the paper volume the entire conducted analyses of refrigeration systems failures in fishing vessels wasn't quoted here (among others matrix analysis, Pareto-Lorentz, Ishikawa), and limited only to descriptive characteristics. Conclusions resulting from these analyses can be a base to draw up guidelines for both designers as well as operators of refrigerant systems in fishing vessels.

Energy consumption level by refrigeration systems is one of the most important parameters determining refrigeration industry impact on the global warming level. Therefore, there is a tendency to minimize emission and maximize energy efficiency in order to reduce Total Equivalent Warming Impact (TEWI) indicator. Dominating phenomena are listed below:

- preferential refrigerants selection, regarded as ecological, such as natural hydrocarbons, ammonia and carbon dioxide,
- improvement of procedures for installation operation,
- reduction of the direct refrigerants emission from installation,
- reduction of the refrigerant mass in installation,
- increase of manufacture and assembly standards,
- changes in machine design and system design in order to increase refrigerating efficiency.

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