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The use of Pareto-Lorenz analysis for the determination of faults in fishing vessel refrigerating systems

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Abstract

This study is aimed at the determination of the significance of faults diagnosed in refrigerating plant components of fishing vessels. The problem is described by the Pareto-Lorenz analysis. The field work covers vessels of the Polish fishing fleet. Ships under examination are typical of the Polish fishing vessels operating at sea. The research has been based on data gathered in 2007–2011, consisting of 235 faults, detected and estimated for refrigerating systems of 25 small vessels of the Polish fishing fleet. Taking the refrigerant as a criterion of division, we have analyzed two types of vessels.

Introduction

Polish fishing fleet operating on the Baltic Sea from Polish ports consists of a variety of vessels and boats of different age. At some point of their long operation, these vessels were modernized, which comprised refrigerating installations. The operation of outdated and worn refrigerating systems in fishing vessels often affects frequent faults resulting from untight installations and resultant leaks of the refrigerant, faults of refrigerating units, condensers, evaporators, fans etc. [1, 2, 3]. The multitude of refrigerating equipment used in Poland and all over the world adversely affects the ozone layer and adds to the greenhouse effect. Ozone in the upper stratum of the atmosphere (ozonosphere) protects people from harmful ultraviolet radiation. In refrigerating practice ozoning has been used to prevent the development of microorganisms in refrigerating chambers [3]. For decades, a dramatic drop of ozone content in the Earth's protective layer of the atmosphere has been observed. The main reason for this phenomenon is appearance in the atmosphere of large amounts of CFCs (chloroflourocarbons) and nitrogen compounds (greenhouse gases) [1, 2]. On the one hand, the presence of greenhouse gases in the atmosphere enables life on our planet (without them, the temperature would have dropped much below zero). On the other hand, leaking refrigerants and wrong energy management are among factors contributing to the melting of glaciers due to growing temperature of the atmosphere. As a result, the level of the seas may rise, leading to flooding of many areas located low above the sea level, some of them being most densely populated places on Earth.

Other effects of the depleted ozone layer include enhanced ultraviolet radiation, adverse impact on physiological and developmental processes of plants, climatic changes, limited development of phytoplankton in the oceans, increase in skin cancer and eye diseases in people and animals.

For these reasons it is important to forecast and limit faults of fishing vessel refrigerating systems, to prevent such faults by continuous monitoring, and the determination of likelihood of most frequent failures and their causes. These measures are necessary for the protection of marine environment in which fishing vessels operate, and to avoid situations in which such a failure might stop operation of the vessel, creating a threat to other vessels in vicinity [2].

The research

On the basis of [1, 2, 3] and data gathered during this study we found that the most frequent reasons of cooling system component faults include damage to:

1) sealings in refrigerating installations and related refrigerant leaks (Fig. 1a);
2) refrigerating compressors (Fig. 1b);
3) heat exchangers (condensers and evaporators);
4) control systems;
5) fans (Fig. 1c);
6) water, brine and oil pumps;
7) defrosting systems.

a)
b)
c)

Fig. 1. Examples of refrigerating system component faults: a) refrigerant leaking from a refrigerating installation, b) damage to a compressor, c) damage to a condenser fan [4]

The faults were divided into seven main categories (as points 1–7 above) and related research was done exploring data gathered in the years 2007–2011. 235 faults of refrigerating systems were gathered and evaluated from 25 vessels of Polish fishing fleet, distributed in ports on westerns, central and eastern coasts (Table 1).

The analysis focused on two groups of fishing vessels, divided by the type of refrigerant:

1) Vessels herein marked **X** – those using an old type of refrigerant belonging to the group of hydrochlorofluorocarbons (HCFC) (16 such vessels were examined);
2) Vessels herein marked **Y** – those with modernized refrigerating equipment (or having it originally installed), using refrigerants that replace HCFCs and clorofluorocarbons or CFCs (9 such vessels were examined).

Table 1. Data on refrigerating system component faults, with a division into two groups of vessels X and Y, from 2007–2011

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

We have analyzed the recorded faults of refrigerating systems in fishing vessels by the Pareto-Lorenz method [5]. The diagram, an effect of the analysis, is based on the empirically observed regularity that in engineering generally 20–30% of causes (factors) contributes to 70–80% of effects (Fig. 2).

The diagram is constructed in the following phases [5, 6]:

– gathering data on the examined object that are related to a given problem;
– determination of the quantity to be used for measuring the process outcome in reference to

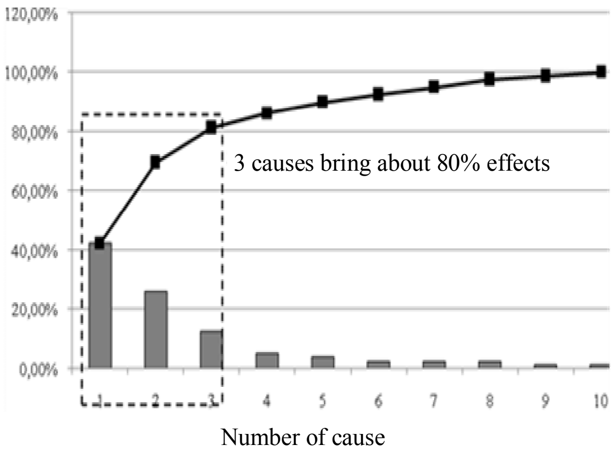

Fig. 2. Pareto-Lorenz diagram illustrating unequal cause-effect distribution: relatively few causes account for many effects

the problem under consideration. In the case herein described the determination of the quantity was based on seven categories of faults selected during analyses, in the course of acquiring data from 25 vessels in all. The sample of 25 vessels under examination is a sufficient and representative sample while using tools for the description of the problem according to the specialized literature [7];

- putting faults in order (on the basis of information gathered and knowledge) due to the force with which they affect the fault outcome;
- determination of cumulative percentage values of each fault;
- drawing a line through points corresponding to the cumulative values;
- analyzing the diagram to identify a group of faults that are mostly responsible for affecting the object under consideration.

From the data included in control sheets, the faults of fishing vessel refrigerating installations were segregated by the number of occurrences in the descending order. The faults are given in table 2 for vessels of group X and in table 3 for vessels of group Y. The tables, in respective columns, contain cumulative values needed to draw up a Pareto-Lorenz diagram. The diagrams, a graphic result of the analysis, are shown in figures 3 and 4.

Table 2. Classification of faults identified in refrigerating systems of fishing vessels by the frequency of occurrence in fishing vessels of group X

No.	Type / location of fault	Number of faults	Relative number (%)	Cumulative number of faults	Relative cumulative number (%)
1	Untight refrigerating installation and related leaks of refrigerant	39	31.70	39	31.70
2	Refrigerating compressors	29	23.58	68	55.28
3	Control system	23	18.70	91	73.98
4	Heat exchangers (condensers and evaporators)	15	12.20	106	86.18
5	Fans	11	8.94	117	95.15
6	Water, brine and oil pumps	4	3.23	121	98.37
7	Defrosting systems	2	1.63	123	100
	Total	123			

Table 3. Classification of faults identified in refrigerating systems of fishing vessels by the frequency of occurrence in fishing vessels of group Y

No.	Type / location of fault	Number of faults	Relative number (%)	Cumulative number of faults	Relative cumulative number (%)
1	Control systems	36	32.14	36	32.14
2	Refrigerating compressors	29	25.89	65	58.03
3	Heat exchangers (condensers and evaporators)	18	16.07	83	74.01
4	Fans	13	11.61	96	85.71
5	Untight refrigerating installation and related leaks of refrigerant	9	9.04	105	93.75
6	Water, brine and oil pumps	4	3.57	109	97.32
7	Defrosting systems	3	2.68	112	100
	Total	112			

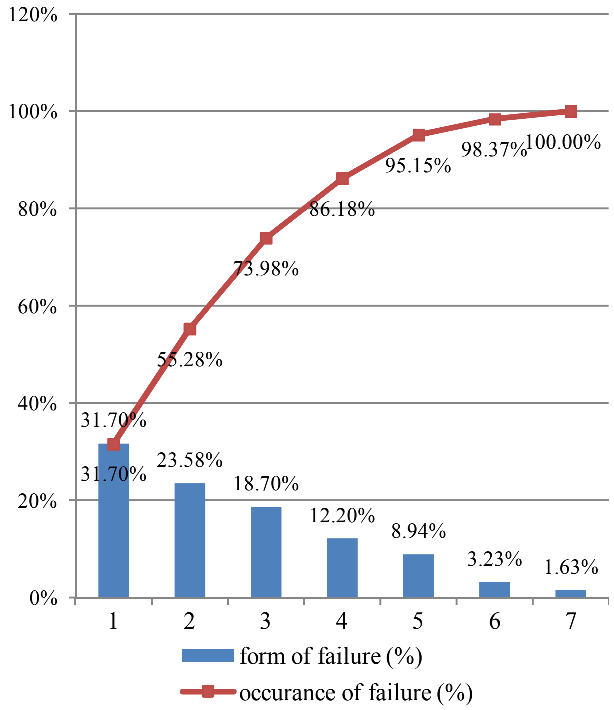

Fig. 3. Pareto-Lorenz diagram for refrigerating system faults in fishing vessels of group X – based on table 2

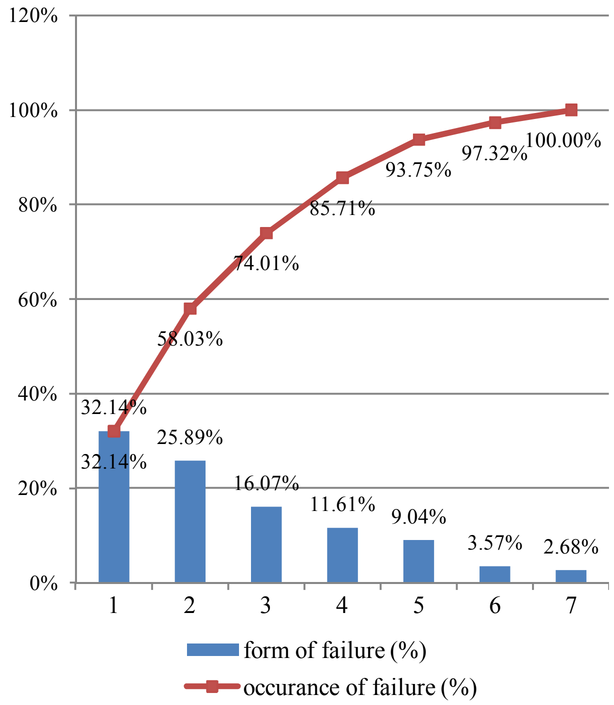

Fig. 4. Pareto-Lorenz diagram for refrigerating system faults in fishing vessels of group Y – based on table 3

Conclusions

The Pareto-Lorenz diagram presents in the descending order a relative share of each factor in the overall effect of operation [6]. It puts in order the faults of refrigerating systems in two groups of fishing vessels defining their significance for the operation of such vessels. In case of fishing vessels of X type – untight refrigerating installation and related leaks of refrigerant, refrigerating compressors, control system is 73.98% of this group and according to the Pareto-Lorenz rule, has main influence on its failure. In case of fishing vessels of Y type – damages of control systems, refrigeration compressors and heat exchangers (condensers and evaporators) the importance of interaction is 74.1%.

The presented analysis has shown a large diversity of faults occurring in fishing vessel refrigerating installations of two, previously defined types: older X type and new Y type. The outcome allows to quickly and effectively assess the profitability of the vessels. It is also a valuable tool describing the probability of fault occurrence. Identification of these causes in the assessment of faults of refrigerating systems in fishing vessels permits to determine directions of actions to be taken to effectively contribute to better and smooth operation of vessels under consideration, or to gather and store onboard a vessel necessary spare parts.

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