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AN ANALYSIS OF VARIANCE OF FISHING VESSEL REFRIGERATING SYSTEMS FAULTS

We have performed an analysis of variance to verify the hypothesis that independent variables differentiate the number of faults and frequencies of faults occurring in refrigerating systems installed on board fishing craft. The analysis specifies a probability with which identified factors may cause differences between values of observed category means. The grouping factors used in the analysis are: year of fault occurrence, fault category and a type of fishing vessel. We have tested hypotheses that mean numbers of faults or mean frequencies of fault occurrence are approximately equal in each group of independent variable. The examined faults of refrigerating system components, derived from data collected in the years 2007–2011, have been divided into seven categories and analyzed statistically. We have gathered and estimated 235 faults of refrigerating system components from 25 fishing vessels of the Polish fishing fleet. The vessels are divided into two types depending on the refrigerant used in their systems.

Key words*: analysis of variance, refrigerating systems, damage, fishing feet, vessels.*

1. INTRODUCTION

Polish fishing fleet operating on the Baltic Sea from domestic ports is characterized by a variety of vessels and their age. Over many years of their operation, many vessels have been modified, which included the refrigerating systems. Fishing vessels have varied refrigerating systems, i.e. different technologies of storing and transporting fish. The operational performance of those systems directly affects the quality of fish, which translates into market value and higher demand on the fish market. The operators of obsolete shipboard refrigerating systems are haunted with frequent defects due to leaky refrigerating installations, resulting in spills of the refrigerant, as well as failures of refrigerating units, condensers etc [1, 3–5, 11–12]. One specific reason for some faults is unsatisfactory condition in refrigerating systems due to temporary repairs or conversions, installation of new equipment, often fitted in a hurry and without proper tools. Those modifications have often been a response to breakdowns during the operation of fishing vessels. Finally, some changes have been necessitated by obligatory replacement of specific refrigerants due to their adverse effect on the environment.

Some damage to refrigerating systems may be also be caused by insufficiently qualified personnel. This is particularly true in case of new vessels with modern, often complex, refrigerating plants using acceptable environmentally friendly refrigerants. A large number of refrigerating units used in Poland and in the world still depletes the ozone layer and thus contributing to the creation of the greenhouse effect. Ozone in the upper layer of the atmosphere protects us before harmful ultraviolet radiation. Ozoning in the refrigeration practice was used to prevent development of micro-organisms in refrigerated chambers [3–4, 6–7, 9, 11]. We have witnessed a steady drop of the ozone level in the protective layer of the Earth for decades now. The phenomenon was mainly initiated by the appearance in the atmosphere of large amounts of chlorofluorocarbons (CFCs) and nitrogen compounds, making up what we call greenhouse gases [9–10]. Although these gases are needed in the atmosphere to sustain life on the planet (without the gases temperature would drop much below zero), due to uncontrollable growth of average air and ocean temperatures, we record excessive melting of the glaciers and ozone explosions, as the gas is unstable and explodes in the presence of hydrogen, iron, copper and chromium. These undesired phenomena are caused by a number of factors, inter alia, refrigerant leaks or improper energy management. The warmer climate is expected to lead to increased water level of the seas and consequent flooding of areas lying low above the sea level, often densely populated areas. As a result of the warming of the climate, winters will be warmer and, summers dramatically hotter, which will lead to such effects of more intense ultraviolet radiation as reduction of chlorophyll in plants, climate changes, restricted development of phytoplankton in the oceans, more cases of skin cancer and eye diseases in people and animals.

The use of refrigeration equipment and installations calls for skillful and experienced operators. The proper operation of refrigerating units with minimized number of failures can only be achieved by qualified personnel and the application of high quality materials and components. Despite constant increase in the reliability of refrigerating systems, we cannot prevent faults from occurring. Therefore, if operational faults are properly anticipated by determining their probability of occurrence, users will avoid situations where a defect of one component will negatively affect the work of an entire unit.

2. ONE FACTOR ANALYSIS OF VARIANCE

We have adopted seven categories of faults of refrigerating system elements for the purpose of determining the probability of these faults [7–8, 10]:

1) leaks of refrigerants in refrigeration installations,
2) defects of compressors,
3) damage to heat exchangers (condensers and evaporators),

4) control system faults,
5) defects of ventilators,
6) damage to water (brine) oil pumps,
7) defrosting system faults.

From data gathered in the years 2007–2011 we have evaluated 235 occurrences of faults in refrigerating systems of 25 vessels belonging to the Polish fishing fleet [8]. Two types of vessels have been analyzed. The analysis has covered two groups of vessels, divided by the type of refrigerant used in them [10]:

1) vessels herein denoted as X; these vessels use an old type of refrigerant belonging to the hydro chlorofluorocarbon compounds (HCFCs) (refrigerating system faults in 16 vessels have been analyzed),

2) vessels denoted as Y; these vessels are equipped with modernized or original refrigerating systems running on refrigerants other than HCFCs or CFCs (we have examined refrigerating system faults in nine such vessels).

A one factor analysis of variance has been done to find out the probability with which the factors: year of occurrence, fault category and the type of vessel may cause variation between observed group mean values.

We have verified a hypothesis [2] that independent variables differentiate two kinds of variables: number of faults and frequency of faults occurring in refrigerating systems of fishing vessels. In ANOVA (Variance analysis is a statistical method used to examine the observation that depend on one or more operating simultaneously factors. This method explains the probability with which the extracted factors may be the reason for the differences between group averages), an analysis of variance used, our classifying factor is the year in which a fault occurred, the category of fault and the type of vessel. We have tested hypotheses that mean numbers of faults or mean frequencies of fault occurrence are equal in particular groups of independent variable. The test results are given below.

A test for the variable number of faults (in refrigerating systems of fishing vessels) in each category:

H_0: $m_1 = m_2 = \ldots = m_7$, against an alternative hypothesis

H_1: not all m are equal.

The value of testing statistic and a critical level of probability p are given in Figure 1.

Assumptions that independent variables differentiate variables of the number of faults and frequency of faults of refrigerating systems of fishing vessels have been verified by means of a one factor analysis of variance, where the classifying factors were: year of occurrence, fault category and the type of vessel. We have tested hypotheses that mean numbers of faults or mean frequencies of fault occurrence are equal in particular groups of the independent variable. The results of these tests are given below.

A test for the variable 'number of faults' of refrigerating systems of fishing vessels in each category:

H_0: $m_1 = m_2 = \ldots = m_7$, against an alternative hypothesis

H_1: not all m are equal.

The value of testing statistic and critical level of probability p are shown in Figure 1.

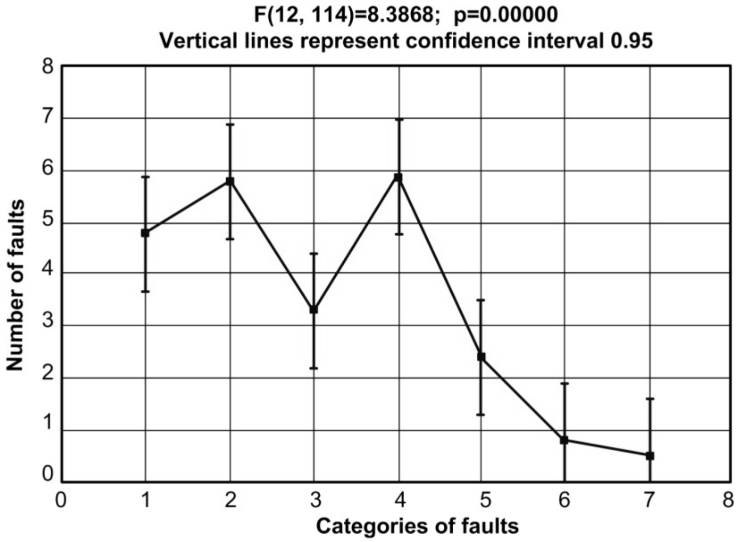

Fig. 1. ANOVA for the variable number of faults against categories of faults occurring in refrigerating systems of fishing vessels

At the significance level $\alpha = 0.05$ we reject the null hypothesis on the equality of means, which is interpreted as follows: variable category of faults differentiates the number of faults, and it can be observed that the greatest mean numbers of faults are those for categories 2 and 4, while the smallest means fall on categories 6 and 7. A test for the variable frequency of faults in each category:

H_0: $m_{c1} = m_{c2} = \ldots = m_{c7}$, against an alternative hypothesis

H_1: not all m are equal.

The value of testing statistic and critical level of probability p are shown in Figure 2.

At the significance level $\alpha = 0.05$ we reject the null hypothesis on the equality of means, which is interpreted as follows: variable category of faults differentiates the frequency of faults, and it can be observed that the greatest mean frequencies of faults are those for categories 2 and 4, while the smallest means fall on categories 6 and 7.

A test for the variable number of faults in successive years:

H_0: $m_1 = m_2 = \ldots = m_5$, against an alternative hypothesis

H_1: not all m are equal.

A test for the variable frequency of faults in successive years:

H_0: $m_{c1} = m_{c2} = \ldots = m_{c5}$, against an alternative hypothesis

H_1: not all m are equal.

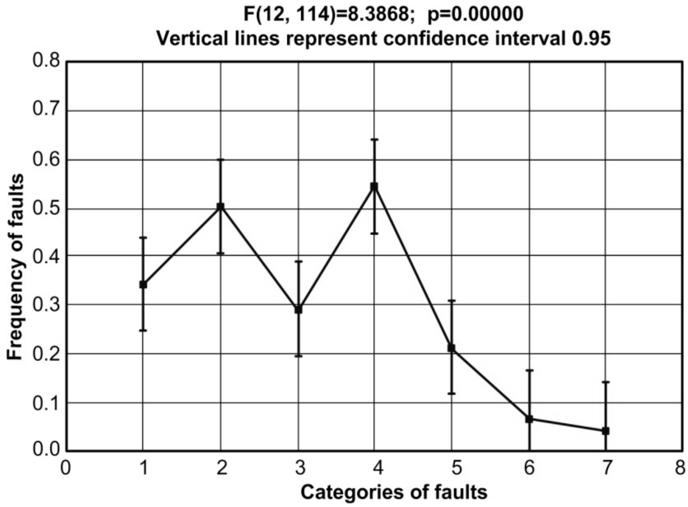

Fig. 2. ANOVA for the variable frequency of faults against categories of faults occurring in refrigerating systems of fishing vessels

The value of testing statistic and critical level of probability p are shown in Figure 3.

At the significance level $\alpha = 0.05$ there are no grounds to reject the null hypothesis on the equality of means, therefore the variable year of occurrence does not differentiate the number of faults.

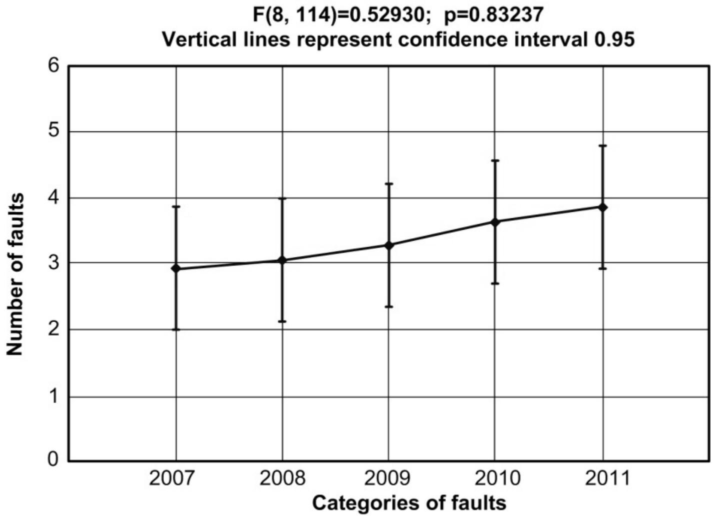

Fig. 3. ANOVA for the variable number of faults against the independent variable year of occurrence

The value of testing statistic and critical level of probability p are shown in Figure 4.

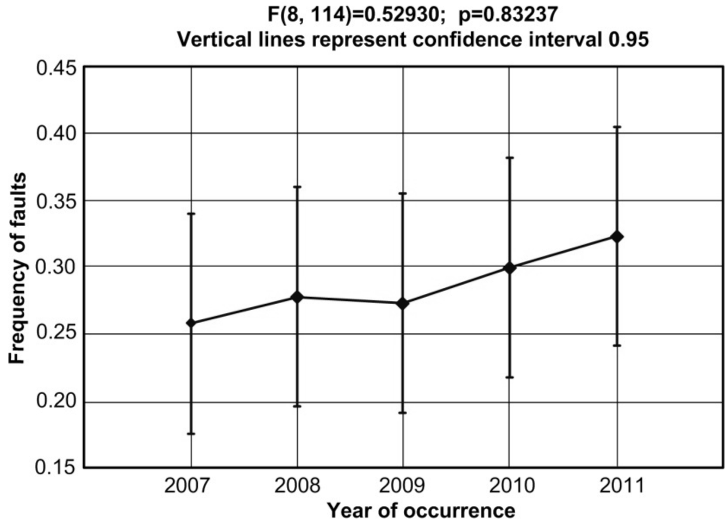

Fig. 4. ANOVA for the variable frequency of faults against the independent variable year of occurrence

At the significance level $\alpha = 0.05$ there are no grounds to reject the null hypothesis on the equality of means, therefore the variable year of occurrence does not differentiate the frequency of faults.

A test for the variable number of faults for two types of vessels:

H_0: $m_1 = m_2$, against an alternative hypothesis,

H_1: $m_1 \neq m_2$.

The value of testing statistic and critical level of probability p are shown in Figure 5.

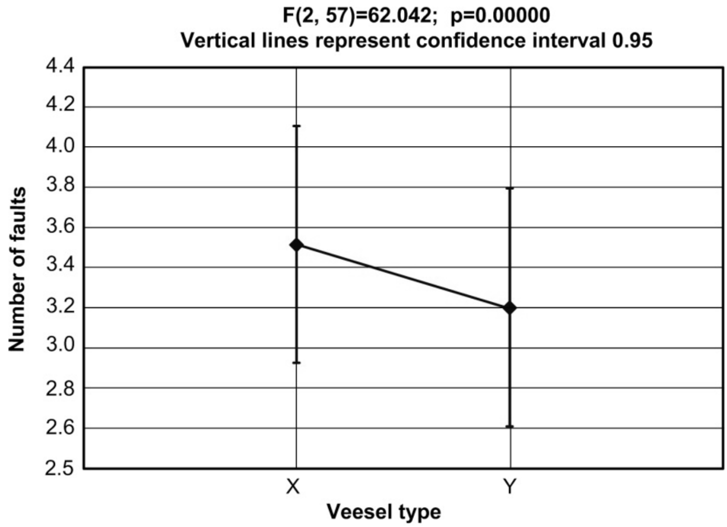

Fig. 5. ANOVA for the variable number of faults against the vessel type

At the significance level $\alpha = 0.05$ we reject the null hypothesis on the equality of means, which is interpreted as follows: variable vessel type differentiates the number of faults, and it can be observed that more faults occur on vessels X.

A test for the variable frequency of faults for two types of vessels:

H_0: $m_{c1} = m_{c2}$, against an alternative hypothesis,

H_1: $m_{c1} \neq m_{c2}$.

The value of testing statistic and critical level of probability p are shown in Figure 6.

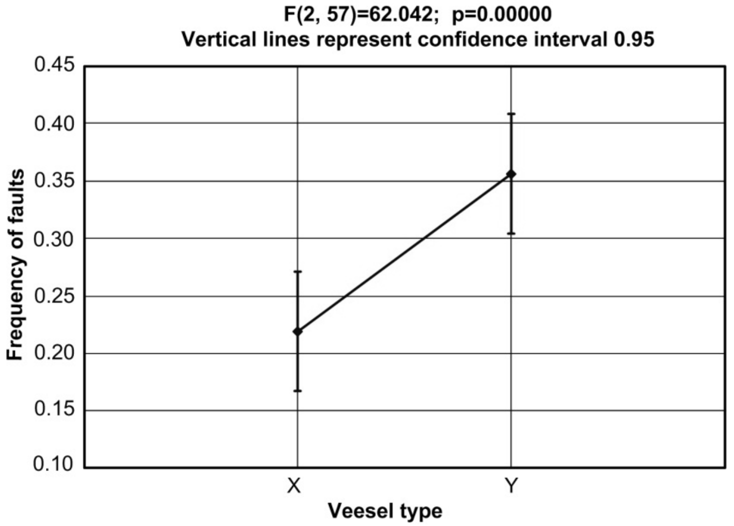

Fig. 6. ANOVA for the variable frequency of faults against the vessel type

At the significance level $\alpha = 0.05$ we reject the null hypothesis on the equality of means, which is interpreted as follows: variable vessel type differentiates the frequency of faults, and it can be observed that faults occur more frequently on vessels Y.

3. SUMMARY AND CONCLUSIONS

The method described in the article, used for the determination of the probability of fault occurrence in refrigerating systems, allows to characterize the operation of such systems quickly and objectively, and to define interrelations between specific decision groups. The ANOVA analysis has confirmed that the variable 'fault frequency' does not depend on the year of occurrence, which means each year the number of faults was similar. It does depend, however, on the category of fault depending, in turn, on the vessel type X and Y. Additionally, the analysis has indicated that the number of refrigerating system faults in fishing vessels does not depend on a year of occurrence but it depends on the category of faults and the type of vessel, which in this case is related to the kind of refrigerant used. The results of variance analysis directly affects damage terming, which translates into market value and higher demand on the fish market

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ANALIZA WARIANCJI USZKODZEŃ SYSTEMÓW CHŁODNICZYCH JEDNOSTEK RYBACKICH

Streszczenie

W pracy zastosowano jednoczynnikową analizę wariancji do sprawdzenia założenia, czy zmienne niezależne różnicują zmienne dotyczące liczby uszkodzeń oraz częstości uszkodzeń systemów chłodniczych jednostek rybackich. Metoda ta wyjaśnia, z jakim prawdopodobieństwem wyodrębnione czynniki mogą być powodem różnic między obserwowanymi średnimi grupowymi. Czynnikiem klasyfikującym wykorzystanym w tej analizie były: rok, kategoria uszkodzenia oraz rodzaj kutra. Badano hipotezy, że średnie liczby uszkodzeń lub średnie częstości uszkodzeń są równe w poszczegól-

nych grupach zmiennej niezależnej. Przyjęto podział uszkodzeń elementów systemów chłodniczych na siedem głównych kategorii i przeprowadzono analizę na podstawie danych zgromadzonych w latach 2007–2011. Zebrano i oszacowano 235 uszkodzeń systemów chłodniczych z 25 kutrów polskiej floty rybackiej z terenów kraju. Analizie poddano dwa typy kutrów, uwzględniając za kryterium podziału rodzaj czynnika chłodniczego.

Słowa kluczowe: *analiza wariancji, systemy chłodnicze, uszkodzenia, flota rybacka, kutry.*