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APPLICATION OF STATISTICAL METHODS IN FORECASTING FOR SPARE ELEMENTS DEMAND

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Abstract: *The problem of predicting the demand for spare elements is extremely important for continuous operation of machines. It is necessary to know when and how much to order. To calculate and ensure the availability of spare elements, appropriate mathematical models should be applied. The statistical method for predicting spare elements demand is considered in this paper. The study shows how to use a demand forecasting technique for determining the expected number of spare elements. Some of the results are given by engineering software.*

Key words: *statistical calculations, spare elements.*

I. Introduction.

The maintenance of exploitation reliability of the machines requires conducting of technical diagnosis, prevention and repair work in order to restore the efficiency. Conducting an effective and timely repair work is only possible when the proper nomenclature and quantity of spare elements are available. It's a fact that the basic reliable parameter of the machines is the intensity of failures flow [2]. The process of failure appearance which is a function of the machine flawlessness, from the point of view of the inventory management theory can be presented as a process of searching spare elements. Because the spare elements are a specific kind of spare inventory, the process of searching for them is being characterized with some specific traits such as: the intervals of time between two consecutive moments of searching for spare elements are random; the searched for quantity of the corresponding nomenclature spare elements is a random value; the intervals of the supply time are a function of random values, etc.

Usually, when the parameters of the search process of spare elements are defined, the results from the machine reliability tests are being used. Since these tests are conducted in laboratories, it is not always possible to consider the influence of every exploitation factor on the machine flawlessness. This is the reason why if the variability law of changes in the demand for spare elements for a certain machine is not known in advance, the provision of the necessary nomenclature and quantity can be done by means of statistical methods of the search prognosis.

II. Statistical modeling of the search for spare elements.

The prognosis procedure includes several stages. During the first one the data for the demand for spare elements with similar characteristics in the past is processed and the reliability of the gathered information is being evaluated. During the second stage the proper mathematical model is being selected considering the demand for spare elements of similar machines and on the basis of analysis from the point of view of the reliability theory and having in mind the processed a priori statistical information. The last stage includes evaluating the parameters of the selected mathematical model.

On the basis of the method of the least squares, and by using the program product MATLAB [6], a method is developed for the search prognosis of the spare elements which are necessary to exchange the failed elements as a result of mechanical wearing.

The variable values are the quantity of spare elements *R* and the intensity *U* with which the elements are worn out. They are statistically interrelated.

Data base with volume *n* is examined. The results from the experiment (u_i, r_{ij}) are described where $i=1, 2, 3, \ldots, n$ and $j=1, 2, 3, \ldots, m$ in points of a Decartes' coordinate system and the graphic form of systematization of statistical data (correlation field) is received. On the basis of the volume *n* of the statistical data sample, the function of the model should be evaluated and the mathematical expectation of the variable *R*. In order to evaluate the function of the model, an approximate empirical function is being used which is close to the unknown model by means of a selected criteria.

To select the class of the empirical functions which describe the process of searching the spare elements, it is necessary to perform the following activities:

1) analysis of the experiment and the research connected with the problem;

2) evaluation of the coordinates of the statistical results from the measuring in the correlation field;

3) analysis of the results (u_i, r_{ij}) considering the specific conditions.

Considering the accumulated experience and the character of the wearing process, the mathematical modeling of the search for spare elements by means of functions of a higher order is considerably more realistic in comparison with the linear approximation. On the basis of experience and expert analysis [1, 3, 7, 8] a polynomial of the kind was selected:

$$R_u = a.e^{bu} + c.e^{du} \quad . \qquad (1)$$

To find the coefficients of the polynomial, a system of four regular linear equations is created:

(2)

$$\begin{cases}\sum_i^n u_i \ln r_i = \ln a \sum_i^n u_i + \ln b \sum_i^n u_i^2 + \ln c \sum_i^n u_i + \ln d \sum_i^n u_i^2 \\ \sum_i^n u_i^2 \ln r_i = \ln a \sum_i^n u_i^2 + \ln b \sum_i^n u_i^3 + \ln c \sum_i^n u_i^4 + \ln d \sum_i^n u_i^3 \\ \sum_i^n u_i^3 \ln r_i = \ln a \sum_i^n u_i^3 + \ln b \sum_i^n u_i^4 + \ln c \sum_i^n u_i^3 + \ln d \sum_i^n u_i^4 \\ \sum_i^n u_i^4 \ln r_i = \ln a \sum_i^n u_i^4 + \ln b \sum_i^n u_i^5 + \ln c \sum_i^n u_i^4 + \ln d \sum_i^n u_i^5 \end{cases}$$

These systems are always defined and incompatible and they allow finding the polynomial coefficients.

After the coefficient evaluations are defined, a statistical analysis should be done on the equation. Procedures to check hypotheses, such as the hypothesis test for equation adequacy, hypothesis test of the equation coefficients significance, defining the confidence intervals, etc. are being performed [5]. To receive precise results and to decrease the time of the problem solution, the following procedures are performed by “Statistics Toolbox” of “Matlab”:

- Definition of the sum of the squares of the deviation of every r_{ij} from the predicted $\hat{r}_u$

(3) $$g_{ij} = \sum_{j=1}^{n} \left(u_{ij} - \hat{u}_r\right)^2 ,$$

Evaluation of the residual dispersion

(4) $$s_R^2 = \frac{1}{n-(k+1)} \sum_{j=1}^{n} \left(u_{ij} - \hat{u}_r\right)^2 ,$$

where: $k+1$ is the coefficient number of the model.

The closer to zero values of g_{ij} show a better approximation of the model.

Defining the sum of the squares of the deviations of the mean values for the groups $\overline{u_i}$ from the total value $\hat{u}_r$

(5) $$w_{ij} = \sum_{j=1}^{n} \left(\hat{u}_r - \bar{u}_i\right)^2$$

where $\bar{u}_i = \frac{1}{n} \sum_j^n u_{ij}$,

dispersion evaluation by the factors

(6) $$s_A^2 = \frac{1}{k-1} \sum_{j=1}^{n} \left(\hat{u}_r - \bar{u}_i\right)^2 .$$

Defining the squares sum by the deviation of their mean value

(7) $$h_{ij} = \sum_{j=1}^{n} \left(u_{ij} - \bar{u}_i\right)^2 ,$$

The total dispersion evaluation

(8) $$s_T{}^2 = \frac{1}{kn-1} \sum_{j=1}^{n} \left(u_{ij} - \bar{u}_i\right)^2 .$$

Evaluation of the approximation extent of the data variables by means of the correlation square N^2 .

N^2 can be defined as a relation of the squares sum of the deviations of every measurement from the predicted value and the total sum of the squares of all the measurements.

It is known that the total sum of the squares of the differences from all the data is equal to the sum of the squares and the residuals [4]

Then N^2 is

(9)

$$N_{\text{square}} = N^2 = \frac{\sum_{j=1}^{n}\left(\hat{u}_r - \bar{u}_i\right)^2}{\sum_{j=1}^{n}\left(u_{ij} - \bar{u}_i\right)^2} = 1 - \frac{\sum_{j=1}^{n}\left(u_{ij} - \hat{u}_r\right)^2}{\sum_{j=1}^{n}\left(u_{ij} - \bar{u}_i\right)^2}$$

.

N^2 can have values only in the interval from 0 to 1. The closer the value is to 1, the better approximation with the selected empirical equation.

Defining the degrees of freedom of the “residuals” (u_{ij} - $\hat{u}_r$),

(10) $$D=n-k,$$

where: n – levels of the factor;

k – the coefficient number in the model equation.

The adjusted correlation coefficient is:

(11)

$$adjusted\ N_{square} = \frac{n-1}{k-1}\frac{\sum_{j=1}^{n}\left(\hat{u}_r - \bar{u}_i\right)^2}{\sum_{j=1}^{n}\left(u_{ij} - \bar{u}_i\right)^2} =$$

$$= 1 - \frac{n-1}{n-k}\cdot\frac{\sum_{j=1}^{n}\left(u_{ij} - \hat{u}_r\right)}{\sum_{j=1}^{n}\left(u_{ij} - \bar{u}_i\right)^2}.$$

It can have every value which is smaller or equal to 1 and the closer these values are to one, the greater is the parity of the chosen model with the results.

Calculation of the statistical mean squared error

(12) $$M_{se} = \frac{1}{n-k}\sum_{j=1}^{n}\left(u_{ij} - \hat{u}_r\right)^2.$$

It’s obvious that when the values of the standard error are closer to zero, the results from the model are closer to the experimental ones.

Calculation of the confidence intervals for the significance coefficients

$$b_j - t_K s_b\left(b_j\right) < C < b_j + t_K s_b\left(b_j\right)$$

where: t_k is a statistics which has the Stundent’s distribution [5];

s_b – characteristics of the coefficient dispersion [4].

Depending on the accepted significance level, the size of the confidence interval is defined.

Part of the experimental data is presented on fig. 1.

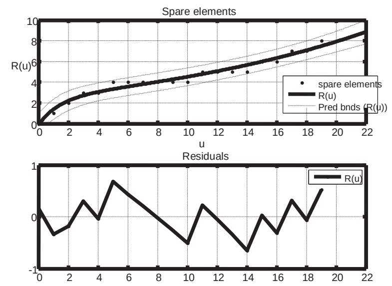

Fig. 1.

The used method for forecasting the quantity of spare elements with the calculation by means of a program product creates opportunities to elect a proper mathematical model in the search process in the conditions of limited statistical information. Using similar kind of method leads to decreasing the time for managing the statistical data and a better economic effect with the inventory management.

References:

1. Rizhikov Yu. I. Manual of designing tailed systems, Military engineering and space team, A.F. Mozhayskii ,M, 1995
2. Rizhikov Yu. I. Inventory Management – K.; Science, 1999.
3. Zipkin, P.H., Foundations of Inventory Management, McGraw Hill, New York, 2000.
4. Thomas Hill, Paul Lewicki. Statistics: Methods and Applications. ISBN-13: 9781884233593. StatSoft, Inc. Tulsa. 2006.
5. Jun Shao. Mathematical statistics – 2 end ed. Springer, ISBN 0387-95382-5. Madison. 2012.

Web sites:

6. http://matlabdb.mathematik.unistuttgart.de/download.jsp?MC_ID=8&SC_ID=12&MP_ID=112
7. Murray, Wiseman (2008) “Optimal Maintenance Decisions Inc.: Asset Reliability.
8. Workshps.http://www.omdec.com/wiki/tiki-index.Php?page=Workshop