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SOME CONSIDERATIONS CONCERNING THE VIBRATION LEVEL AT ELECTRIC MOTORS

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Abstract: In the paper, it is effected the evaluation of electric motors, from the point of view of vibration level, by determining the effective value of vibration velocity, in accordance to the recommendations of Romanian and international standards. The vibration measurements have been effected at the "Electromotor" Company of Timişoara, on electric asynchronous motors. The aim of measurements was to establish a selection criterion for the motors, in two categories, "good" and "faulty", on the basis of admissible vibration level. As mathematical apparatus, it was applied the statistic calculus.

1. INTRODUCTION

The evaluation of electric motors, from the point of view of vibration level, is made by determining the effective value of vibration velocity, in accordance to the recommendations from [1] and [2].

The vibration measurements have been effected at the "Electromotor" Company of Timişoara, on electric asynchronous motors, with the main technical specifications as follows:

- nominal power: 22 kW;
- synchronism number of rotations: 1000 rot/min;
- height of shaft axis: 200 mm.

The chosen points for the measurement of vibration characteristic quantities are noted as follows (figure 1):

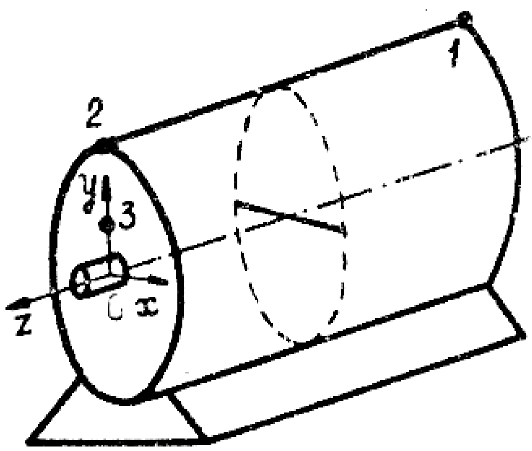

Fig.* 1. *Location of vibration measure points

- *1* – on the bearing plate, in *Oy* direction, at the side where the cooling fan is mounted;
- *2* - on the bearing plate, in *Oy* direction, at the opposite side to the point *1*;
- 3 - on the bearing plate, in *Oz* direction, at the same side as the point *2*.

The aim of measurements was to establish a selection criterion for the motors, in two categories, “good” and “faulty”, on the basis of admissible vibration level. The experimental determinations were effected on 53 motors, using vibration measurement equipment, type *SIM 132*, equipped with an octave filter, type *OF 101* and a piezoelectric transducer, type *KD 12*, manufactured by R.F.T. Company (Germany).

The first problem which was approached has been to appreciate the characteristic distribution of the population of samples (motors), randomly extracted from the current production of motors.

By the calculus method [1] and by drawing the frequency histograms, it was remarked that the distribution of measured vibration velocities, approximates the Gauss curve. To exemplify, it is presented the histogram of absolute, relative and cumulated frequencies for the vibration velocities (figure 2).

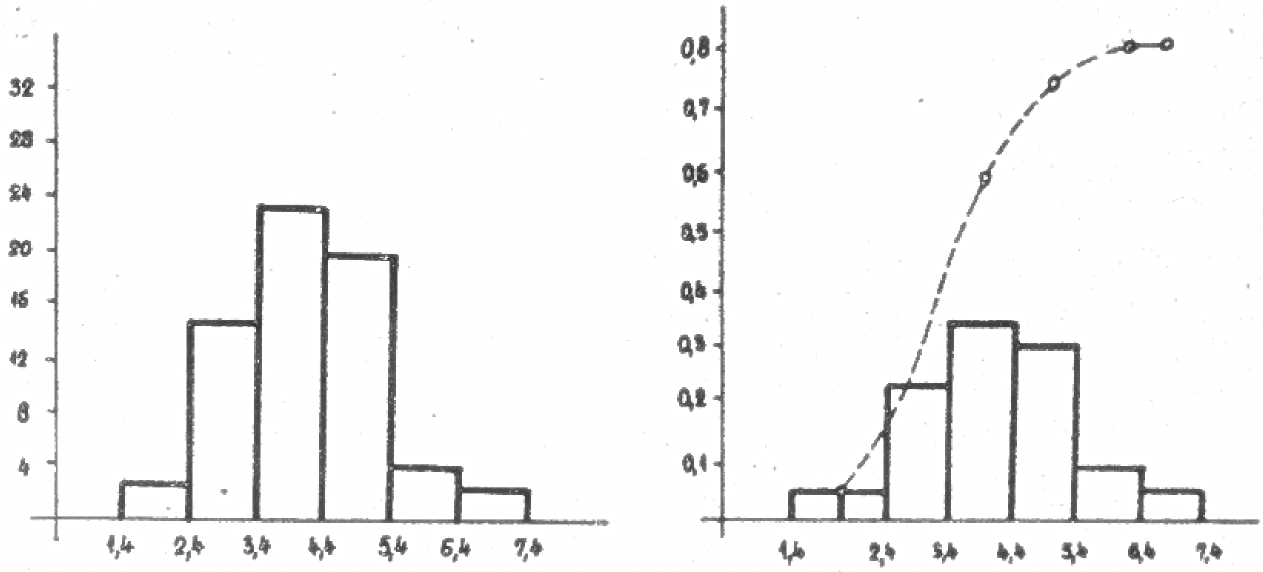

***Fig.* 2. Frequency histogram for vibration velocities**

Because the measurement results follow a normal law of distribution, it can be applied the method of statistic calculus, characteristic to this distribution.

2. STATISTIC CALCULUS

From the statistic point of view, to interpret the obtained experimental results, means to satisfy the following desires [3], [4]:

- considering all obtained data, experimentally obtained and also, by bibliographic information;
- limiting the conclusions only to the strictly deduced data;
- conclusions must have technical meaning and statistic signification;
- estimating of imposed limits, concerning the used methods.

The results, obtained by vibration measurements were processed by framing them in a statistic plan, without blocks.

The electric motors, being practically identical, the experimental data are homogenous, so that they must not be separated in blocks; that is why it was adopted the data processing in a statistic plan, without blocks.

Because the measurements were effected in three measure points for each motor, each measure point is considered as a 'treatment", so that, in the conceived statistic plans, the results are arranged in 3 series, appertaining to the 3 mentioned treatments.

In the hypothesis of the statistic plan, without blocks, the experimental data are arranged, generally, under the table form, presented in table 1.

Table 1

	Treatments - j									
	1	2	.	.	.	j	.	.	.	k
Observations - i	Y_{11}	Y_{21}	.	.	.	Y_{j1}	.	.	.	Y_{k1}
	Y_{12}	Y_{22}	.	.	.	Y_{j2}	.	.	.	Y_{k2}
	.	.	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.
	Y_{1i}	Y_{2i}	.	.	.	Y_{ji}	.	.	.	Y_{ki}
	.	.	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.
	Y_{1n_1}	Y_{2n_2}	.	.	.	Y_{jn_j}	.	.	.	Y_{kn_k}
Total	T_1	T_2	.	.	.	T_j	.	.	.	T_k
Number of observations	n_1	n_2	.	.	.	n_j	.	.	.	n_k
Averages	Y_1	Y_2	.	.	.	Y_j	.	.	.	Y_k

To test the treatment signification, at calculus it is used the F statistic criterion, and the appreciation of component for test is made on the basis of calculus of following quantities:

- $T = \sum_{j=1}^{k} T_j$ - sum of all experimental observations;
- $n = \sum_{j=1}^{k} n_j$ - number of all experimental observations;
- $Y = \frac{T}{n}$ - arithmetic average of all experimental observations;
- $T_{YY} = \sum_{j=1}^{k} n_j(\overline{Y}_j - \overline{Y})^2$ - sum of squared deviations of treatment averages, in relation to the general average, with taking into account the number of observations, on each treatment; if it is introduced the quantity $M_{YY} = \frac{T^2}{n}$, than

$$T_{YY} = \sum_{j=1}^{k} \frac{T_j^2}{n_j} - M_{YY}; \quad (1)$$

- $\sum Y^2 = \sum_{j=1}^{k}\sum_{i=1}^{n_j} Y_{ji}^2$ - sum of squared observations;
- $E_{YY} = \sum_{j=1}^{k}\sum_{i=1}^{n}(Y_{ji} - Y_j)^2 = Y^2 - M_{YY} - T_{YY}$ - sum of squared deviations of experimental units, in relation to the average on treatment.

With the obtained quantities, it is drawing up the table of variant analysis (table 2), which also contains the necessary components for the testing of treatment signification.

Table 2

Degrees of freedom	Sum of squares	Components for testing
1	M_{YY}	M
$k-1$	T_{YY}	T
n_j-1	E_{YY}	E
n	Y^2	

The components for testing are obtained by the ratio between the quantities in the column "Sum of squares" and the quantities in the column "Degrees of freedom":

$$M = \frac{M_{YY}}{1}, \quad (2)$$

$$T = \frac{T_{YY}}{k-1}, \quad (3)$$

$$E = \frac{E_{YY}}{\sum_{j=1}^{k}(n_j - 1)}. \quad (4)$$

If it is tested the signification of the *k* treatments, it is formed the ratio

$$F^* = \frac{T}{E}, \quad (5)$$

which is compared to the value $F\left\{1-\alpha, k-1, \sum_{j=1}^{k}(n_j - 1)\right\}$, representing the *F* distribution function (under tabular form), used as statistic criterion.

The quantity α represents the assumed risk to reject a true hypothesis and, usually, the interval 0.1-0.01 is chosen.

If $F^* \geq F$, the calculus conclusion is that the treatments are significantly different between them.

In the case when the treatments are significantly different between them, it is important to find the limits between the average effect of each treatment varies. With this aim, it is calculated the quantity $\sqrt{\frac{E}{n_j}}$ for each of *k* approached treatments, and the limits of the confidence interval of the average of observations for each treatment is calculated with the relations:

$$\left.\begin{matrix} L_i \\ L_s \end{matrix}\right\} = \overline{Y}_j \mp t\left\{\frac{1+\gamma}{2}, \sum_{j=1}^{k}(n_j - 1)\right\}\sqrt{\frac{E}{n_j}}. \quad (6)$$

In the relations (6), t is a quantity, tabular on a “Student” distribution, which also varies in relation to the confidence γ, previously chosen, in relation to the respective experimental conditions. The usual values for the γ confidence are comprises in the interval 0.8-0.95.

In the case when the treatments are not significantly different, the experiment is characterized by the average.

3. STATISTIC RESULTS AND CONCLUSIONS

The above principles of statistic calculus were applied to the measurement results, testing the treatment signification, i. e. watching if the location of measure points $M1$, $M2$, $M3$ introduces differences, concerning the determined vibration level.

The results were separately analyzed for vibration velocities, accelerations and displacements, obtaining the following conclusions:

- a) the F statistic criterion has the value $F\{0.99;2;90\} = 4.85$ (for $\alpha = 0.01$), for the motors, considered as “good” and the value $F\{0.00;2;63\} = 4.98$ (for $\alpha = 0.01$), for the motors, considered as “faulty”;
- b) the testing of treatment signification was made by the calculus of the F^* quantities, whose values are presented in table 3:

Table 3

Measured quantities	“Good” motors		“Faulty” motors	
	F^*	F	F^*	F
Velocities	1.67	4.85	2.05	4.98
Accelerations	2.54	4.85	4.36	4.98
Displacements	1.29	4.85	11.58	4.98

The analysis of data in table 3 shows that, at the “good” motors, the position of measure point does not introduce significant differences in the measurement results, because always $F^* \prec F$.

At the “faulty” motors, the conclusions remain valid for the measurements of vibration velocities and accelerations, but concerning the displacement measurements, the location of measure points is not indifferent. The difference of treatment signification, in this case is evident ($11.52 \succ\succ 4.98$).

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