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A STATISTIC INTERPRETATION ABOUT THE RESULTS OF FATIGUE TESTING OF WIRES

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ABSTRACT

The present paper deals with some graphical analysis concerning the life-time of wires under fatigue loading conditions. Results have been obtained on the Nădăşan-Boleanţu fatigue testing machine and then statistically studied by considering both a normal (gaussian) and a Weibull life-time distribution. A sophisticated mathematical apparatus has been converted into a graphical solution in order to estimate some important values of the life-time of wires.

KEYWORDS:
life-time distribution, fatigue tests, contact compression stress.

1. INTRODUCTION

It is a important to know the fatigue resistance of wires both when it comes to wire ropes and when we are dealing with fore-compressed concrete. In the case of wires belonging to a wire rope, it is enough to know the fatigue resistance for 10^6 basic cycles, as the wire rope is considered as a resistance element with limited hardness, due to its specific exploitation.

Wire fatigue tests lead to results characterized by a wide degree of dispersion. In order to have a statistical analysis of the results, we can apply the results obtained in the general study of the fatigue phenomenon, using standard test rods. One specific element of this statistic processing of data is the clear difference between the domain of higher strains and that of lower ones, which are close to the fatigue resistance value.

In the field of high strains, we determined [2] that the statistical distribution of logarithm hardness is of Gauss-Laplace type. The experiments have been carried out on a Nădăşan-Boleanţu machine (NB) for fatigue testing of wires with contact pressure [2], machine which exists in the Laboratory of Resistance of Materials, at the Faculty of Mechanics of Timişoara.

Fig. 1 gives the variation of wire hardness for samples having the diameter D = 40 mm and D = 90 mm, untrained (curves 1 and 3) and tensioned (curves 2 and 4), depending on the maximal contact compression stress σ_{cmax}, which depends on several factors.

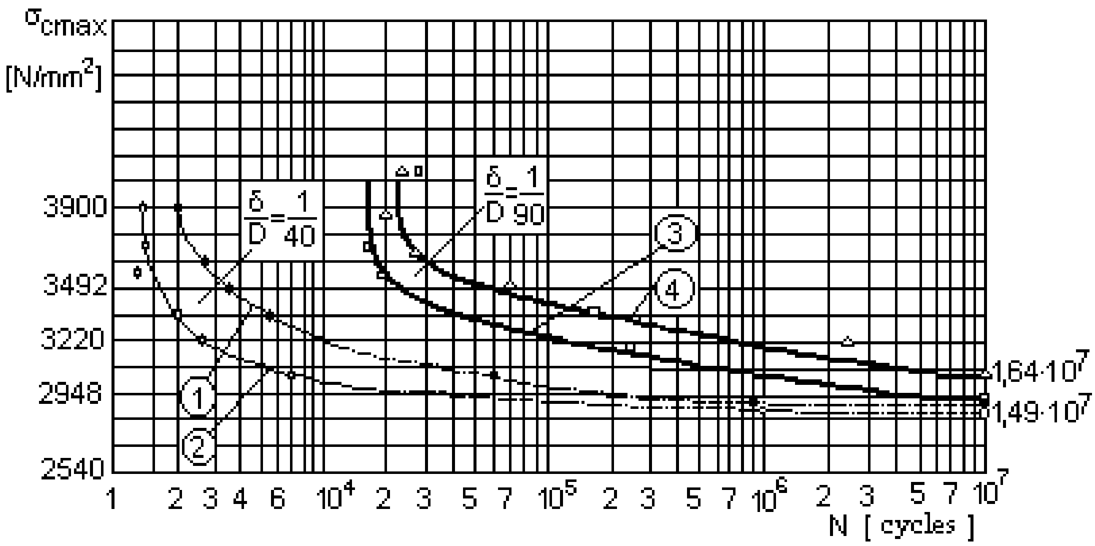

FIGURE 1. THE RESULTS OF WIRES FATIGUE TESTING ON NB MACHINE

2. THE STATISTICAL ANALYSIS OF THE RESULTS OBTAINED IN CONTACT FATIGUE TESTING

Considering a population of elements that are subjected to contact fatigue, the elements being identical in terms of material, manufacturing technology and exploitation conditions, the individual hardness of each of these elements will be different and randomly distributed. The selections are lots of test rods, which characterize a certain type of parts, subjected to fatigue testing. In making the selections, two precautions should be taken into consideration:

- the preparation of the test rods (thermal treatment, cutting) should be similar, in order to avoid the differences that may increase the dispersion of results.
- by a proper grouping the test rods according to selections, the influence of factors that escape a strict control will be eliminated (position of test rods in the oven, the wear of the cutting machines).

The determination of selected parameters by statistical methods, for a constant contact pressure, implies finding a theoretical distribution that should best emulate the experimental results. The reference literature points out to two situations, whose calculation algorithm has been standardized by L.G. Johnson [3]: the case of hardness distributed according to the log-normal law and that of hardness distributed according to Weibull law.

2.1. STATISTIC PROCESSING OF THE RESULTS OF TESTS, ACCORDING TO THE LOG-NORMAL LAW

On the basis of the results of wires fatigue testing on NB machine we are making two selections with data distribution according to the log-normal law: the first has 14 wire rods corresponding to the ratio $\frac{\delta}{D}=\frac{1}{40}$ (curves 1 and 2 of the diagram given in figure 1) and the second has 9 wire rods corresponding to the ratio $\frac{\delta}{D}=\frac{1}{90}$ (curves 3 and 4 in figure 1).

For the first selection we represented in Fig.2 and Fig.3 the life-time of wires in function of the contact compression stress in a double-logarithm axes system. The graphically representation is a plotter one and to line up the experimental points it is necessary to suppress usually the minimum value of the experimental obtained life-time.

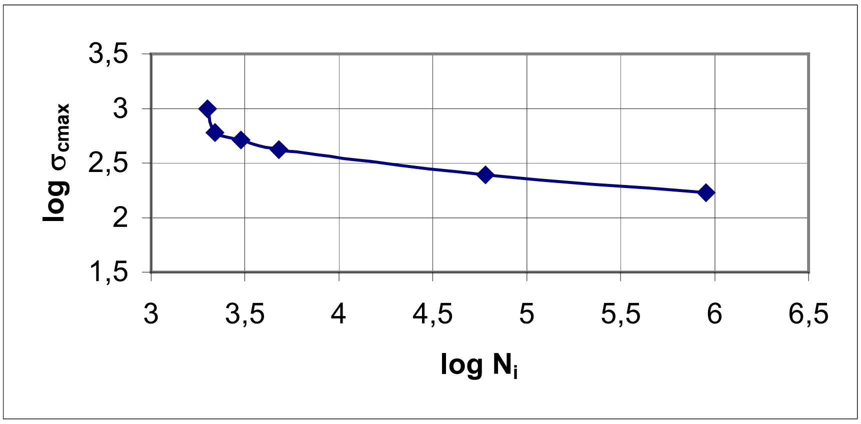

FIGURE 2. THE LIFE-TIME VARIATION IN FUNCTION OF THE NORMAL CONTACT STRESS FOR 6 WIRE RODS FROM THE FIRST SELECTION

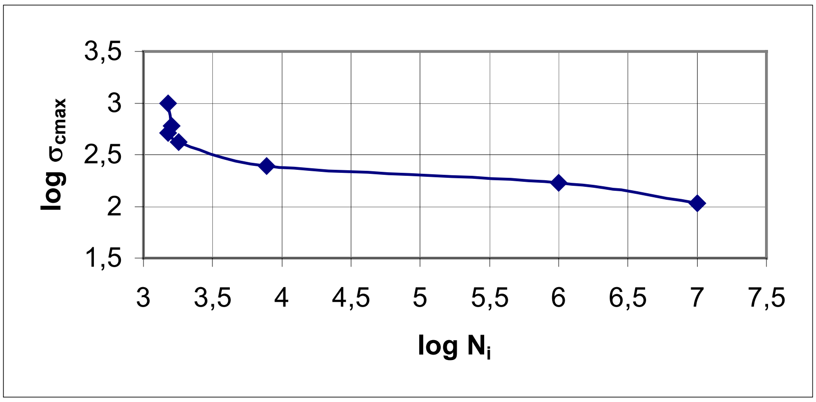

FIGURE 3. THE LIFE-TIME VARIATION IN FUNCTION OF THE NORMAL CONTACT STRESS FOR 7 WIRE RODS FROM THE FIRST SELECTION

The same we proceeded for the second selection and we represented in Fig.4 and Fig.5 the life-time of wires in function of the contact compression stress in a double-logarithm axes system. To line up the plot representation from Fig.4 it was necessary to suppress the maximum of the experimentally obtained life-time value.

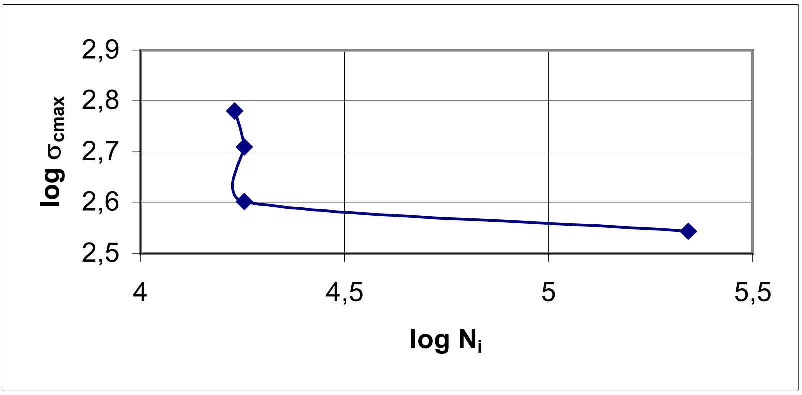

FIGURE 4. THE LIFE-TIME VARIATION IN FUNCTION OF THE NORMAL CONTACT STRESS FOR 4 WIRE RODS FROM THE SECOND SELECTION

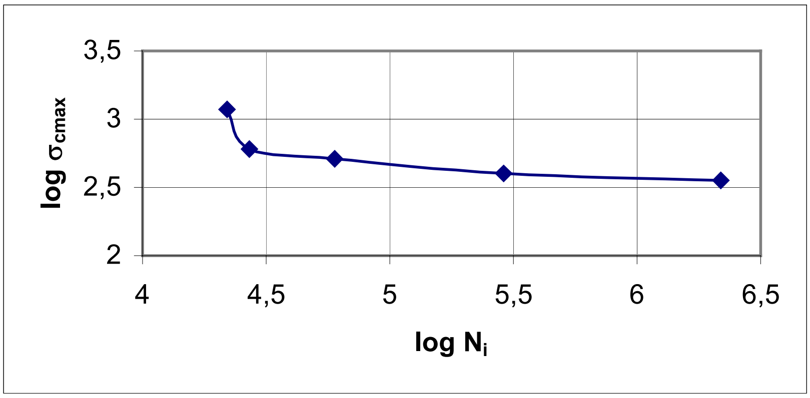

FIGURE 5. THE LIFE-TIME VARIATION IN FUNCTION OF THE NORMAL CONTACT STRESS FOR 5 WIRE RODS FROM THE SECOND SELECTION

The parameters of the selection are graphically or analytically determined by drawing the empirical distribution curve, their determination order being the following:

- The hardness of the selection extracted from the test files is increasingly ordered and, according to the number of order assigned to each hardness, we calculate the median destruction probability by means of Blom's relation [1]:

$$p_i = \frac{i - 0,3}{n + 4} \tag{1}$$

where: i – the number of order;
n – the number of test rods tested for one selection.

- We estimated the value of the log-normal distribution function of hardness and we represented the points determined by the values (p_i– log N_i) for a log-normal distribution network. The normal distribution is a limit law towards which the other distribution laws tend, and which observes a Gauss-type distribution around one distribution center.
- We estimated the value N_0 in order to line up the experimental points p_i–log[N_i-N_0] coordinates. We usually choose value N_0 as the smallest value experimentally obtained.

- The parameters of the distribution line are calculated by means of the relations:

$$\alpha = \frac{\sum_i \log[N_i - N_0]}{n} \qquad \beta = \frac{\sum_i Z_i \log[N_i - N_0]}{\sum_i Z_i^2} \tag{2}$$

where: Z_i –the value of the normed variable of the normal distribution function for probability pi, obtained from tables of statistics.

- The hardness values N_{10} and N_{50} are analytically obtained by means of the relation

$$\log[N_i - N_0] = \alpha + \beta z_p, \tag{3}$$

or graphically in Fig.6.

N_{10} is the hardness attained or surpassed by 90 % of the elements, and N_{50} is the hardness surpassed or attained by 50 % of the elements.

After the lining up of the distribution line (Fig.6) of the experimental results for tests on the first selection we obtained the value: N_0=1500 cycles. The results obtained by an analytical calculus are shown in Table1.

After the lining up of the distribution line (Fig.7) of the experimental results for tests on the second selection we obtained the value: N_0=17000 cycles. The results obtained by an analytical calculus are shown in Table2.

TABLE 1

p_i = 50%	N_i -N_0 =2,45.10^9 cycles	log(N_i -N_0) = 9,39	N_{50} = 2,454.10^9 cycles
p_i =10%	N_i -N_0 =156,675 cycles	log (N_i-N_0)=2,19	N_{10} = 1650 cycles

TABLE 2

p_i = 50%	N_i -N_0 = 7,58.10^6 cycles	log(N_i -N_0) = 6,88	N_{50} = 7,6.10^6 cycles
p_i =10%	N_i -N_0 =39,81 cycles	log (N_i-N_0)=1,66	N_{10} = 17300 cycles

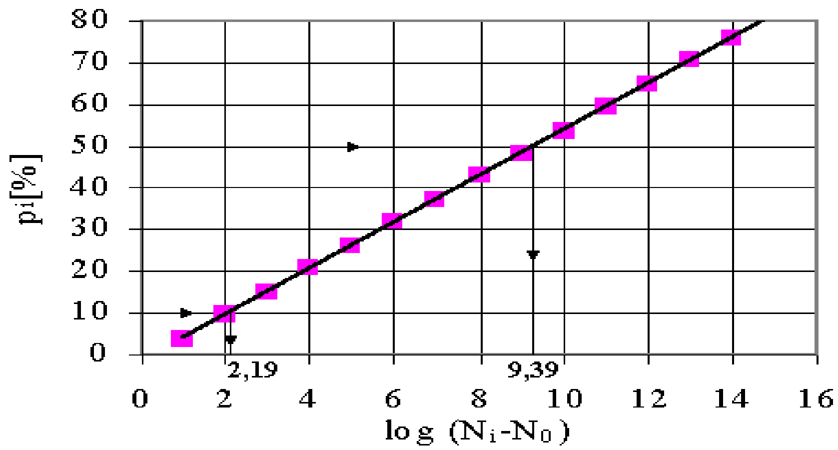

FIGURE 6. THE LINING UP OF THE DISTRIBUTION LINE OF THE EXPERIMENTAL RESULTS FOR $\frac{\delta}{D} = \frac{1}{40}$

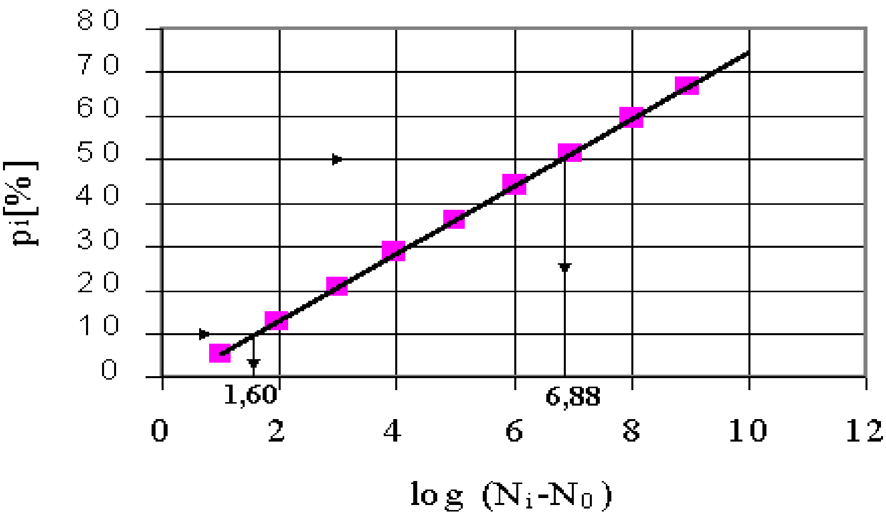

FIGURE 7. THE LINING UP OF THE DISTRIBUTION LINE OF THE EXPERIMENTAL RESULTS FOR $\frac{\delta}{D} = \frac{1}{90}$

3. CONCLUSIONS

The analysis of the contact fatigue problems needs special test machines, work conditions and specific norms meant to check quality, as well as statistic methods for the interpretation of the results.

This is where the personal contribution of the authors lies, as they uses a complicated mathematical apparatus, turned into graphical solution that allows hardness estimation for wires, making up wire ropes. The values of hardness obtained by calculation or graphically is ranking within the usual limits given in reference literature.

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