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Statistical Analysis of the Results of Surface Treatment with Optical Pulses Applied to Parts of Metallic Powders

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Within a wide range of theoretical and experimental research, the possibility of realizing a new method of superficial treatment of materials made of metallic powders and the validation of the results obtained after the treatments were carried out with gas discharge lamps. The structural transformations carried out in the superficial layer of the pieces made of metal powders used in the experiments led to a statistical analysis of the results obtained in this article. Thus, with the TREND statistical function of Excel program, the evolution of the changes in roughness was determined, depending on the variable parameters of the treatment process. The verification was performed with the ZTEST function by making assumptions about the average values of selection reported against the critical value of the test. The results were interpreted on the basis of the phenomena and processes that occur at superficial level at the interaction of the radiation with the non-homogeneous layer specific to the pieces made by the aggregation of powders, consisting of granules and pores. The conclusions recommend the optimal treatment regimes in order to obtain the maximum efficiency of the action of the optical radiation pulses emitted by the gas discharge lamps on the surface of the metal powders.

Keywords: *superficial treatments, metal powders, gas discharge lamps, TREND statistical function, ZTEST statistical function.*

1. Introduction

The approach taken during the research program required intensive studies and theoretical analyses, the interpretation of the phenomena occurring in the superficial metal layer at the interaction with electromagnetic fields, the identification of energy sources, the study of their behavior during the treatment operations, the realization of a surface treatment installation, the performance of the experimental operations, the determination of the results and the shaping of the behavior of the treated parts for different working regimes [1, 2, 3, 4, 5].

To this end, it was necessary to statistically process the data obtained in order to identify the evolution of roughness of other possible electro-technical working regimes, which were not applied within the experimental program [6].

The roughness measurements were performed with specific apparatus, the electron beam scanning microscope, the results being highlighted by metallographic images and certified analysis bulletins [7].

2. Working method

The statistical and mathematical processing of the data resulting from the experimental research of the influence of the radiant energy, emitted by the lamps with discharge in xenon, on the roughness of the parts sintered of the metal powders, will be performed with the Excel program, using the TREND and ZTEST statistical functions [8].

The TREND function estimates the evolution of the output parameters of the process, using the method of the smallest squares, and the ZTEST function allows the appreciation of the continuation of the experimental research in the respective direction.

The functions defined in mathematics express a connection between different phenomena. The $y = f(t)$ relation denotes the fact that for each t of the function definition interval there results a well determined value of y.

If an experience is achieved and the correspondence between the values of y is measured, an empirical function is obtained, where deviations from the calculated values occur due to the fact that an experience cannot be done in perfect conditions.

Thus, the experiences generally lead to empirical functions. The empirical function can be the approximate representation of a theoretical function defined in a mathematical way.

The definition of stochastic laws is made using the notion of probability. An example of a stochastic distribution is represented by the normal, binomial distribution, etc. within the theory of probabilities.

The removal of the irregularities that occur in the empirical distributions due to unknown causes is done by the operation of adjusting the statistical data.

It is assumed that there are *n* points:

$$A_1(t_1, y_1),\ldots, An(t_1, y_n), \quad (1)$$

where t_i $(i = 1, n)$ corresponding to the abscissae, and y_i $(i = 1, n)$ are the values corresponding to the ordinates in the *tOy* rectangular axis system.

Thus, A_i $(i = 1, n)$ can be the elements of a statistical series, the abscises measuring different moments, and the ordinates the frequencies of the phenomenon considered.

The purpose of the adjustment is to find a curve that is closest to the A_i points given and, consequently, it can be admitted that this curve can indicate the direction of development of that phenomenon.
The simplest curve, the right one respectively is taken into consideration. It has the equation:

$$y=a+bt \tag{2}$$

We will determine the unknown *a* and *b* coefficients so that the expression (2) has the minimum value:

$$\sum_{i=1}^{n}(a+bt_i-y_i)^2=\min \tag{3}$$

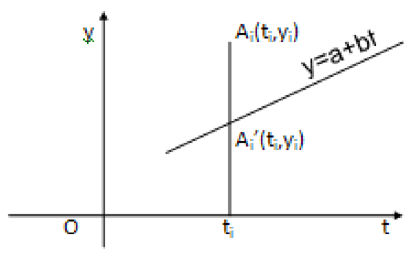

Figure 1. The function graph

From the above figure 1 we can see that *Ai'* is the intersection point of a parallel to *Oy* that crosses the right *y = a + bt*.

Thus the relation (3) becomes:

$$\sum_{i=1}^{n}\overline{A_iA_i'}^2=\min \tag{4}$$

In both situations, the sum of the squares of the differences between the ordinates must be minimal.

Verification of statistical hypotheses

All assumptions are in fact hypotheses whose validity has to be verified and since their verification is achieved statistically, i.e. by working on the observed data obtained in a random selection of a statistical population, they are called statistical hypotheses.

For the present study, the purpose is to verify some hypotheses of the form:

$$H_0:\ \mu \le \bar{x}, \tag{5}$$

since it is desired to check to what extent the average roughness is less than the roughness of the blank sample and, respectively, to what extent the average hardness is greater than the hardness of the blank sample by applying superficial treatment with ultrafast optical radiation pulses.

These assumptions are verified by applying the unilateral *Z* test. In this case, the hypothesis and its alternative are:

$$H_0: \mu \leq \bar{x}, \; H_1: \mu > \bar{x}. \qquad (6)$$

For example, for a significance level of *a = 0.05*, the region between the average value and the critical value is *0.45* and the critical value of the *Z* test is *1.645* (value in the normal law table). In the following figure you can see the regions where the H_0 hypothesis is rejected and the region where it is accepted.

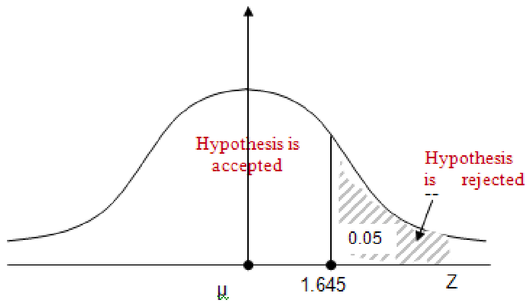

Figure 2. The regions where the H_0 hypothesis is rejected and the region where it is accepted

If *Z > 1.645*, then the H_0 hypothesis is rejected, otherwise it is accepted. In conclusion, it is assumed that there is a sample of n measurements, which is the average of selection, *σ* is the standard deviation of the sample and *μ* is the theoretical average.

Then the value of the *Z* test is:

$$Z = \frac{\bar{x} - \mu}{\sigma / \sqrt{n}} \qquad (7)$$

If this value is smaller than 1.645, then the formulated hypothesis is true.

3. Statistical processing of results

For example, from the whole set of results obtained in the experimental application [6], we have chosen an electrotechnical regime at the upper limit of the safety possibilities of the experimental device, namely the 2.2 kV value of the block loading voltage of capacitors.

The roughness estimation at the 2.2 kV voltage for group VIII of unpainted parts [6] at 800 J is shown in fig. no. 3.

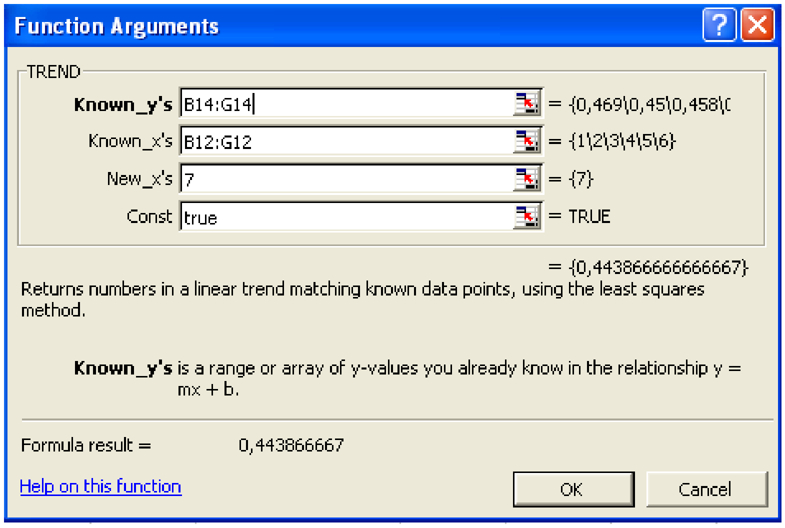

Figure 3. Estimation of roughness at i = 7 pulses for group VIII of parts

It is noted that the optimum value of the roughness is obtained at the second impulse, after which the phenomena are repeated as in the previous case. The combined and repeated action of the effects on the sintered materials is reflected on the powder grains with different mesh orientations and determines a certain homogenization of the surface layer structure, which explains the stabilization of the structure after a certain number of impulses.

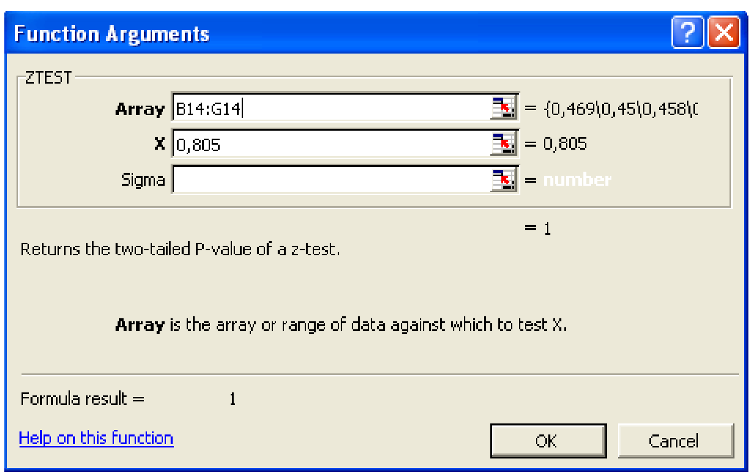

Figure 4. ZTEST Verification of Roughness for Group VII Pieces

The hypothesis <0.805 (blank value) is allowed (given that Z = 1 is greater than 0.5) - fig. no. 4, the average roughness obtained is less than roughness under normal conditions. It is recommended to use this working regime.

4. Conclusion

Estimation of roughness can be appreciated either by varying the charge voltage value of the capacitor block or by increasing the number of impulses applied by the gas discharge lamp.

In both cases, the TREND function leads to the following conclusions:

- With the increase of the voltage applied to the capacitor terminals to over 2.0 kV, there is an improvement of the roughness due to the absorption of a large amount of energy in the superficial layer, which leads to the sudden formation of partial melts and by solidification in a time extremely short is a more rough surface;
- in the increase of the number of impulses, the optimum value of the roughness was obtained at the second impulse, and in a higher number of impulses, the combined and repeated action of the thermal and mechanical effects is reflected on the powder grains with different network orientations which determines a certain homogenization of the superficial layer structure.

The ZTEST function certifies the estimated roughness values and recommends the use of the expected work patterns.

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