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VERIFICATION OF THE RANDOM NATURE OF THE EXPERIMENTAL DATA IN THE END-MILLING PROCESS OF ALUMINUM ALLOYS

From a theoretical point of view, the research carried out in this manuscript was carried out starting from the study of the links between surface roughness and cutting speed, cutting depth and feed per tooth in the end milling process. From an experimental point of view, it started from the organization and development of the physical cutting process, the cutting regimes to be analyzed were established, after which the surface roughness was determined and measured. In this way, the connections between the factors and parameters pursued in the research resulted. The main purpose of this research is to check the random nature of the measured data related to the quality of the end milled surface of the Al7136 aluminum alloy. The main types of statistical processing performed on the sample values from the experimental measurements, the algorithms and the corresponding work modes are according to the method of research that is based on the use of the Young test. The conclusions highlighted the importance of adopting this research method and opened new directions of study.

Keywords: Al7136; end-milling process; surface roughness; Young's test; experiment

1. Introduction

Experimental research involves organizing the development of a phenomenon or process under well-established conditions, eliminating as much as possible the disturbing external influences [1,2]. The general objective is to perform measurements to establish the value or intensity of the physical quantity's characteristic of the phenomenon or process considered [3,4]. By measuring the quantities that characterize them, a series of connections can be deduced between the factors and the laws that govern the phenomenon [5,6]. The value of the results obtained from the research, the cost, and the duration of the research program, depend on the choice of methods, means and techniques of investigation, the organization of the stages of experimentation and the way of processing the results [7,8]. From a theoretical point of view, the research made during this work was carried out starting from the study of the links between different factors and parameters used in the analyzed cutting processes, based on the knowledge provided by the basic sciences. place the evolution of these processes [9,10]. From an experimental point of view, the problems were approached starting from the organization and development of the physical cutting process by cylindrical-front milling. The cutting regimes to be analyzed were established, after which the characteristic quantities were determined and measured, thus resulting in the links between the factors and parameters pursued in the research.

In situations where the determination of the value of a variable in a certain process is sought, when it is desired to eliminate or reduce the effects due to various types of errors, the obtained experimental values are subjected to tests that evaluate the influences induced by the factors that generate measurement errors [11,12]. The main categories of statistical tests applicable to a sample of experimental values are dedicated to the identification and eventual elimination of influences due to the three types of errors that can lead to differences between the measured and real values of the variable that is to be determined: aberrant (gross) errors, systematic errors, random errors [13-15]. Statistical tests are the name given to methods for verifying statistical hypotheses. They are practically the procedure for verifying a statistical hypothesis, which has as its object the decision to reject or accept a statistical hypothesis [16].

The processing of experimental data is performed in the following stages [17]: checking statistical hypotheses; estimating the true value of a measured quantity; elimination of

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aberrant results from the series of measurements performed under the same conditions; checking the randomness of the scattering of the values of the quality characteristic; checking the normal distribution of experimental data; determining the interval and the level of confidence; distribution and reporting of statistical data; comparing the values of arithmetic means; dispersion comparison. If the identification of experimental values affected by outliers can be followed by the elimination of the respective values from the sample of experimental data, the presence of systematic errors can only be perceived through its influence on the entire sample of experimental values [18]. Reducing the effects induced by systematic errors can only be achieved by comparing the results of processing several samples of experimental values [19]. Since random errors appear in most samples of experimental values (except for making some precise determinations of some variables of a discrete nature), statistical tests in this case only seek to highlight the degree to which these errors have affected the respective sample, indicating whether its probability density it also coincides as a general form with that of the real variable that was measured [20]. The problem of detecting and eliminating systematic errors is more difficult due to the multitude of interrelated factors. In this research, Young's test will be used because this test does not provide the possibility of eliminating systematic errors, but only that of assessing the influence of systematic causes on the analyzed data.

2. Materials and methods

The fundamental objective of the present research – is the study of the arithmetic mean deviation of the surface profile R_a, resulting from the processing by end milling, of aluminum alloy parts code 7136, depending on the parameters of the cutting process. In this study, the point problem analyzed is to verify the randomness of a sample of measurements taken from the processing of seven blocks. One of the most used tests to check the randomness of a sample of experimental values is the Young's test [8]. The planning of the research activity aims to obtain the expected results in conditions of maximum efficiency. The choice of measurement volume will be made based on the following considerations: precision; duration of purchase of measuring instruments and devices; duration of processing the results; the cost price of the research. Too little volume of measurements has a negative effect on their accuracy, and too many loads the research program unnecessarily. Excessive repetition of some measurements can even lead to the measurement of trends in the variation of parameters, because of the inevitable dispersion of data, resulting in incomplete and erroneous conclusions. The cutting operation chosen for the experimental research is the end milling, using a SECO R217.69-1616.0-09-2AN cutting tool with 2 teeth and a diameter of 16 mm. The CNC used is HAAS VF2. The device for measuring surface roughness is the Mitutoyo SURFTEST SJ-210. The research's own strategy involves conducting an experimental study on the defined research problem, based on an experimental plan. The parameters of the cutting regime were chosen, the influence of which is monitored on the surface roughness. This study is part of a larger research project in which the cutting parameters that have the greatest influence in the end milling process were analyzed. Given the proposed objective, the study factors pursued in achieving the objective are: cutting speed: 495, 530, 570, 610, 660, 710 [m/min]; cutting depth: 2, 2.5, 3, 3.5, 4 [mm]; feed per tooth: 0.04, 0.06, 0.08, 0.11, 0.14 [mm/tooth]. Following the experiments, the measurements are performed. Montgomery [7] states that experiments and measurements can be repeated between 3 and 7 times for each set of values of the input parameters, to determine the constancy of the measurements. To obtain the most accurate results, this research will be repeated 7 times. In accordance with this decision, the subsequent statistical analysis of the resulting data will be based on methods that are appropriate in this direction. Verification of the random nature of the experimental data will be performed using the Young's test. The purpose of this test is to certify that the values obtained are real values of the milling process. For the three factors chosen for the study: cutting speed, cutting depth and feed rate and their corresponding levels, it is necessary to perform $6\times5\times5 = 150$ experiments. The roughness of the processed R_a surfaces will be determined, on the milling direction in the direction of advance as well as transversely on this direction, further marked with R_a longitudinally, respectively R_a transversely. The measurements were performed on each combination of values of the parameters of the established cutting regimes, resulting in a total of 300 (150×2) measurements. Regarding the repeated experiments (Fig. 1) (each 7 times), we will have a total of 2100 measurements (1050 measurements related to R_a longitudinally, respectively 1050 measurements related to R_a transversely).

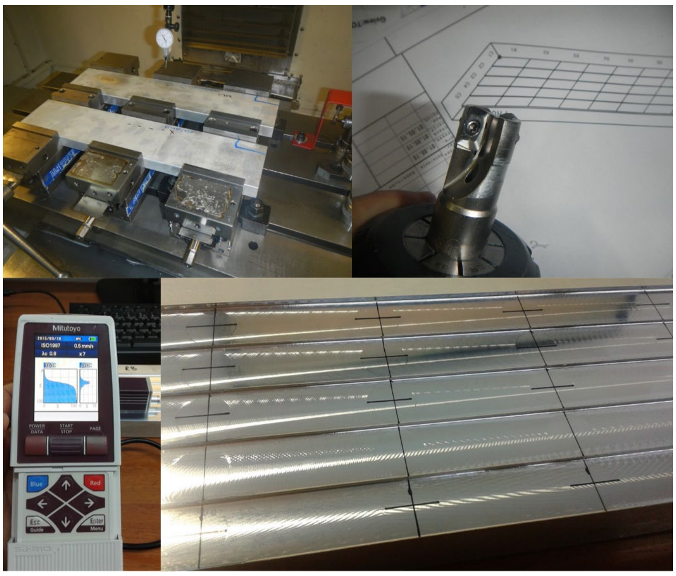


Fig. 1. Experimental procedure

3. Result and discussion

The test proposed in this step is the Young's test. A string of experimental data is random if the following condition is met [9]:

$$vci < m < vcs \tag{1}$$

where: vci is the lower critical value; m is the test coefficient; vcs is the higher critical value.

Lower critical value vci is calculated according to the Eq. (2) [9]:

$$vci = 0{,}491 + 0{,}081 \cdot n - 0{,}003 \cdot n^2, \text{ for } \alpha = 0{,}95 \tag{2}$$

Test coefficient m is calculated according to the Eq. (3) [9]:

$$m = \frac{\delta^2}{\sigma^2} \tag{3}$$

where: δ represents the average of the successive differences and is calculated according to Eq. (4) [9]:

$$\delta^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_{i+1} - x_i)^2 \tag{4}$$

σ represents the dispersion of the experimental data and is calculated according to Eq. (5) [9]:

$$\sigma^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2 \tag{5}$$

n represents the number of values in the experimental data string; x_i is the string of experimental data; $\bar{x}$ is the arithmetic mean; α is the confidence level chosen in this case $\alpha = 0{,}95$.

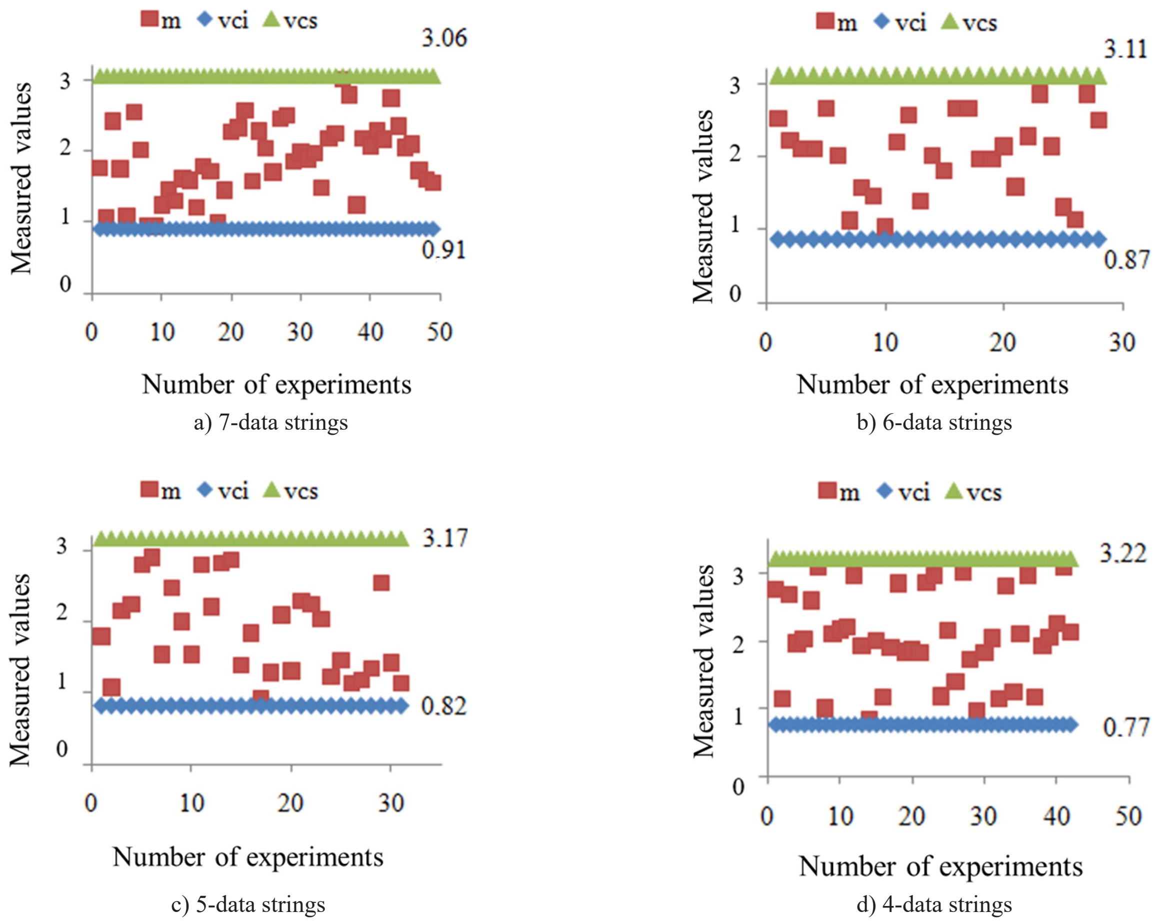
Higher critical value vcs is calculated according to the Eq. (6) [9]:

$$vcs = 3{,}317 - 1{,}057e^{-8{,}919 \cdot n^{-0{,}941}}, \text{ for } \alpha = 0{,}95 \tag{6}$$

If the test value m satisfies condition (1), then the experimental data strings satisfy the random condition [9]. Respecting the calculation methodology imposed by the Youg test, we performed the calculations related to the verification of the random character of the experimental data related to the arithmetic mean deviations of the surface profile, measured longitudinally and transversely in the direction of the advance movement. The results obtained are presented below. In tables 1 and 2 we presented the situation resulting from the calculation steps to determine the random nature of the data.

4.1. R_a longitudinally – discussions

For the first R_a longitudinally case, we centralized the statistical data through TABLE 1. This table shows that all strings of 7, 6, 5, and 4 data, respectively, are random. In Fig. 2, we argued this finding, in terms of graphical representations related to the tested statistical data. In all the cases presented in



a) 7-data strings
b) 6-data strings
c) 5-data strings
d) 4-data strings

Fig. 2. Graphical representations of Young's test results on longitudinal R_a measurements

this figure (a, b, c and d) we presented graphically the results obtained from the calculations of the lower critical values *vci*, the upper critical values *vcs*, as well as the test coefficients *m*, corresponding to each data string.

TABLE 1

Young test – verification of the random nature of R_a longitudinally data

No of string data	The given condition	No of cutting regimes	Random character
7	*vci* < *m* < *vcs*	49	YES
6		28	YES
5		31	YES
4		42	YES

Therefore, the conditions imposed were as follows:

a) *vci* = 0,91 and *vcs* = 3,06 – for the 7-value strings of the 49 experiments;

b) *vci* = 0,87 and *vcs* = 3,11 – for the 6-value strings of the 28 experiments;

c) *vci* = 0,82 and *vcs* = 3,17 – for the 5-value strings of the 31 experiments;

d) *vci* = 0,77 and *vcs* = 3,22 – for the 4-value strings of the 42 experiments.

Thus, according to these graphs, it appears that all the values calculated for *m*, fall within the determined lower and upper limits. Therefore, as mentioned in TABLE 1, the randomness of the data tested for the surface roughness measured longitudinally in the direction of the feed rate is fulfilled.

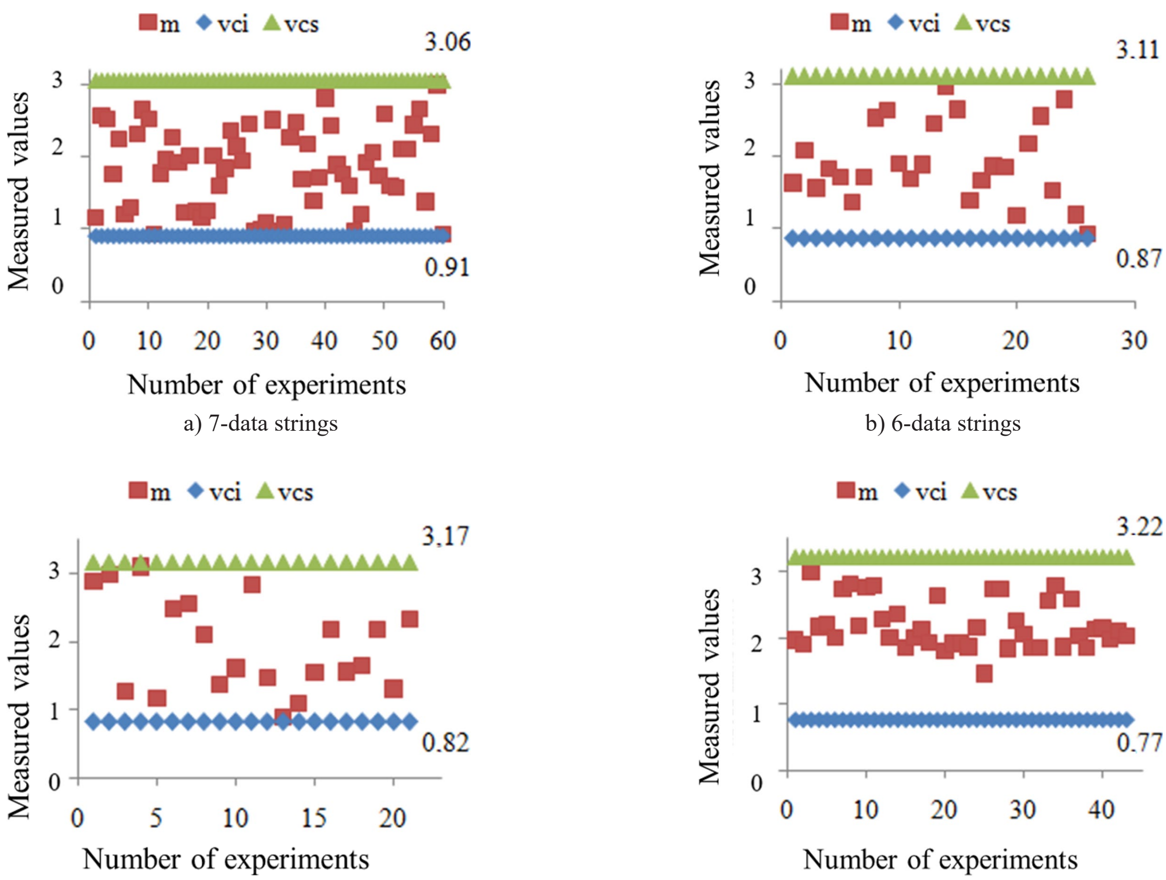
4.2. R_a transversely – discussions

Like the previous case, through TABLE 2, we synthesized the statistical data regarding the results of the calculations of the verification of the random character of the experimental data related to R_a transversely. As it results from this table, all the strings of 7, 6, 5, and 4 data, respectively, have a random character. The arguments of this finding were made based on graphical representations related to the statistical data tested for R_a transversely, presented in Fig. 3. In the mentioned figure, we presented graphically the results obtained after performing

TABLE 2

Young test – verification of the random nature of the data on R_a transversely

No of string data	The given condition	No of cutting regimes	Random character
7	*vci* < *m* < *vcs*	60	YES
6		26	YES
5		21	YES
4		43	YES



a) 7-data strings

b) 6-data strings

c) 5-data strings

d) 4-data strings

Fig. 3. Graphical representations of Young's test results on transversely R_a measurements

the calculations of the lower critical values *vci*, respectively of the higher critical values *vcs*, as well as of the test coefficients *m*, related to each data series.

According to these graphs, it appears that all the values calculated for *m*, fall within the determined lower and upper limits. These conditions imposed by *vci* and *vcs*, have the following values, corresponding to each data string:

a) *vci* = 0,91 and *vcs* = 3,06 – for the 7-value strings of the 60 experiments;
b) *vci* = 0,87 and *vcs* = 3,11 – for the 6-value strings of the 26 experiments;
c) *vci* = 0,82 and vcs = 3,17 – for the 5-value strings of the 21 experiments;
d) *vci* = 0,77 and *vcs* = 3,22 – for the 4-value strings of the 43 experiments.

Therefore, the random nature of the related tested data is fulfilled.

As a general conclusion, for all 150 measurements the stages of the Young test were completed and, it turns out, all experimental data sets verify the condition of randomness of the data, both in the situation of the roughness of the measured surface longitudinally and transversely in the feed rate direction.

5. Conclusions

After checking the randomness of the experimental data, using the Young test:

1. We found that all the tested values fall within the critical limits imposed by the test.
2. Therefore, all tested data strings are random in both cases: both in the case of the arithmetic mean deviation of the measured surface profile longitudinally and transversely, in the direction of the feed rate.
3. In carrying out the experimental study of the end milling process, the aim is to obtain the best surface quality under the influence of the parameters of the cutting regime.
4. Subsequent research directions include regression analysis that aims to identify a quantitative relationship between the parameters of the studied cutting process and the arithmetic mean deviation of the R_a surface profile, describing the system studied at any point in the chosen experimental field.
5. In the specialized literature, no research has been identified that analyzes the subject of processing aluminum alloys in this manner. In conclusion, the current research constitutes a new element brought to this area.

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