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APPLICATION OF TAGUCHI METHOD AND REGRESSION ANALYSIS ON SURFACE ROUGHNESS IN END MILLING OF ALUMINUM 6082-T6

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ABSTRACT

This paper presents the Taguchi method and regression analysis for obtaining surface roughness in end milling of aluminum 6082-T6. Surface roughness was measured using a Mahr profilometer. The values of the experimental measurements were compared with the values obtained by regression analysis. The optimization was performed using the Taguchi method, which showed the greatest influence of the cutting parameters (cutting speed, feed rate, depth of cut) on surface roughness.

Keywords: Milling, Taguchi, Regression analysis, Surface roughness.

INTRODUCTION

Today the appearance of a large number of workpiece materials, tools, processing processes, a complex mathematical apparatus is necessary for the calculation of optimal processing conditions, shortening the final time, automatic design of technological procedures, increasing quality levels and sustainable development (Pavel, 2015).

It is necessary development a mathematical model of the machining process that describes and simulates certain laws of tribology of the process. In order to successfully solve the research of processes or systems in the design of new processes or systems, the cybernetic approach of the "black box" is often used (Radovanović, & Madić, 2019).

Surface roughness is one of the important indexes for parts design and measurement of surface quality. Roughness affects the wear resistance, corrosion resistance and fatigue resistance of parts directly, and also affects the accuracy and quality (Chen, Sun, Lin, & Zhang, 2018).

The objective of this study is to determine the influence of the factors (spindle speed, feed rate and depth of cut) on the performance (surface roughness) in the end milling of aluminum alloy 6082-T6 using Taguchi method. The mathematical model of the surface roughness was obtained using regression analysis with mutual three influencing factors for facilitates planning the milling process.

EXPERIMENTAL SETUP AND CUTTING CONDITIONS

In experimental measurements of surface roughness in the end milling process, samples of aluminum alloy 6082-T6 were used, with workpiece dimensions: 50x30x400 mm.

The cutting tool that was used was solid carbide end mill JS413160D2SZ3.0, manufactured by SECO.

The experimental research was carried out on the universal milling machine “Prvomajska” UGH and surface roughness, Figure 1. (Stanojković, & Radovanović, 2018).

Surface roughness was measured using a Mahr profilometer the laboratory conditions.

Figure 1. Miling machine “Prvomajska” UGH.

DESIGN OF EXPERIMENT

An experiment involves procedures and techniques to test a process under certain conditions. The experiment is often the only way to obtaining process information and efficient way for their mathematical modeling and optimization. Both theory and experiment are needed to investigate the process, but the accuracy of the mathematical model of the process will depend on the experiment. The experiment should provide the required information with minimum time and effort. Therefore, the experimental plan and program must be well prepared and designed to conduct experiments. The various steps involved in the design of experiments (Palanisamy, Rajendran, & Shanmugasundaram, 2008):

- identifying the important process variables,
- finding the upper and the lower limits of the variables,
- development of the design matrix,
- conducting the experiments as per the design matrix,
- evaluation of regression coefficients for the mathematical model
- development of regression mathematical model

The selected process parameters of the experiment of surface roughness, with their limits, units and notations, are given in Table 1. (Stanojković, & Radovanović, 2020).

Table 1. Process parameters and their levels.

Factors	**Levels**		
	-1	**0**	**1**
Spindle speed-n (rev/min)	405	465	560
Feed rate-V_f (mm/min)	93	130	175
Depth of cut-a_p (mm)	1.5	2.0	2.5

The plan of the experiment and measurement results of surface roughness Ra is shown in Table 2.

Table 2. Design matrix values.

No.	*n* [rev/min]	V_f [mm/min]	a_p [mm]	*n* [rev/min]	V_f [mm/min]	a_p [mm]	R_a [μm]
1	-1	-1	-1	405	93	1.5	1.299
2	1	-1	-1	560	93	1.	0.589
3	-1	1	-1	405	175	1.5	1.403
4	1	1	-1	560	175	1.5	0.723
5	-1	-1	1	405	93	2.5	0.978
6	1	-1	1	560	93	2.5	0.711
7	-1	1	1	405	175	2.5	1.809
8	1	1	1	560	175	2.5	0.69
9	0	0	0	465	130	2.0	0.74

DEVELOPMENT OF REGRESION ANALYSIS

Regression analysis is a set of statistical methods used for the estimation of relationships between a dependent variable and one or more independent variables. The functional dependence between the three influencing factors is presented in the form, Equation 1 (Pavel, 2015):

$$R_a = C n^{p_1} {V_f}^{p_2} {a_p}^{p_3} \qquad (1)$$

The mathematical model with real coordinates is obtained by Equation 2:

$$R_a = 3881.6\, n^{-2.11} {V_f}^{0.69} {a_p}^{1.05} \qquad (2)$$

The experimental and mathematical value of surface roughness in end milling of aluminum 6082-T6 is shown in Table 3.

Table 3. Experimental and mathematical values of surface roughness.

No.	*n* [rev/min]	V_f [mm/min]	a_p [mm]	Experimental R_a [μm]	Mathematical R_a [μm]
1	405	93	1.5	1.299	0.427
2	560	93	1.5	0.589	0.215
3	405	175	1.5	1.403	0.661
4	560	175	1.5	0.723	0.334
5	405	93	2.5	0.978	0.731
6	560	93	2.5	0.711	0.369
7	405	175	2.5	1.809	1.128
8	560	175	2.5	0.69	0.569
9	465	130	2.0	0.74	0.543

ANALYSIS OF RESULTS AND DISCUSSION

Using regression analyis to obtain the mathematical model of surface roughness in end milling of aluminum 6082-T6 comes to the result of measurement as a value to be different from the mathematical.

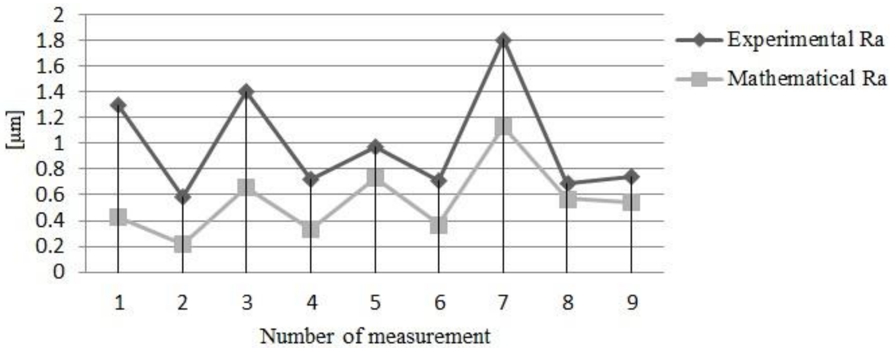

Figure 2. Experimental and mathematical values of surface roughness.

The surface roughness measurement results were analyzed by using the analysis of variance (ANOVA) in the Minitab 17 software package. Based on the obtained data, the influence of the factors on the surface roughness in the end milling of aluminum 6082-T6 can be determined. The greatest effect on the surface roughness during the end milling of aluminum
6082-T6 with solid carbide end mill has the spindle speed, followed by the feed rate and depth of cut, Table 4. By increasing the spindle speed feed rate, decrease of surface roughness, Fig. 3.

Table 4. Effect on the surface roughness.

Level	***n***	V_f	a_p
1	1.3722	0.892	1.0035
2	0.740	0.740	0.7400
3	0.6783	1.153	1.0470
Delta	0.6940	0.413	0.3070
Rank	1	2	3

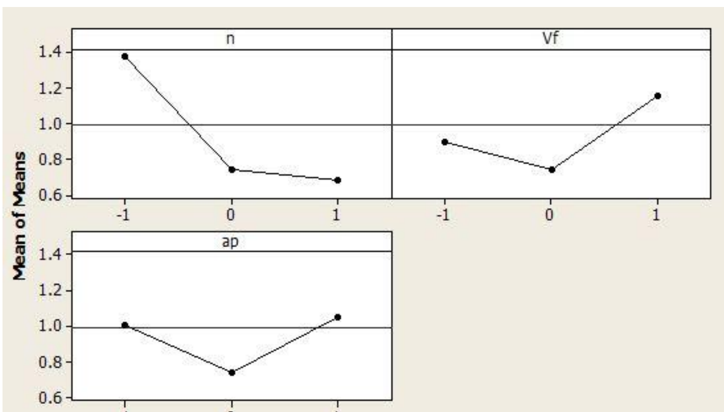

Figure 3. Influence of factors on surface roughness.

CONCLUSIONS

Investigating the surface roughness is important for milling process and that is the basic criterion for the quality of parts. Knowing the parameters that affect milling process is important and efficient planning of the machining process.

Using regression analysis, created a mathematical model of surface roughness whose results are slightly different from the results obtained experimentally. Mathematical modeling using regression analysis is a faster procedure for obtaining results and therefore cheaper The influence factor on the surface roughness in the end milling of aluminum 6082-T6 is spindle speed.

LITERATURE

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