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EXPERIMENTAL MODELING OF SURFACE ROUGHNESS PARAMETERS DURING CUTTING STEEL 30NiMo8

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ABSTRACT
The surface roughness was the subject of experimental research during cutting steel 30NiMo8 with cermet tool under different cutting conditions. For experimental work the experimental plan was prepared by the methodology of mathematical planning of experiment. The data collected was statistically analyzed using regression and dispersion analysis technique and developed a model of surface roughness.
Keywords: Surface roughness, Minitab, Cutting parameter

1. INTRODUCTION
Surface roughness is often taken as an indicator of the quality of treated workpieces. Achieving the desired surface quality is of great importance to perform the function the product. The paper observed effect of the treated material, tools, depth of cut, feed rate and cutting speed on surface roughness. The collected results of experimental investigations are used to assess the surface roughness. In order to reduce processing time, reduce the cost of processing researchers often implemented optimization of cutting parameters. In doing so, take a large number of constraints such as cutting force, machine power, tool life, the temperature in cutting zone, etc. Selected machining conditions subsequently affect the quality of machined surface. Better quality of machined surface has positive influence on the tribological properties, fatigue strength, corrosion resistance and aesthetics, but also raises costs of production. For this reason, the problem of evaluation of the roughness of machined surfaces was of great interest of many authors [1,2,3,4]. To estimate the roughness parameters different techniques apply: multiple regression analysis, mathematical modelling, expert systems, etc.[3,4].

2. EXSPERIMENTAL WORK

2.1. The problem and investigating goal definition
There are many factors influencing the roughness of surfaces. Influencing factors could be classified into several groups [4]: the workpiece factors (chemical composition, mechanical properties, surface condition factors ...), the selected machine tool (stability, performance, accuracy ...), factors the selected tool (type tool material, tool geometry, cutting surface condition factors...), the selected cutting conditions (depth of cut, feed rate and cutting speed) and factors of the means for cooling and lubricating (chemical composition, viscosity, method and location of cooling). The experiment was conducted in the Laboratory for metal cutting and machine tools - LORAM, at the University of

Zenica. The rough material was a bar full cross-section Ø 50 mm of steel 30CrNiMo8. The levels of cutting conditions i.e. rpm, feed rate. depth of cut are listed in table 1. The cutting insert used for turning operation was CNMG 120408 NF IC 20N..

Table 1. Levels of cutting parameters

Levels	Revolution n(o/min)	Feed rate s (mm/o)	Depth of cut a (mm)	code
High	1100	0,2	0,75	+1
Low	600	0,05	0,25	-1

The experiment was performed on universal lathe. All cutting operation tests followed by measurement of surfaces roughness at the observed area. Roughness was measured at three points on a given surface. The data obtained were used to set the process model to estimate surface roughness, which is based on the use of regression analysis as a mathematical tool.

2.2. Experimental model of surface roughness

The relationship between the surface roughness and machining independent variables represented in the following equation. The equation is:

$$Ra = C \cdot n^x \cdot s^y \cdot a^z , \qquad \ldots (1)$$

where C is constant, and x, y, z are the exponents. Equation (1) can be represented in linear mathematical form as follows:

$$\ln Ra = \ln C + x \cdot \ln n + y \cdot \ln s + z \cdot \ln a \qquad \ldots (2)$$

The constants and exponents C, x, y, z can be determined by the method of least squares. The introduction of a replacement get the following expression.

$$Y = \ln Ra,\ b_0 = \ln C,\ x_1 = \ln n,\ x_2 = \ln s,\ x_3 = \ln a,\ x = b_1,\ y = b_2\ \ z = b_3 \qquad \ldots (3)$$

Linear model developed from the equation can be represented as follows:

$$y = b_0 + b_1 \cdot x_1 \cdot b_2 \cdot x_2 + b_3 \cdot x_3 \qquad \ldots (4)$$

Where, x_1, x_2, x_3, are logarithmic transformations of factors: workpiece revolution, feed rate and depth of cut and b values are the estimates of corresponding parameters. The variables coded by taking into account the capacity and the limiting cutting conditions of lathe machine. The coded values of variables to be used in equation (4) were obtained from the following transforming equations.

$$X_1 = 3.299 \ln n - 22.107,\ X_2 = 1.443 \ln s + 3.322,\ X_3 = 1.820 \ln a + 1.523. \qquad \ldots (5)$$

Finally, mathematical model of surface roughness (1) is:

$$Ra = \frac{9.1129 \cdot s^{0.6963} \cdot a^{0.0325}}{n^{0.1204}}. \qquad \ldots (6)$$

Table 2 shows natural and coded values of variables, plan matrix of eksperimatal design, and surface roughness measurement results.

Table 2. Experimental plan matrix, and measurement results

Exp. runs	Values of physical factors			Matrix of coded values			Measured values			Mean values	
	n, r/min	s, mm/r	a, mm	x_1	x_2	x_3	Ra1	Ra2	Ra3	$\bar{y}$	$\ln \bar{y}$
1.	600	0.05	0.25	-1	-1	-1	0,443	0,477	0,498	0,473	-0,749
2.	1100	0.05	0.25	+1	-1	-1	0,468	0,431	0,422	0,440	-0,820
3.	600	0.2	0.25	-1	+1	-1	1,284	1,322	1,378	1,328	0,284
4.	1100	0.2	0.25	+1	+1	-1	1,389	1,396	1,281	1,355	0,304
5.	600	0.05	0.75	-1	-1	+1	0,671	0,515	0,612	0,599	-0,512
6.	1100	0.05	0.75	+1	-1	+1	0,452	0,438	0,514	0,468	-0,759
7.	600	0.2	0.75	-1	+1	+1	1,197	1,207	1,31	1,238	0,213
8.	1100	0.2	0.75	+1	+1	+1	1,224	1,159	1,352	1,245	0,219

3. ANALISYS OF RESULTS

After completion of the experimental results regression and dispersion analysis with goal of identify significant factors affecting the surface roughness were conducted. Table 3 and table 4 presents statistical analysis of experimental results.

Table 3. Analysis of variance

ANOVA					
	df	SS	MS	F	Significance F
Regression	3	1,877	0,626	51,751	0,001
Residual	4	0.048	0,012		
Total	7	1,925			

Table 4. Regression analysis

Regression Statistics	
Multiple R	0,987
R Square	0,975
Adjusted R Square	0,956
Standard Error	0,110
Observations	8,000

Value of "probability>F" less than 0.05 indicate model terms are significant. This is desirable as it indicates that the terms in the model have significant effect on the response.

Regression coefficients obtained by regression analysis are presented in Table 5. R Square (coefficient of determination), Table 4, have very high value (0,975). Its means that model (6) covered 97,5% variability of *Ra* caused by factors of model (*n*, *s*, *a*). So, model (6) can be used for practical means.

This results shows that feed rate has the most significant effect on the roughness, followed by number of revolution and depth of cut.

Table 5. Coefficients of regression

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-0,228	0,039	-5,854	0,004	-0,335	-0,120
x_1	-0,037	0,039	-0,940	0,401	-0,144	0,071
x_2	0,483	0,039	12,416	0,000	0,375	0,591
x_3	0,018	0,039	0,461	0,669	-0,090	0,126

4. CONCLUSION

- It was found that the regression analysis of successful techniques in the analysis of surface roughness when cutting steel with respect to different cutting conditions (revolution per minute, feed rate and depth of cut). Power model, which is result of the experiment, adequately describes effects of *n*, *s* and *a* on the surface roughness.
- A logarithmic data transformation can be applied to convert the nonlinear form of equation into to the linear form.
- The model developed in the research produces smaller errors and have satisfactory results. Therefore the proposed model can be used to predict the corresponding surface roughness in cutting of steel 30CrNiMo8 at different cutting parameters.
- From the model equations can be select the best combination of cutting variables for achieving optimum or minimum surface roughness during cutting steel. This eventually may reduce the machining time, operator efforts, cost and save the cutting tools.

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