Pavel Kovač, Borislav Savković, Marin Gostimirovic, Dušan Jesic, Ildiko Mankova

Modeling of the machining surface roughness parameters for steel difficult to machining

The objective of this study is to examine the influence of machining parameters on surface finish in turning. A new approach in modeling surface roughness which uses design of experimentsis described in this paper. The values of surface roughness predicted by these models are then compared. The results showed that the proposed system can significantly increase the accuracy of the product profile when compared to the conventional approaches. The results indicate that the design of experiments with central composition plan modeling technique can be effectively used for the prediction of the surface roughness for steel difficult to machining.

Keywords: in turning, design of experiment, surface roughness

1. Introduction

Increasingly, research in manufacturing processes and systems is evaluating processes to improve their efficiency, productivity and quality. The quality of finished products is defined by how closely the finished product adheres to certain specifications, including dimensions and surface quality. Surface quality is defined and identified by the combination of surface finish, surface texture, and surface roughness. Surface roughness (R_a, R_{max}...) is the commonest index for determining surface quality [1, 2].

Manufacturing processes do not allow achieving the theoretical surface roughness due to defects appearing on machined surfaces and mainly generated by deficiencies and imbalances in the process. Due to these aspects, measuring procedures are necessary; as it permits one to establish the real state of surfaces to manufacture parts with higher accuracy. To know the surface quality, it is necessary to employ theoretical models making it feasible to do predictions in function of response parameters [3].

A lot of analytically methods were also developed and used for predicting surface roughness. Hadi et al. developed a empirical model for prediction of surface roughness in finish turning [4]. Nonlinear regression analysis, with logarithmic data transformation is applied in developing the empirical model. Metal cutting experiments and statistical tests demonstrate that the model developed in this research produces smaller errors and has a satisfactory result. Chen et al. present the mathematical models for modeling and analyzing the vibration and surface roughness in the precision turning with a diamond cutting tool [5].

In this study, cutting speed, feed and depth of cut as machining conditions were selected. The design of experiments with central composition plan were developed and compared using these cutting parameters.

Through surface roughness is affected by many parameters such as properties of cutting tool material and work piece material, tool geometry, and rigidity of machine tool; machining parameters, namely cutting speed, feed and depth of cut are considered to be the most significant. In the present study the machining parameters, namely, cutting speed, feed and depth of cut were modeled for surface roughness in machining of carbon steel using hard metal cutting tool [6, 7].

Factorial design of experiment have been recognized as an inevitable tool whose application can be achieved by improving product quality, increase productivity, decrease response time of the system, increase reliability etc. In many of the applications of design of experiment have replaced its recent methods and techniques, often are used in combination with other methods, but very often the only way to solve tasks and seeking solutions.

2. Experimental Procedure and Material

The first aim of the experiment was to carry out the measurement of surface roughness for cutting different cutting conditions.

Terms of the experimental study a) Machining was performed on Vertical turning machine for hard turning VL5 (Fig. 1.). Machine control unit was Fanuc 18i-TB. Number of Axes: 2 to 3, cutting diameter: 127 to 200 mm, cutting length: 119 mm, tool Stations: 12, spindles: 1, motor power: 20.88 kw, spindle speed: 4500 rpm.

Figure 1. Vertical turning machine for hard turning

b) Tool: The survey was used interchangeable plates tags WNMG 080408-QM, manufacturer SANDVIK Coromant, analogous to the ISO standard (EN ISO 9001:2000, EN ISO 14001:2004) with P30-50. Use was holder for external processing PWLNL 2525 M08 H4.

c) Equipment for cooling and lubrication was used ALUSOL of Castrol, conc. 6-10%. Castrol Alusol™ RAL BF is a high performance soluble metalworking fluid which is boron and chlorine free. It contains a unique additive package that works in synergy to enhance machining performance and surface finish, provide excellent product stability, improve bio-resistance properties and lower the overall operations costs

d) For measuring the surface roughness was used Surftest Mitutoyo SJ-301, the needle of the diamond, and the radius of curvature at the top of the needle 5 microns. Path length measured was 3.7 mm. The measured values of: R_a, R_{max}. The measurement results are given in Table 1.

e) Material used in tests was steel IDM 8365 it has a large degree of elongation, toughness due to the high content of Ni, corrosion resistance due to the presence CrNi, belong to the group of stainless steel and high-alloy steels. The chemical composition is presented in Table 2, results were obtained by the spectrometer ARL 3460. Also, mechanical properties of processed materials are given in Table 3.

Table 1. The measurement results - Input parameters

No.	Cod of factor				Factor			Measured values	
	x_0	x_1	x_2	x_3	v [m/s]	s [mm/rev]	a [mm]	R_a [µm]	R_{max} [µm]
1	1	-1	-1	-1	3.0	0.12	0.5	0.86	5.22
2	1	1	-1	-1	4.33	0.12	0.5	0.88	6.07
3	1	-1	1	-1	3.0	0.187	0.5	1.58	10.03
4	1	1	1	-1	4.33	0.187	0.5	1.8	11.06
5	1	-1	-1	1	3.0	0.12	1.4	0.97	6.39
6	1	1	-1	1	4.33	0.12	1.4	0.97	6.63
7	1	-1	1	1	3.0	0.187	1.4	2.17	11.04
8	1	1	1	1	4.33	0.187	1.4	2.4	12.03
9	1	0	0	0	3.6	0.15	0.84	1.33	6.86
10	1	0	0	0	3.6	0.15	0.84	1.16	7.58
11	1	0	0	0	3.6	0.15	0.84	1.17	6.71
12	1	0	0	0	3.6	0.15	0.84	1.29	7.78
13	1	-2	0	0	2.5	0.15	0.84	1.18	6.87
14	1	2	0	0	5.22	0.15	0.84	1.25	8.43
15	1	0	-2	0	3.6	0.096	0.84	0.81	4.94
16	1	0	2	0	3.6	0.234	0.84	3.49	16.26
17	1	0	0	-2	3.6	0.15	0.3	1.105	7.83
18	1	0	0	2	3.6	0.15	2.34	1.34	8.09
19	1	-2	0	0	2.5	0.15	0.84	1.037	6.72
20	1	2	0	0	5.22	0.15	0.84	1.082	8.45
21	1	0	-2	0	3.6	0.096	0.84	0.74	5.01
22	1	0	2	0	3.6	0.234	0.84	3.05	14.92
23	1	0	0	-2	3.6	0.15	0.3	1.34	8.11
24	1	0	0	2	3.6	0.15	2.34	1.48	8.21

Table 2. The chemical composition steel IDM 8365

Chemical composition:				
	Mark:	Unit	Limits	Composition
Carbon	C	(%)	0,25-0,35	0,33
Silicon	Si	(%)	1,00-2,50	1,63
Manganese	Mn	(%)	Max 1,50	0,35
Sulphur	S	(%)	Max 0,04	0,025
Phosphorus	P	(%)	Max 0,04	0,020
Chromium	Cr	(%)	23,00-27,00	24,40
Nickel	Ni	(%)	19,00-22,00	20,38
Molybdenum	Mo	(%)	Max 0,50	0,025
Niobium	Nb	(%)	1,20-1,50	1,26

Table 3. Mechanical properties

	Mark:	Unit	Limits	Size
Tensile Strength	Rm	MPa	Min. 450	486
Prof Stress	Rp0,2	MPa	Min. 240	351
Elongation:	A	%	Min 10	10,3
Brinell hardness	HBW 5/750		162-229	207

This work was performed and morphological examination of material microscope, "Leitz" ARISTOMET QI 01297 / "OLYMPUS BH" OPTICAL Japan QI QI 01298 and 01298/1.

Testing has shown that the microstructure shall consist of interdendritic eutectic chromium carbides in an austenitic matrix, Figure 2.

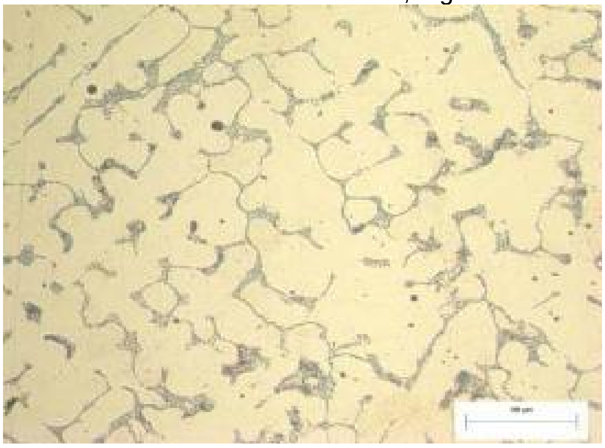

Figure 2. The microstructure shall consist of interdendritic eutectic chromium carbides in an austenitic matrix

3. Analysis of the results

In Table 4 shows the correlation between the experimental and expected values of surface roughness (R_a, R_{max}).

Table 5 shows the coefficients obtained by the dispersion analysis. Value F_{ra} represents dispersion ratio, based on which can be concluded that both models are adequate. Values F_{ri} determine the significance of selected parameters (dispersion ratio: F_{r1} is for the cutting speed, F_{r2} is for the feed per revolution and F_{r3} is for the cutting depth).

Table 4. The measurement results and modeled values

No.	Factor			Surface roughness			
	v [m/s]	s [mm/rev]	a [mm]	R_a [µm]	R_{max} [µm]	R_a model [µm]	R_{max} model [µm]
1	3.0	0.12	0.5	0.86	5.22	0.76	5.11
2	4.33	0.12	0.5	0.88	6.07	0.80	5.78
3	3.0	0.187	0.5	1.58	10.03	1.86	10.32
4	4.33	0.187	0.5	1.8	11.06	1.95	11.67
5	3.0	0.12	1.4	0.97	6.39	0.89	5.46
6	4.33	0.12	1.4	0.97	6.63	0.94	6.18
7	3.0	0.187	1.4	2.17	11.04	2.17	11.03
8	4.33	0.187	1.4	2.4	12.03	2.28	12.47
9	3.6	0.15	0.84	1.33	6.86	1.32	8.00
10	3.6	0.15	0.84	1.16	7.58	1.32	8.00
11	3.6	0.15	0.84	1.17	6.71	1.32	8.00
12	3.6	0.15	0.84	1.29	7.78	1.32	8.00
13	2.5	0.15	0.84	1.18	6.87	1.26	7.08
14	5.22	0.15	0.84	1.25	8.43	1.39	9.06
15	3.6	0.096	0.84	0.81	4.94	0.54	3.94
16	3.6	0.234	0.84	3.49	16.26	3.22	16.18
17	3.6	0.15	0.3	1.105	7.83	1.13	7.48
18	3.6	0.15	2.34	1.34	8.09	1.54	8.55
19	2.5	0.15	0.84	1.037	6.72	1.26	7.08
20	5.22	0.15	0.84	1.082	8.45	1.39	9.06
21	3.6	0.096	0.84	0.74	5.01	0.54	3.94
22	3.6	0.234	0.84	3.05	14.92	3.22	16.18
23	3.6	0.15	0.3	1.34	8.11	1.13	7.48
24	3.6	0.15	2.34	1.48	8.21	1.54	8.55

Table 5. Adequacy of models and significance of parameters

Model adequacy		R_a	R_{max}
		F_a=3.09891	F_a=3.23658
Signific	F_{ro}	28269.36	218.57
	F_{r1}(v)	16.55	1.17
	F_{r2}(s)	539.63	375.76
	F_{r3}(a)	4.87	11.38

Equations for surface roughness modeling by design of experiment determined by central compositional plan.

$$R_a = 3.93\ v^{0.135}\ s^{2.002}\ a^{0.150} \qquad (1)$$

$$R_{max} = 4.667\ v^{0.335}\ s^{1.585}\ a^{0.065} \qquad (2)$$

Any change in the cutting speed leads to a corresponding change in the value surface roughness, so the cutting speed should influence the roughness processing. The cutting speed has a small and increasing effect. Influence of feed on value surface roughness is higher than that of the cutting speed. Depth of cut at least influences the wear on the flank surface. Value surface roughness is improved by decreasing cutting speed.

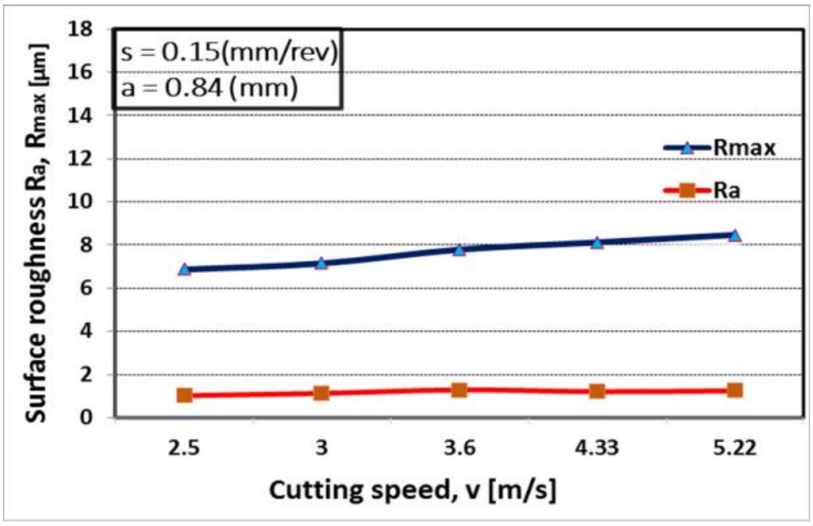

Figure 3. The surface roughness (R_a, R_{max}) versus cutting speed

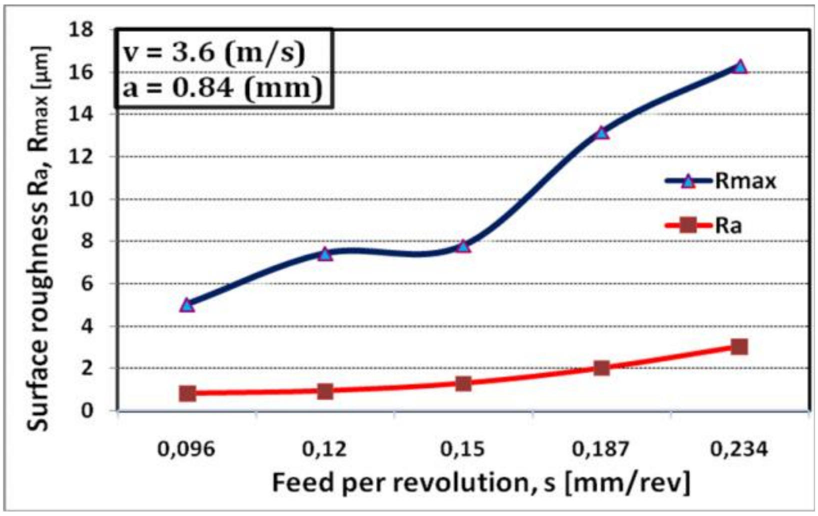

Figure 4. The f surface roughness (R_a, R_{max}) versus feed per revolution

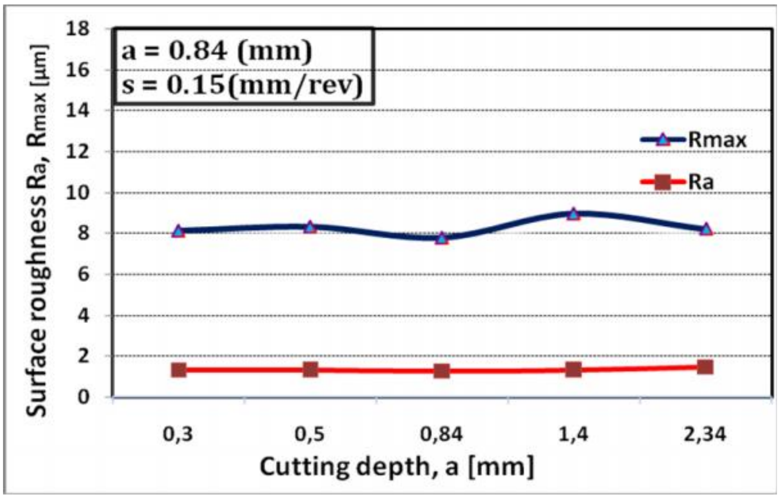

Figure 5. The surface roughness (R_a, R_{max}) versus the cutting depth

Factorial design of experiment gives the influence of cutting conditions on machining surface quality during turning difficult to machine material, are investigated through experimental verification. The investigation results confirm the highly consent of experimental research and design of experiment techniques modeling. The factorial design of experiment optimization techniques and experimental results show some good information which could be used by future researches for optimal control of machining conditions. This paper has successfully established model, which consist of the pertinent process parameters, for predicting the surface roughness parameters of workpiece.

4. Conclusion

Figure 3, 4, 5 shows the compared predicted values obtained by experiment and estimated by the factorial design of experiment show a good comparison with those obtained experimentally. The average deviations of models are checked and are found to be adequate (under the value 4.42).

The model adequacy can be further improved by considering more variables and ranges of parameters.

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- Prof. Dr. Pavel Kovač, University of Novi Sad, Faculty Technical Sciences, Trg Dositeja Obradovića 6, Serbia, pkovac@uns.ac.rs
- Assis. Prof. Dr. Borislav Savković, University of Novi Sad, Faculty Technical Sciences, Trg Dositeja Obradovića 6, Serbia, savkovic@uns.ac.rs
- Prof. Dr. Marin Gostimirovic, University of Novi Sad, Faculty Technical Sciences, Trg Dositeja Obradovića 6, Serbia, maring@uns.ac.rs
- Dr. Dušan Ješić, International Technology and Management Academy Novi Sad, Trg Dositeja Obradovića 7, Serbia, dusanjesic@hotmail.com
- Prof. Dr. Ildiko Mankova, Technical University in Kosice, Faculty of Mechanical Engineering, Masiarska 74, Slovakia, ildiko.mankova@tuke.sk