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Research of the Surface Roughness During Hard Turning of 42CrMoS4 Steel with a Quick-Change Tool Holder

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***Abstract*— This paper presents an analysis of the surface roughness during turning of hardened 42CrMoS4 steel using a quick-change tool holder with innovative design. The experiments used a Swiss-type CNC lathe - GOODWAY SW-20. The process was performed at cutting speed of 130 to 170 m/min, feed of 0.12 to 0.18 mm/tur and cutting depth of 1.5mm. Based on the results obtained, a mathematical model was developed, the graphic interpretation of which is presented in two-dimensional and three-dimensional coordinate systems. The mathematical model was used in the dispersion analysis to determine the influence of speed and feed during turning on the roughness of the machined surface. Graphical relationships are presented for the influence of the controlling factors on roughness.**

Keywords—hardened alloy steels, regression analysis, Swiss type lathes.

I. INTRODUCTION

When solving quality problems, it is important to ensure the accuracy and stability of technological processes, especially those parameters that have a significant functional impact on the performance of manufactured products [1], [2], [3]. Perhaps the most significant event that almost completely changed the world of tools is associated with the emergence and development of powder metallurgy. It created the technology for the production of metal-ceramic hard alloy - carbide [4], [5], [6]. Over the next few decades, a wave of innovations was observed that improved the performance characteristics of carbide tools and expanded their range of applications [7], [8], [9]. Most of the key technologies in the field have already existed for several decades, which is expected to lead to a certain degree of standardization in some product groups and markets. However, the tool manufacturing industry manages to maintain a high level of innovation in most of its areas, which allows for increased competitiveness through savings, increased productivity and capacity, and in some cases, improved quality. In this regard, in recent years, various modifications of quick-change holders have been designed and implemented in production, which have significantly improved the conditions for turning and increased the quality of the machined surfaces [2], [3].

Swiss-type CNC lathes are widely used in various sectors of the industry due to their many advantages over other CNC machines and turning centers. They are automatic lathes with a movable headstock and a guide bushing, designed for precise high-performance machining of complex small-sized parts with a short cycle of the technological process, obtained from bar material in conditions of high-volume production. Their application is especially effective in machining short and thin parts due to their specific design, which allows the cutting tool to perform machining in close proximity to the guide bushing [10], [11]. In this regard, the aim of the present study is to investigate, model and analyze the influence of the elements of the cutting mode (speed and feed) [3], [12], [13] on the roughness of the machined surfaces when turning short axisymmetric parts made of hardened steel 42CrMoS4 using a new design of a quick-change toolholder.

II. MATERIALS AND METHODS

Experimental studies on the influence of the type of tool holder on the roughness of the machined surfaces were conducted when manufacturing parts from alloy steel 42CrMoS4 (1.7227) – Fig. 1 with a hardness of 33-35 HRC and a chemical composition according to Table 1[14,15].

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TABLE 1 CHEMICAL COMPOSITION OF STEEL 42CRMOS4, %

C	Si	Mn	Ni	Cr	Mo	P	S
0.38-0.45	0.17-0.37	0.50-0.80	≤0.3	0.9-1.2	0.15-0.25	≤0.035	≤0.035

The turning process was carried out on a Swiss CNC lathe, model GOODWAY SW-20. – Fig. 2. In the experiments, an innovative design of a quick-change holder type NX02-K-SV-HCL11– Fig. 3[2] was used, allowing the delivery of coolant directly to the cutting zone, thus significantly reducing local heating at the tip of the cutting tool and improving the chip removal process [16]. In the research process, a carbide insert type VCMT11.03.02 was used.

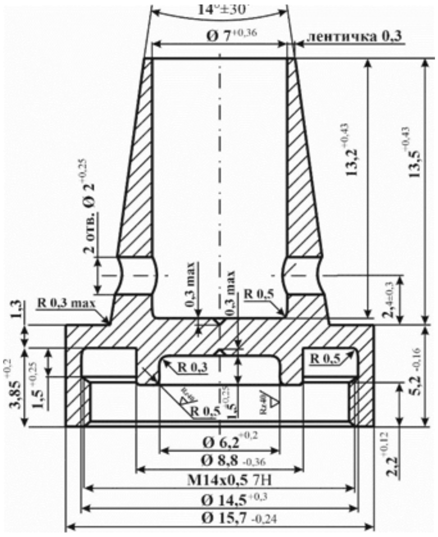


Fig.1. Detail drawing.

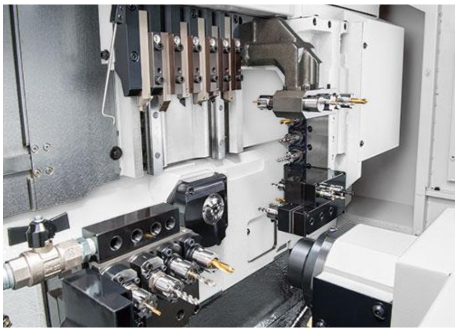


Fig. 2. GOODWAY SW-20 system[3], [13]

Fig.3. Quick-change holder.

The used quick-change tool holder ensures constant tool geometry:

- front angle – γ= -5°;
- rear angle – α = 0.7°;
- main setting angle – kr = 93°;
- auxiliary setting angle - kr¹ = 32°;
- tool tip radius - rε.= 0.2mm.

The turning process was carried out with the following parameters:

- cutting speed Vc = 130÷170 m/min;
- feed f = 0.12÷0.18 mm/turn;
- cutting depth ap = 1.5mm.

When assessing the roughness, a control size Ø15.7+0.2 was used – Fig. 1, on the surface of the machined parts. The measurements were made with a TESA Rugosurf 20 profilometer according to the methodology described in [17], [16]. The device is compatible with the following standards and regulations: DIN 4762, DIN 4768, DIN 4771, DIN 4775 and DIN 4766-1, ISO 4287; ISO 12085 (BDS 728-79).

In practice, various methods are used for the formation of mathematical models and optimization of technological processes [18], [4], [5]. In this particular case, the regression analysis method was used. When building the mathematical model based on preliminary experiments and literature data, the cutting speed (Vc, m/min) – X1, and the feed rate (f, mm/tur) – X2 were selected as input variables, and the roughness of the machined surfaces – Y1(Ra, µm) was studied as a target function.

The areas of variation of the factors are shown in Table 2.

III. RESULTS AND DISCUSSIONS

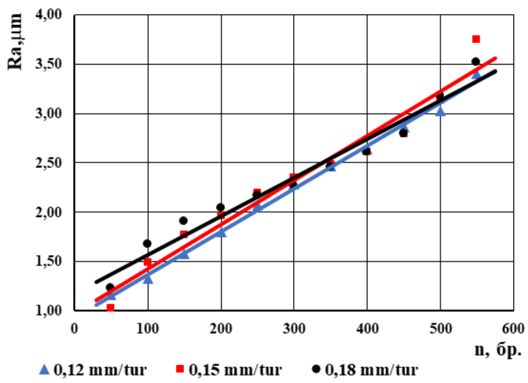
The roughness values in – table 3 were determined when turning batches of 550 parts, with measurements made every 50 pieces. The graphical interpretation is presented in Fig. 4. The statistical processing of the experimental results was carried out in accordance with the methodology set out in [18], [5], in the following sequence: ¬ determination of the model coefficients; ¬ determination of the significance of the regression coefficients using Student's t-test ¬ determination of the multiple correlation coefficient R^2 ¬ determination of the significance of multiple coefficients using the Fisher criterion. The results of the study were processed with the QstatLab software and a mathematical model – 1 was obtained, describing with high accuracy the relationship between the roughness and the cutting mode (Vc m/min and f mm/tur).

TABLE 2 FACTORS AREAS OF VARIATION

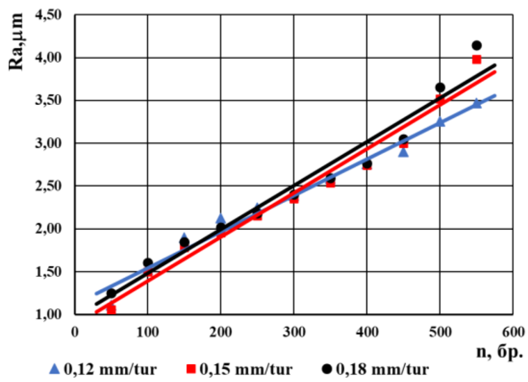
Factor levels	X_1,(Vc) m/min	X_2, (f)mm/tur	Coded value
$X_{i0} + \Delta X_i$	170	0,18	+1
X_{i0}	150	0,15	0
$X_{i0} - \Delta X_i$	130	0,12	-1

The graphical interpretation of the model is shown in Figure 5.

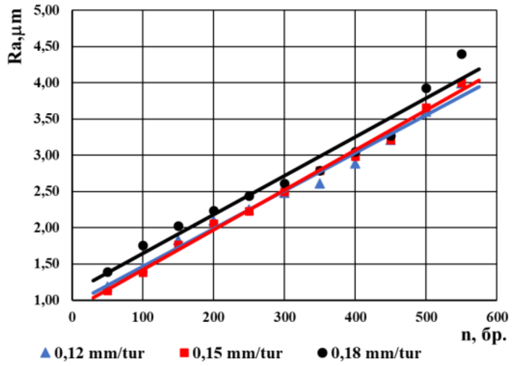
$$У=3,4395556+0,30916667X_1+0,147X_2 \quad (1)$$



a



b

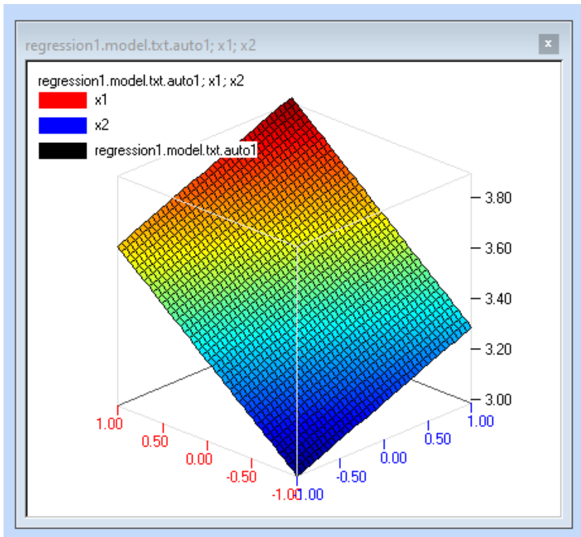


c

Fig.4. Roughness changes on a 550 pcs. batch and feed rate 0,12; 0,15 и 0,18 mm/tur and cutting speed: a - 130 m/min; б - 150 m/min и в - 170 m/min.

TABLE 3. EXPERIMENT PLAN

№	X_0	X_1	X_2	$X_1 X_2$	X_1^2	X_2^2	Y_1
1	+1	+1	+1	+1	+1	+1	3,927
2	+1	-1	+1	-1	+1	+1	3,182
3	+1	+1	-1	-1	+1	+1	3,605
4	+1	-1	-1	+1	+1	+1	3,022
5	+1	+1	0	0	+1	0	3,658
6	+1	-1	0	0	+1	0	3,131
7	+1	0	+1	0	0	+1	3,654
8	+1	0	-1	0	0	+1	3,254
9	+1	0	0	0	0	0	3,523



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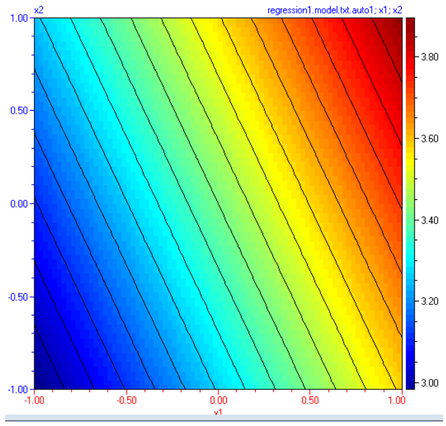

b

Fig.5.Graphical presentation of the mathematical model
a – tridimensional; b – bidimensional.

Based on the obtained model, an analysis of variance (ANOVA) was performed to determine the influence of the controlling factors on the roughness of the machined surface.

A graphical interpretation of this influence is shown on Figure 6.

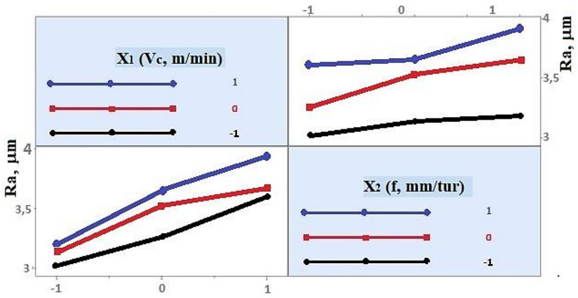

Fig.6. Influence of the factors cutting speed – Vc and feed rate -f to the roughness of the surface.

IV. CONCLUSION

From the studies conducted and the results obtained, the following important conclusions can be formulated:

1. The change in roughness during hard turning of short rotary parts was monitored depending on the cutting speed - Vc = 130÷170 m/min, and the feed - f = 0.12÷0.18 mm/tur, at a constant cutting depth - ap = 1.5mm.

2. Graphical dependences for the change in roughness - Ra, µm, as a function of the cutting speed and feed, for batches of parts from 50 to 550 pieces, were developed.

3. It has been proven that with an increase in the number of processed parts from 50 to 550, the roughness of the size Ø15.7+0.2 increases by 3.5÷4.5 µm.

4. The cutting speed has a more significant influence on the roughness. With its increase from 130 to 170 m/min, the roughness of the machined surfaces when processing batches of 550 parts increases by approximately 1 µm.

5. It has been proven that with a roughness limit of Ra=3.0µm with a cutting speed of 130 m/min, up to 450 parts can be processed regardless of the feed. With an increase in the cutting speed to 170 m/min, while maintaining the roughness requirement, up to 400 parts can be processed.

6. Based on the experimental results, a mathematical model was compiled for the influence of the factors cutting speed and feed on the roughness of the machined surfaces.

7. Graphical dependencies in two- and three-dimensional coordinates of the compiled mathematical model were developed.

8. A dispersion analysis of the mathematical models was performed and graphical dependences for roughness as a function of cutting speed and feed were presented.

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