DEPENDENCE OF PROCESSED SURFACE ROUGHNESS PARAMETERS AND CONCENTRATED TOOLS WEARING FOR TURNING OF THE STEEL C60 BY MIXED CERAMIC CUTTING TOOLS

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Abstract. The paper gives a summary of the experimental research the quality of surface roughness at the final turning of the steel C60 by mixed ceramic cutting tools SH20F from the firm SPK-Feldmuhle. The aim of the research was to determine the best polynomial equation who represent roughness surface in dependence of concentrated tools wearing by comparative analysis various polynomial equations. In the paper is given the original methodology in choice of the polynomial equation. For this experimental researching choosing the third power polynomial, with index nonlinear corelation coefficient R=0,97325.

1. INTRODUCTION

In the theory of metalworking by cutting, there are two ways for determining theoretical laws of change in processed surface roughness [2, 10, 17]:

- geometrical consideration of processed surface quality at processing by sharp cutting tools where cutting tools describe curved line on the material as a result of turning movement of material and straight movement of tools and
- geometrical consideration of processed surface quality at concentrated tools wearing where the process is done in the period of time in which the shape of cutting tools is changed through concentrated tools wearing which is reflected on the processed surface.

Dealing with the problem of final processing on the lathe many researchers in their testing have determined that the parameters of processed surface roughness change in the pass of the time (the other way) which depends on many factors among which the most influential are tools wearing and elements of cutting regime.

2. DEPENDENCE OF PROCESSED SURFACE ROUGHNESS PARAMETERS AND CONCENTRATED TOOLS WEARING

Many researchers developed several mathematical models of dependence of tools wearing and processed surface roughness. In all developed models as an important parameter appeared values of concentrated tools wearing [2, 16]. Using as a starting point developed models so far in the monograph [2] and dissertation [16] is given one theoretical model for calculation of mean arithmetical deviations of profile R_a in the function of concentrated tools wearing in the form of (figure 1.):

$$R_a = \frac{(x_1' + x_2') \cdot b_1''}{s} \quad \textbf{(1)}$$

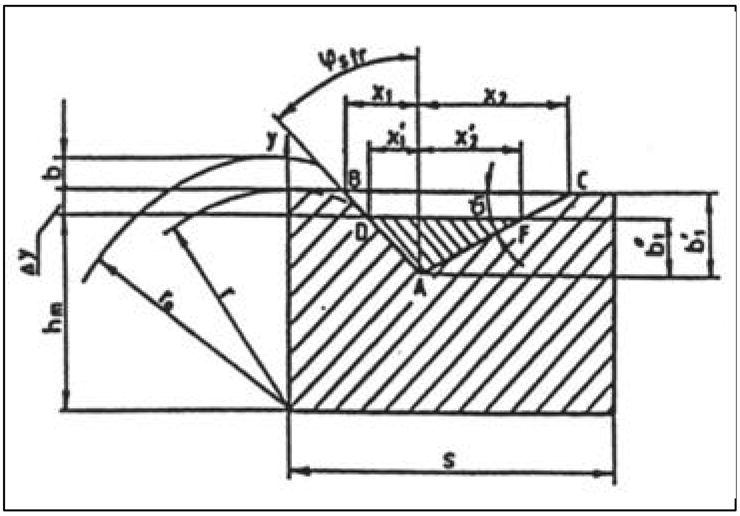


Fig. 1. *Theoretical model of worn cutter projection with elements for determination of* R_a

In books [11-15, 18-21] have given different dependences of tools wearing and processed surface roughness. Many researchers developed several mathematical models of dependence of tools wearing and processed surface roughness. In all developed models, as an important parameter, appeared values of concentrated tools wearing [2, 4, 7, 10, 16, 17]. Dependence of surface roughness parameters and concentrated tool wearing could be mathematical represent by equation:

$$R_a = f(VB) \quad \textbf{(2)}$$

or equation:

$$R_a = f(t) \quad \textbf{(3)}$$

in which the concentrated tool wearing *VB* is replaced with cutting time *t*.

3. TERM OF TESTING

The experiment has been realized in the production conditions of the Industry "14. October" in Krusevac under the following conditions [4, 6, 7]:

- operation: external finished turning,
- material: steel C60 (according to DIN standard) or En9 (according to BS standard), which characteristics are: R_m=800-950 [N/mm^2] and 230-270 HB,
- machine for turning: CNC lathe MD10S from the firm Max Muller,
- cutting tools: tool holder CCLNL2525M16 and the indexable inserts CNGN160808(and 12)T02020 made of mixed ceramic SH20F from the firm SPK-Feldmuhle,
- nose radius: r=0.8 and 1.2 [mm],
- elements of the cutting regime: a=0.25 [mm], s=0.08 [mm/rev] and v=600 [m/min] and
- processing without cooling or lubrication means.

In flow testing have been registered processed surface roughness parameters R_a depended to cutting time *t*. The review of measured values of mean arithmetic deviation of the profile R_a in [µm] depended to cutting time *t* in [min], for finished turning of steel C60 with cutting tool from mixed ceramic, is given in the table 1 [4, 6, 7].

Table 1. *The table review of measured values of R_a depended to cutting time t for finished turning of the steel C60 by mixed ceramic cutting tools*

No. of exper.	t [min]	R_a [µm]	No. of exper.	t [min]	R_a [µm]
1.	0,00	0,34	15.	8,25	0,81
2.	0,75	0,42	16.	9,00	0,82
3.	1,25	0,48	17.	9,75	0,84
4.	1,75	0,52	18.	10,50	0,82
5.	2,50	0,65	19.	11,00	0,86
6.	3,00	0,71	20.	12,00	0,88
7.	3,25	0,75	21.	12,50	0,88
8.	4,00	0,78	22.	13,25	0,90
9.	4,50	0,72	23.	14,00	0,90
10.	5,25	0,70	24.	14,75	0,91
11.	5,75	0,73	25.	15,50	0,92
12.	6,50	0,72	26.	16,50	0,95
13.	7,00	0,76	27.	17,00	0,98
14.	7,75	0,78	28.	18,00	1,05

4. APPROXIMATION EXPERIMENTAL DATA BY POWER POLYNOMIAL

For measured experimental data (table 1) regression dependence was analyzed between R_a=f(t) in form of power polynomial:

$$R_a = b_0 + b_1 \cdot t + b_2 \cdot t^2 + b_3 \cdot t^3 + b_4 \cdot t^4 + b_5 \cdot t^5 \quad \textbf{(4)}$$

Mathematical process of experimental data consists of determination of numerical values of parameters b_0, b_1, b_2, b_3, b_4 and b_5 of power polynomial, choice of the polynomial equation by original methodology and correlation analysis of observed equations of regression, which is performed by software [5], which has been described in monograph [2, 6]. In papers [1-4, 6-10, 17] are given some examples of use of this software.

Determination of polynomial power is problem which appears right at the beginning of analysis of experimental data. The greatest possible theoretical number of the polynomial members is: m-n-1 (n-number experimental points and m-ower polynomial). But, practically, regression beyond the fifth polynomial power hasn't, its application, until the squared (m=2) and the cubic (m=3) regression have often use. Comparative analysis of polynomials 1-st, 2-nd, 3-th, 4-th and 5-th degree, dependence the parameter of surface roughness R_a and cutting time t with variations whose result from individual degree of polynomials t, t^2, t^3, t^4 and t^5 is shown in table 1, and for test the statistical hypothesis about compatibility of experimental data with specify polynomials in table 2. Fig. 2a show graphical data ABC or Pareto diagram relative percent participation only degree of polynomials in form histogram and fig. 2b show graphical data ABC or Pareto diagram cumulative line of dependence the cumulative values of relative percent participation only degree of polynomials on cumulative variation of dependent variable R_a. Fig. 2 show three characteristic fields of dependence the degree of polynomials various significance on overall variation dependent variable R_a:

- Field A: field the biggest influence degree of polynomials 1-st (t) degree, even 82,724 % from overall variation dependent variable R_a;
- Field B: field the influence degree of polynomials 2-nd (t^2) and 3-rd (t^3) degree, even 11,998 (5,480+6,518) % from overall variation dependent variable R_a and

- Field C: field insufficient significant, small influence the degree of polynomials 4-th (t^4) and 5-th (t^5) row and residue of variation, only 2,176 % from overall variation the dependent variable R_a.

From table 2 it can observe that three last polynomials good present experimental data, because it is value of correlation coefficient R major than 0,98. Also from table 2 and from fig. 2b it can observe that the most influence on function R_a=f(t) have degree of polynomial 1-st degree (t), which clear even 82,724 % from overall variation dependent variable R_a (field A on fig. 2b) and degree of polynomial 2-nd degree (t^2), width 5,480 % and 3-rd degree (t^3), width 6,518 % same variation (field B on fig. 2b). Residual degrees of polinomials t^4 and t^5 clear only 2,176 % same varation (field C on fig. 2b). This mean that degree of polinomials major than 3-rd have not main practical influence on function R_a=f(t). In this example the residue of variation for all degree polinomials major from 5 is extremely small, only 3,102 %.
The best experimental rezults present the polinomal 3-rd degree in the form:

$$R_a = 0{,}36735 + 0{,}12081 \cdot t - 0{,}0109 \cdot t^2 + 0{,}00035 \cdot t^3 \quad \textbf{(5)}$$

with index curvilinear corelation R=0,97325.

Fig. 3 show graphical values dependence R_a=f(t) for experimental point and polinomial 3-rd degree.

Table 2. *The table review of the analyzing the approximated dependence R_a=f(t) by power polynomial*

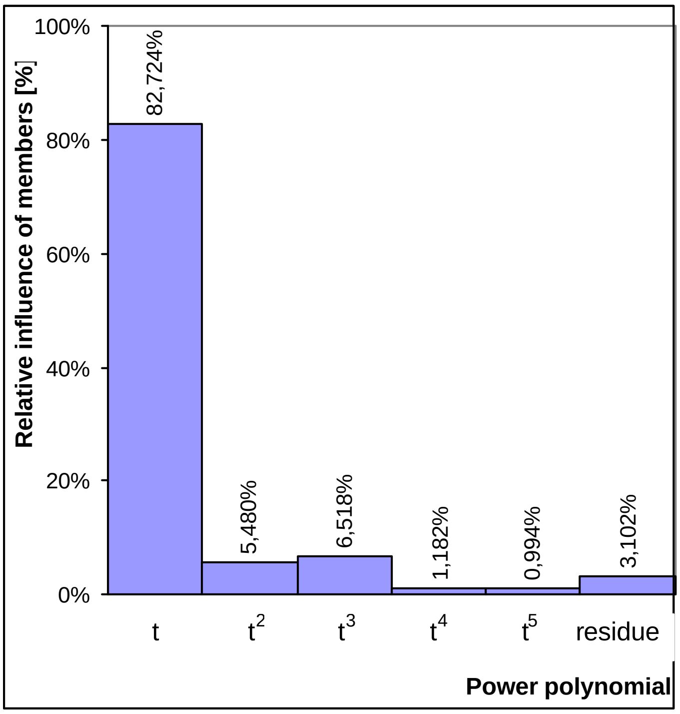
No pp	M	Form of polynomial	S_r^2	S^2	$S_{rm}^2 - S_{r(m-1)}^2$	R	R^2	Influence [%]
1.	1	$R_a = 0{,}53432 + 0{,}02814 \cdot t$	0,62770	0,13109	0,62770	0,90953	0,82724	82,724
2.	2	$R_a = 0{,}45878 + 0{,}05505 \cdot t - 0{,}00152 \cdot t^2$	0,66928	0,08951	0,04158	0,93917	0,88204	5,480
3.	3	$R_a = 0{,}36735 + 0{,}12081 \cdot t - 0{,}0109 \cdot t^2 + 0{,}00035 \cdot t^3$	0,71874	0,04005	0,04946	0,97325	0,94722	6,518
4.	4	$R_a = 0{,}32833 + 0{,}17006 \cdot t - 0{,}0238 \cdot t^2 + 0{,}00149 \cdot t^3 - 0{,}000032 \cdot t^4$	0,72771	0,03108	0,00897	0,97931	0,95904	1,182
5.	5	$R_a = 0{,}29551 + 0{,}23864 \cdot t - 0{,}05253 \cdot t^2 + 0{,}00589 \cdot t^3 - 0{,}00031 \cdot t^4 + 0{,}0000063 \cdot t^5$	0,73525	0,02355	0,00754	0,98437	0,96898	0,994

5. CONCLUSION

Member of power polynomial of characteristics machining processes is chosen on the base of author's original methodology and software [5] of the choice or minimizing of the power polynomial.

In the paper is given the original methodology in choice of the polynomial equation. According to this methodology it has determined functional dependence between surface roughness R_a and cutting time *t* for . Analyzing of experimental results conclusion is that the best equation for functional dependence between surface roughness R_a and cutting time *t* per tooth is polynomial equation 3-rd degree.

a) Paret's (ABC) diagram of relative influence of members polynomial on variation of dependable variable R_a



b) Paret's (ABC) diagram of cumulative influence of members polynomial on variation of dependable variable R_a

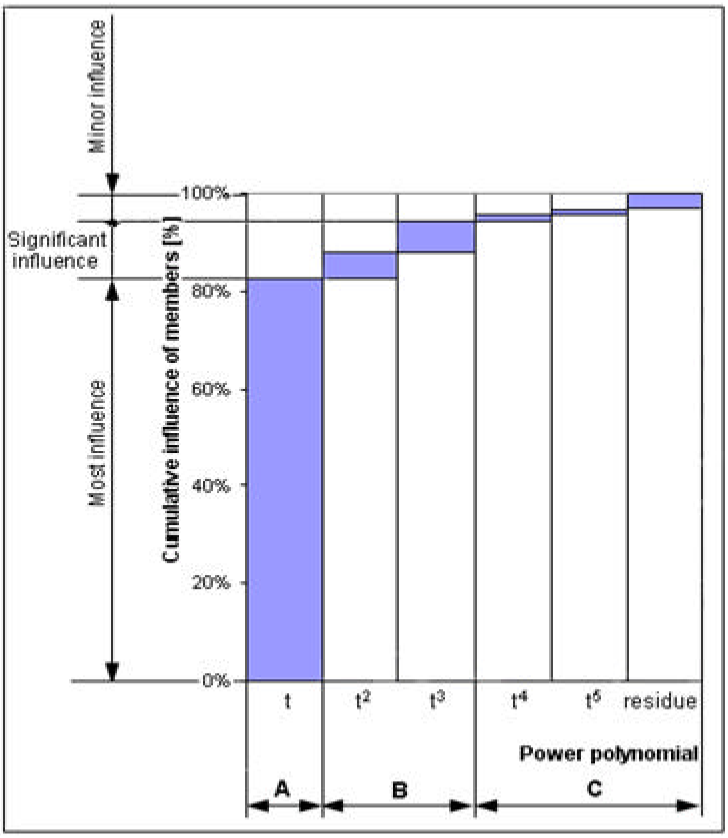


Fig. 2: *Graphic review of grading of members polynomial of the regression equation of dependable variable* R_a

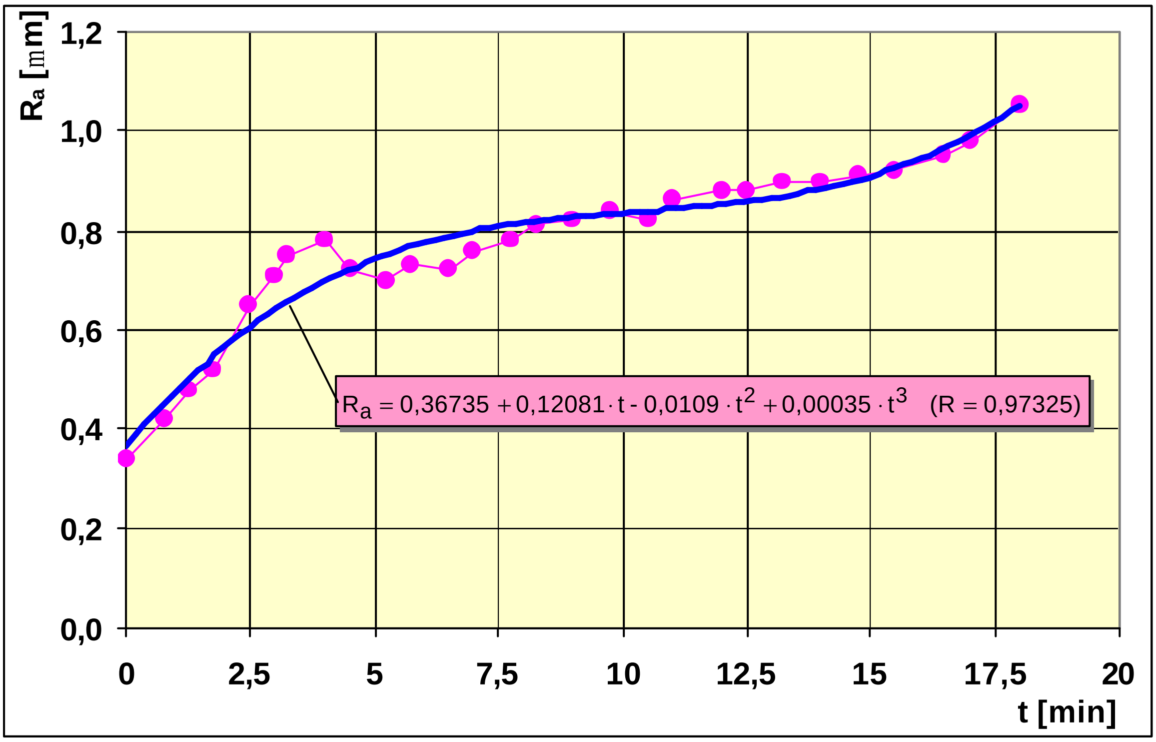


Fig. 3: *Graphic review of dependence R_a=f(t) for of experimental point and polinomial 3-rd degree*

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