Analysis of wear cutting tools by complex power-exponential function for finishing turning of hardened steel 20CrMo5 by mixed ceramic tools

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ANALYSIS OF WEAR CUTTING TOOLS BY COMPLEX POWER-EXPONENTIAL FUNCTION FOR FINISHING TURNING OF THE HARDENED STEEL 20CrMo5 BY MIXED CERAMIC TOOLS

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ABSTRACT

In this paper it is analised the dependence regression between flank wear tools or wear out of belt width on the back surface VB and cutting time t in the form of complex power-exponential regression equation for turning of steel grade 20CrMo5 of cutting tools from mixed ceramic for the different values of the cutting speed v=79.2 and 113.1 m/min. Correlation coefficient for given examples of experimental researching is R=0.993 and it means that relative error of experiment is less than $\overline{\alpha}_{rel}$ *=3.7 %.*

KEYWORDS: Metalworking, turning, ceramic cutting tool, wear cutting tool.

1. INTRODUCTION

Metal cutting causes several types of wear mechanisms depending on cutting parameters (primarily cutting speed and feed), work piece material and cutting tool material. Like most wear applications, tool wear has proved difficult to understand and predict. However, most tool wear can be described by a few mechanisms, which include: abrasion, adhesion, chemical reaction, plastic deformation and fracture. These mechanisms produce wear scars that are referred to as flank wear, crater wear, notch wear and edge chipping as illustrated in figure 1 [25]. Standard parameters of wear independent of type of tool material are defined in international standard ISO 3685:1993 [21]. Most commonly as a parameter of wear it is used the flank wear tools or the wear out of belt width on the back surface *VB* because of this size in significant amount depends the capability of tools to perform the cutting. Papers [2, 3] illustrate typical tool wear features in finish turning and defines *VB* and VB_{max} and its measure.

Monitoring changes of individual parameters of tools wear in the process of cutting comes to so-called wear curve which represent an image of wear process in definite time interval. Existence of more parameters of cutting axle pin wear refers to conclusion that one and the same process of wear can be presented with more wear curves that can be by its shape and position in coordinate system *(VB, t)*, very different.

Research and application of ceramic cutting tools in fields of metalworking is given in paper [1, 4-7, 9-12, 16, 29-31, 33, 37, 39, 40].

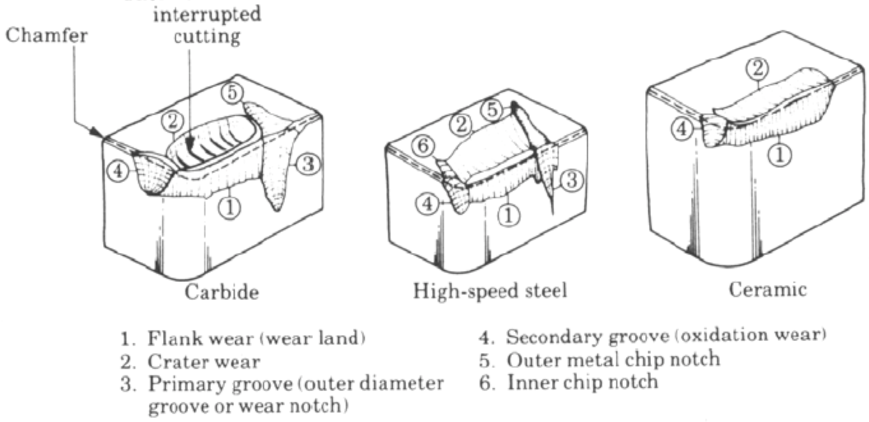

Fig. 1. Tools wear mechanisms for different tool materials [25].

2. POSSIBLE FORMS OF FUNCTION APPROXIMATION OF TOOLS WEAR

Dependence function of tool wear *h* and time of finishing *t*:

$$VB = f(t) \tag{1}$$

is of complex form and is derivated experimentally.

In literature there are present different approaches of approximation of experimental tool wear curve with regression equation of different form.

Approximation function of tool wear is performed mostly with one or two power function, which is parable [18, 22-24, 26, 28, 32, 36]. If it is used an approximation with two power function, it is applied to first phase of wear (usually until appearance of tool flank wear or wear out of belt width on the back surface from 0.1 to 0.3 mm):

$$VB = a \cdot t^{b_1} \quad \Big|_{t=0}^{t=t_1} \tag{2}$$

And the second phase which lasts until appearance of critical wear of cutting tools:

$$VB = c + a \cdot t^{b_1} \quad \Big|_{t=t_1}^{t=t_k} \tag{3}$$

In modern cutting tools with coated hard metal limitations to which lasts the first phase of wear tools process is shifted by set conditions of finishing and to 0.4 mm and even more.

In papers [17, 18, 22-24, 26-28, 32, 36] as approximating function of cutting tool wear there are proposed power and exponential functions.

Process of tool wear is of continual nature and that means that in transformation from first to second phase in point of contact, both parabols (2) and (3) have common tangent. In research practice, however apears experimental curves of tool wear that can be aproximated with two parabols, but which do not have common tangent in the point of transformation from first phase to second phase, but crossing in that point. Existance of cross point implicates the appearance of discontiunity in development of tool wear process for which is hard to find practical explenation.

Among power functions as approximating functions of cutting tool wear, we proposed is power-exponential function form [7, 9, 11, 12, 15]:

$$VB = a \cdot t^{b_1} \cdot e^{b_2 \cdot t} \quad \Big|_{t=0}^{t=t_k} \tag{4}$$

Under theoretical consideration, the approximation function of cutting tool wear can be applied in a polinomial m-level form [7, 9, 18, 34, 38]:

$$VB = P_m(t) = b_1 \cdot t + b_2 \cdot t^2 + b_3 \cdot t^3 + \ldots + \\ + b_m \cdot t^m = \sum_{j=0}^{m} b_j \cdot t^j \tag{5}$$

Curves of complex power-exponential function (4) and polinomial m-level (5) are defined for all zones of tool wear, while in the same case two curves of power function form are needed.

Approximation function of tool wear with complex exponential function (4) and polinomial m-level (5) are far more reliable determined and present a cross point during the transformation from first to second phase in relation to power function.

This paper gives an effort of approximation regression, that is functional dependance between tool flank wear or wear out of belt width on the back surface *VB* and cutting time *t* using complex power-exponential function.

3. TERMS OF TESTING

Using the experimental methods it could be possible to establish regression dependence between the tool flank wear or wear out of belt width on the back surface *VB* and cutting time *t* and influential factors for certain kind of material and cutting tools, too.

For establishing the dependence between tool flank wear *VB* and cutting time *t* during turning of hardened steel grade 20CrMo5 with mixed ceramic cutting tools, experimental testing had been performed in IMK ″14. October″ in Krusevac, under the following conditions:

- *operation:* finish alongside turning,
- *material:* steel grade C.4721 (according to JUS standard) or grade 20CrMo5 (according to DIN standard) or grade 18CD4(S) (according to AFNOR standard), which is hardened to 58...60 HRC,
- *machine for turning:* CNC lathe MD5S from the firm Max Muller,
- *cutting tools:* tool holder CCLNL2525M16 and the multi-bladed indexable inserts CNGN160816T02020 made of mixed ceramic SH1 from the firm SPK-Feldmuhle,
- *nose radius: r= 1.2 [mm]*,
- *elements of the cutting regime:* cutting depth *a=0.3...0.5 [mm]*, number of passes *i=1*, feed *s=0.09...0.16* [mm/rev] and cutting speed *v=79.2* and *113.1 [m/min]*,
- processing without cooling or lubrication means and
- *device for measure of wear tools:* microscope.

In the process of testing it was monitored the value of tool flank wear or wear out of belt width on the back surface *VB* in [mm], whose measured values in dependence to cutting time *t* in [min], shown in the table 1 and figure 2.

4. APPROXIMATION EXPERIMENTAL DATA BY COMPLEX POWER-EXPONENTIAL REGRESSION EQUATION

For measured experimental data (table 1) regression dependence was analysed between *VB=f(t)* in form of a complex power-exponential regression equation:

$$VB = a \cdot t^{b_1} \cdot e^{b_2 \cdot t} \tag{6}$$

Mathematical processing of experimental data consists of determination of numerical values of parameters b_0, b_1, b_2 and a under the form of a complex power-exponential regression equation and correlation analysis of observed equations of regression, which is performed by CoRETV (***C**hoice **o**f **R**egression **E**quation Between **T**wo **V**ariables*) software [8], which has been described in monograph [7, 9] and theory on regression and correlation analysis in books [19, 20, 35]. In papers [4-7, 9, 12-16] are given some examples of use of this software.

In order to find complex power-exponential regression equation by the use of smallest squares linerisation is performed by logarithm and it shows that:

$$lnVB = lna + b_1 \cdot lnt + b_2 \cdot t \tag{7}$$

If for equation (4) are imported shifts:

$$y = lnVB$$
$$X = t \tag{8}$$
$$b_0 = lna$$

equation (4) gains linear form:

$$Y = b_0 + b_1 \cdot lnX + b_2 \cdot X \tag{9}$$

Applying for equation (9) which represents a straight line, method of smallest-squares, it can be determined parameters of cubic regression b_0, b_1 and b_2.

The best shape of approximate curve (7) of assembly of experimental points with coordinates *(VB, t)* is one which addition of squares variations around regression has minimal value:

$$S^2 = \sum_{i=1}^{n}(Y_i-\hat{Y}_i)^2 = \sum_{i=1}^{n}(Y_i-b_0- b_1 \cdot lnX_i-b_2 \cdot X_i)^2 \rightarrow min \tag{10}$$

With the partial differentiate of the function S^2, equation (10), measured with the parameters b_0 and b_1 and to equal those partial perorate with the zero we can get the system of linear algebra equation for determination of the parameters b_0, b_1 and b_1:

$$\begin{aligned} & b_0 \cdot n + b_1 \cdot \Sigma lnX_i + b_2 \cdot \Sigma X_i = \Sigma Y_i \\ & b_0 \cdot \Sigma lnX_i + b_1 \cdot \Sigma (lnX_i)^2 + b_2 \cdot \Sigma X_i \cdot lnX_i = \Sigma (lnX_i) \cdot Y_i \\ & b_0 \cdot \Sigma X_i + b_1 \cdot \Sigma X_i \cdot lnX_i + b_2 \cdot \Sigma X_i^2 = \Sigma X_i \cdot Y_i \end{aligned} \tag{11}$$

The systems' solution of the linear algebra equations (8) can be realized by inversion of the matrix. In general case the normal system equations (8) can be expressed in the following matrix shape:

Table 1. The table review of experimental values of dependence VB=f(t) for the different values of the cutting speed v=79.2 and 113.1 [m/min], for finishing turning of steel 20CrMo5 by mixed ceramic cutting tools.

Experimental values of dependence VB=f(t) for v=79.2 [m/min]			Experimental values of dependence VB=f(t) for v=113.1 [m/min]		
No. exper.	t [min]	VB [mm]	No. exper.	t [min]	VB [mm]
1.	2.50	0.12	1.	0.15	0.12
2.	4.50	0.16	2.	0.25	0.17
3.	7.00	0.20	3.	0.40	0.22
4.	10.00	0.24	4.	5.50	0.25
5.	12.50	0.28	5.	7.50	0.28
6.	15.00	0.33	6.	9.00	0.31
7.	17.50	0.37	7.	10.50	0.35
8.	18.66	0.40	8.	11.80	0.40

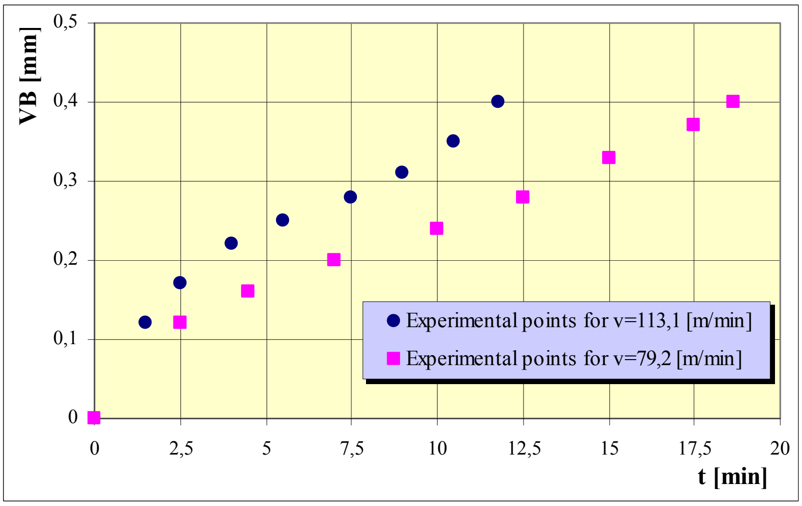

Fig. 2. The graphic review of experimental values of dependence *VB=f(t)*, for the different values of the cutting speed v=79.2 and 113.1 [m/min], for finishing turning of steel 20CrMo5 by mixed ceramic cutting tools.

$$\begin{bmatrix} n & \Sigma lnX_i & \Sigma X_i \\ \Sigma lnX_i & \Sigma (lnX_i)^2 & \Sigma X_i \cdot lnX_i \\ \Sigma X_i & \Sigma X_i \cdot lnX_i & \Sigma X_i^2 \end{bmatrix} \cdot \begin{bmatrix} b_0 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} \Sigma Y_i \\ \Sigma (lnX_i) \cdot Y_i \\ \Sigma X_i \cdot Y_i \end{bmatrix} \quad (12)$$

Or shorter in the shape of the matrix equation:

$$X \cdot b = Y \quad (13)$$

Parameter calculation of the linear regression value b_0 and b_1 is realized in the matrix shape by matrix equation.

$$b = X^{-1} \cdot Y \quad (14)$$

4.1. Determination of Complex Power-Exponential Regression Equation for Functional Dependence between Tool Wear and Cutting Time for Cutting Speed v=79.2 [m/min]

Parameter calculation b_0, b_1 and b_2 of the linear regression for the mentioned example is consisted in the solving of the normal system equation (12) with the following shape:

$$\begin{bmatrix} 8 & 17.69123 & 87.66 \\ 17.69123 & 42.65905 & 222.5935 \\ 87.66 & 222.5935 & 1211.196 \end{bmatrix} \cdot \begin{bmatrix} b_0 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -11.28157 \\ -22.86165 \\ -106.1239 \end{bmatrix} \quad (15)$$

on the base of which is: $b_0=-2.4941$; $b_1=0.3342$; $b_2=0.03147$ and $a=0.08257$.

From that point the equation of the complex power-exponential regression equation has the shape:

$$VB = 0.08257 \cdot t^{0.3342} \cdot e^{0.03147 \cdot t} \quad (16)$$

Confidence interval of parameter b_0, for level of significance $\alpha=5$ *[%]* and 5 freedom level number, is:

$$\begin{gathered} b_0 = b_0 + \Delta b_0 = -2.4941 \pm 0.2914 \Rightarrow \\ -2.4941 - 0.2914 < b_0 < -2.4941 + 0.2914 \end{gathered} \quad (17)$$

or:

$$-2.7855 < b_0 < -2.2027 \quad (18)$$

Confidence interval of parameter b_1, for level of significance $\alpha=5$ *[%]* and 5 freedom level number, is:

$$\begin{gathered} b_1 = b_1 + \Delta b_1 = 0.3342 \pm 0.0896 \Rightarrow \\ 0.3342 - 0.0896 < b_1 < 0.3342 + 0.0896 \end{gathered} \quad (19)$$

or:

$$0.2446 < b_1 < 0.4238 \quad (20)$$

Confidence interval of parameter b_2, for level of significance $\alpha=5$ *[%]* and 5 freedom level number, is:

$$\begin{gathered} b_2 = b_2 + \Delta b_2 = 0.03147 \pm 0.01065 \Rightarrow \\ 0.03147 - 0.01065 < b_2 < 0.03147 + 0.01065 \end{gathered} \quad (21)$$

or:

$$0.020821 < b_2 < 0.04212 \quad (22)$$

The correlation coefficient R is:

$$R = \sqrt{1 - \frac{S^2}{S_y^2}} = \sqrt{1 - \frac{0.001464479}{1.2492952}} = 0.99941 \quad (23)$$

The analogous table value R_t for the result of significance coefficient correlation, for the level of significance $\alpha=5$ *[%]* and the freedom level number $k=8\text{-}3=5$, by the table in [8] is: $R_t=0.7545$.

Because it is:

$$R = 0.99941 > R_t = 0.7545 \quad (24)$$

there is the base that the hypothesis about significance of the correlation coefficient acceptation, i.e. the correlation coefficient r is significant on R-test base, for the significant level $\alpha=5$ *[%]* (assumed complex power-exponential regression equation (16) is good at representation of experimental data).

The determinate coefficient R^2 is:

$$R^2=0.99883 \quad (25)$$

and mean relative error of experiment is:

$$\overline{\alpha}_{rel} = 1.3039\ \%. \quad (26)$$

The calculated value F_r for marking of adequate of regression equation is:

$$F_r = \frac{S_r^2}{S_e^2} = \frac{1.247831}{0.0002928957} = 4260.325 \quad (27)$$

The analogues table value F_t for the result of adequate regression equation, for the level of significance $\alpha=5$ *[%]* and freedom scale number: $k_1=1$ and $k_2=8\text{-}3=5$, by the table in [8] is $F_t=6.6079$.

Because it is:

$$F_r = 4260.325 > F_t = 6.6079 \quad (28)$$

there is the base that the hypothesis of adequate regression equation acceptation, i.e. hypothesis about complex power-exponential regression (16) is adequate (consistent) with the experimental data, on the F-test base, for the significance $\alpha=5$ *[%]* (assumed complex power-exponential regression equation (16) is good at representing of experimental data).

The same conclusion is derived and on the base of the significance the result of the correlation coefficient (R-test), in equation (24).

View of testing of statistical hypothesis for this example is shown in table 2. The dependence between flank wear VB and cutting time t, for cutting speed v=79.2 [m/min], is graphically shown in figure 3.

4.2. Determination Complex Power-Exponential Regression Equation for Functional Dependence between Tool Wear and Cutting Time for Cutting Speed v=113.1 [m/min]

Parameter calculation b_0, b_1 and b_2 of the linear regression for the mentioned example is consisted in the solving of the normal system equation (12) with the following shape:

$$\begin{bmatrix} 8 & 13.4444 & 52.3 \\ 13.4446 & 26.340087 & 106.52 \\ 52.3 & 106.52 & 441.49 \end{bmatrix} \cdot \begin{bmatrix} b_0 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -11.2029 \\ -16.81391 \\ -63.21467 \end{bmatrix} \quad (29)$$

on the base of which is: $b_0=-2.2998$, $b_1=0.5273$, $b_2=0.002029$ and $a=0.10028$.

Table 2. The table view of testing of statistical hypothesis for presented example.

Title hypothesis	Freedom level number k	Calculate values of test	Table values of test	Mark of hypothesis for α=5[%]
Mark of significance parameter of regression b_0 on the basis t-test	5	-21.99841	2.5706	significance
Mark of significance parameter of regression b_1 on the basis t-test	5	9.58563	2.5706	significance
Mark of significance parameter of regression b_2 on the basis t-test	5	7.59897	2.5706	significance
Mark of significance correlation coefficient R on the basis R-test	5	0.99941	0.7545	significance
Mark of adequate regression equation on the basis F-test	1; 5	4260.325	6.6079	adequate

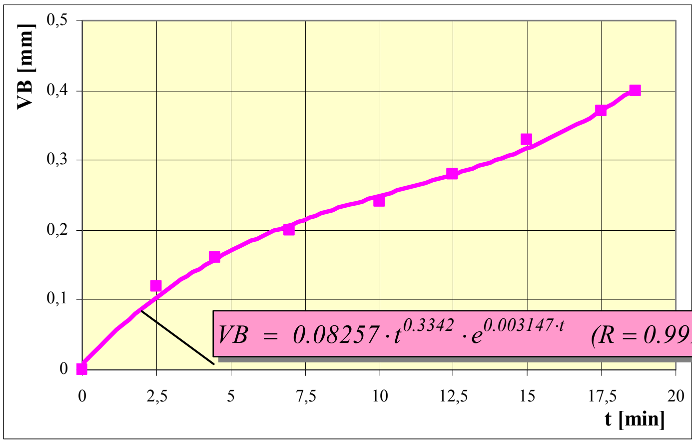

Fig. 3. Graphic review of experimental data and calculated values of dependence $VB=f(t)$, for the cutting speed v=79.2 [m/min], for finishing turning of the steel 20CrMo5 by mixed ceramic cutting tools.

From that point the equation of the complex power-exponential regression equation has the shape:

$$VB = 0.10028 \cdot t^{0.5273} \cdot e^{0.002029 \cdot t} \tag{30}$$

Confidence interval of parameter b_0, for level of significance α=5 [%] and 4 freedom level number, is:

$$\begin{gathered} b_0 = b_0 + \Delta b_0 = -2.2998 \pm 0.7079 \Rightarrow \\ -2.2998 - 0.7079 < b_0 < -2.2998 + 0.7079 \end{gathered} \tag{31}$$

or:

$$-3.0077 < b_0 < -1.5919 \tag{32}$$

Confidence interval of parameter b_1, for level of significance α=5 [%] and 4 freedom level number, is:

$$\begin{gathered} b_1 = b_1 + \Delta b_1 = 0.5273 \pm 0.2617 \Rightarrow \\ 0.5273 - 0.2617 < b_1 < 0.5273 + 0.2617 \end{gathered} \tag{33}$$

or:

$$0.2656 < b_1 < 0.7890 \tag{34}$$

Confidence interval of parameter b_2, for level of significance α=5 [%] and 4 freedom level number, is:

$$\begin{gathered} b_2 = b_2 + \Delta b_2 = 0.002029 \pm 0.050756 \Rightarrow \\ 0.002029 - 0.050756 < b_2 < 0.002029 + 0.050756 \end{gathered} \tag{35}$$

or:

$$-0.048727 < b_2 < 0.052785 \tag{36}$$

The correlation coefficient R is:

$$R = \sqrt{1 - \frac{S^2}{S_y^2}} = \sqrt{1 - \frac{0.01355851}{1.095441}} = 0.99379 \tag{37}$$

The analogous table value R_t for the result of significance coefficient correlation, for the level of significance $\alpha=5$ [%] and the freedom level number $k=8-3=5$, by the table in [8], is $R_t=0.7545$.

Because it is:

$$R = 0.99379 > R_t = 0.7545 \tag{38}$$

there is the base that the hypothesis about significance of the correlation coefficient acceptation, i.e. the correlation coefficient r is significant, on R-test base, for the significant level $\alpha=5$ [%] (assumed complex power-exponential regression equation (30) is good at representation of experimental data).

The determinate coefficient R^2 is:

$$R^2 = 0.98762 \tag{39}$$

and mean relative error of experiment is:

$$\overline{\alpha}_{rel} = 3.6889\ \%. \tag{40}$$

Calculate value F_r for marking of adequate of regression equation is:

$$F_r = \frac{S_r^2}{S_e^2} = \frac{1.081875}{0.002711701} = 398.9655 \tag{41}$$

The analogues table value F_t for the result of adequate regression equation, for the level of adequate regression equation, for the level of significance $\alpha=5$ [%] and freedom scale number: $k_1=1$ and $k_2=8-3=5$, by the table in [8], is: $F_t=6.6079$.

Table 3. The table view of testing of statistical hypothesis for presented example.

Title hypothesis	Freedom level number, k	Calculate values of test	Table values of test	Mark of hypothesis for α=5[%]
Mark of significance parameter of regression b_0 on the basis t-test	4	-8.35164	2.5706	significance
Mark of significance parameter of regression b_1 on the basis t-test	4	5.17985	2.5706	significance
Mark of significance parameter of regression b_2 on the basis t-test	4	0.10275	2.5706	insignificance
Mark of significance correlation coefficient R on the basis R-test	4	0.99379	0.7545	significance
Mark of adequate regression equation on the basis F-test	1; 4	398.9655	6.6079	adequate

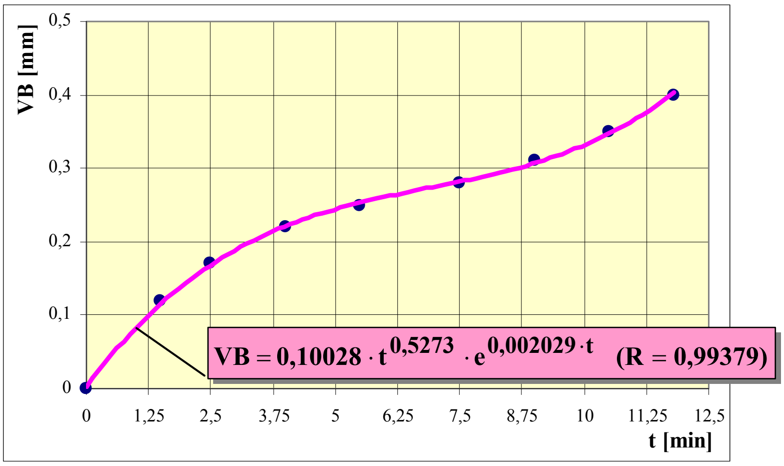

Fig. 4. Graphic review of experimental data and calculated values of dependence *VB=f(t)*, for the cutting speed v=113.1 [m/min], for finishing turning of the steel 20CrMo5 by mixed ceramic cutting tools.

Because it is:

$$F_r = 398.9655 \ > \ F_t = 6.6079 \qquad (42)$$

there is the base that the hypothesis of adequate regression equation acceptation, i.e. hypothesis about complex power-exponential regression (30) is adequate (consistent) with the experimental data, on the F-test base, for the significance $\alpha=5$ [%] (assumed complex power-exponential regression equation (30) is good for representing of experimental data).

The same conclusion is derived and on the base of the result significance of the correlation coefficient, in equation (38).

View of testing of statistical hypothesis for this example is shown in table 3. The dependence between flank wear *VB* and cutting time *t*, for cutting speed v=113.1 [m/min], is graphic shown on the figure 4.

5. CONCLUSION

The complex power-exponential regression equation (16) for functional dependence of tool wear *VB* and cutting time *t* for turning of hardened steel 20CrMo5 by mixed ceramic cutting tools for cutting speed v=79.2 [m/min], is good for the representation of experimental data ($R=0.99941$, $R^2=0.99883$ and $\overline{\alpha}_{\mathrm{rel}}=1.3039$ %).

The complex power-exponential regression equation (30) for functional dependence of tool wear *VB* and cutting time *t* for turning of hardened steel 20CrMo5 by mixed ceramic cutting tools for cutting speed v=113.1 [m/min], is good at representation for the experimental data ($R=0.99379$, $R^2=0.98762$ and $\overline{\alpha}_{\mathrm{rel}}=3.6889$ %).

On the base of R-test and F-test, for the level of significance of $\alpha=5[\%]$, the hypothesis about approximation of the mentioned experimental data by the complex power-exponential regression equations (16) and (30), is consistent.

According to analysis of t-test for parameters b_0, b_1 and b_2 (table 2 and 3) it can be sighted that the biggest effect on function *VB=f(t)* have parameters b_0 and b_1, and minimal effect has parameter b_2 and for regression equations (16) and (30).

REFERENCES

1. **Chneider G.,** 2001, Applied Cutting Tool Engineering, Tooling & Productions, available on Web-site: http://toolingandproduction.com/.
2. **Chou Y. K., Evans C. J.,** 2003, Hard turning of M50 steel with different microstructures in continuous and intermittent cutting. *Wear*, Vol. 255, pp. 1388-1394.
3. **Chou Y. K., Evans C. J.,** 1997, Tool wear mechanism in continuous cutting of hardened tool steels. *Wear*, Vol. 212, pp. 59-65.
4. **Dašić P.,** 2001, Research of processed surface roughness for turning hardened steel by means of ceramic cutting tools. In *Proc.*

of 2nd World Tribology Congress, Vienna, Austria,. Edited by Franek F., Bartz W.J., Pauschitz A., Vienna: Österreichische Tribologische Gesellschaft - ÖTG, pp. 522. (Abstracts Proc. in hard copy) and pp. 1-6, (Proc. on CD-ROM). Available on Web site: http://www.oetg.at/website/wtc2001cd/html/M-51-29-055-DASIC.pdf.

5. **Dašić P.,** 2000, Choice analysis of regression depended on quality characteristics, *Proceedings of 5th Balkan Conf. on Operational Research*, Banja Luka, Republic of Serbs, Banja Luka: Faculty of Electronics Engineering.

6. **Dašić P.,** 2005, Interactive dependence of processed surface roughness parameters for turning of the steel C60 by mixed ceramic cutting tools, *Journal of Optimum Technologies, Technologic Systems and Materials in the Machines Building Field – MSTM*, Bacau (Romania): Romanian Technical Sciences Academy and University of Bacau, MSTM-11, No. 1, pp. 206-212.

7. **Dačić P.,** Research of harder materials for finished turning by means of ceramic cutting tools (in preparation in Serbian language), Monography in preparation

8. **Dašić P.,** 2000, *CoRETV: Software package for choice of regression equation between two variables*. ver. 1.0, Kruševac.

9. **Dašić P.**, *Statistical processing of experimental data,* Book 1: *One-factoring regression analysis* (in Serbian language), Monography in preparation

10. **Dašić P., Ječmenica R.,** 1991, Analysis of the machining efficiency by application of the ceramic cutting tools (in Serbian language). *Journal of Tribology in Industry*, Faculty of Mechanical Engineering, University in Kragujevac, Vol. XIII, No. 2, pp. 51-55.

11. **Dašić P., Ječmenica R., Radovanović M.,** 2005, Analysis of the wear tools for turning by modern cutting tools. *Journal of Optimum Technologies, Technologic Systems and Materials in the Machines Building Field – MSTM*, Romanian Technical Sciences Academy and University of Bacau, MSTM-11, No. 1, pp. 213-218.

12. **Dašić P., Nedić B., Ječmenica R.,** 2006, Analysis of function approximation of the wear tools for turning of the cast iron GG-25 by nitride ceramic cutting tools. *Journal of Modelling and Optimization in the Machines Building Fields – MOCM*, Bacau (Romania): Romanian Technical Sciences Academy and University of Bacau, MOCM-12, Vol. 2, pp. 46-60.

13. **Dašić P., Petropoulos G.,** 2002, Dependence regression of the processed surface roughness parameters for turning of cutting tools made of coated carbides (in Serbian language). *Journal of IMK-14 Research and Development*, Kruševac: Institute IMK "14. October", Vol. VIII, No. (14-15) 1-2, pp. 93-98.

14. **Dašić P., Petropoulos G.,** 2005, Research of interdependence of the 2D parameters of processed surface roughness for turning (in Serbian language). Keynote and invitted paper. In *Scientific Book of 5th Int. Scientific Conf. on Production Engineering "Development and Modernization of Production – Razvoj i modernizacija proizvodnje - RIM 2005"*, Bihać, Bosnia and Herzegovina, Edited by Isak Karbegović, Milan Jurković and Vlatko Doleček. Bihać (Bosnia and Herzegovina): Society for Robotics of Bosnia and Herzegovina, pp. 53-70.

15. **Dašić P., Radovanović M.,** 2002, Analysis of the wear cubic boron nitride for turning of the hardened steel. *International Journal of Applied Mechanics and Engineering – IJAME*. Zielona Góra (Poland): University Press, Vol. 7, Special issue (Papers from the Second International Tribology Conference SITC, pp. 341-346.

16. **Dašić P., Radovanović M., Đorđević LJ.,** 2006, Dependence of processed surface roughness parameters and concentrated tools wearing for turning of the steel C60 by mixed ceramic cutting tools. *Annals of the Oradea University - Fascicle of Management and Technological Engineering*, Romania: University of Oradea, Faculty of Management and Technological Engineering, Vol. V (XV), pp. 230 (hard copy) and 1305-1311 (electronic form).

17. **Dawson G.,** 2002, *Machining hardened steel with polycrystalline cubic boron nitride cutting tools.* Dissertation. Georgia (Atlanta): Georgia Institute of Technology, pp.264.

18. **Ekinović S.,** 2001, *Obrada rezanjem*, Zenica: Dom štampe, 2001, s. 307.

19. **Грановский Г. И.,** 1982, *Обработка результатов экспериментальных исследований резания металлов.* Москва: Машиностроение, 112 с.

20. **Hadživuković S., Zegnal R., Čobanović K.,** 1982, *Regression analysis* (in Serbian language). Belgrade: Privredni pregled, pp.262.

21. ISO 3685:1993- Tool life testing with single-point turning tools. Geneve: International Organization for Standardizations (ISO).

22. **Ivković B.,** 1991, *Theory of cutting* (in Serbian language). Kragujevac: Absolutely authors edition, pp. 354.

23. **Janáč A., Bátora B., Baránek I., Lipa Z.,** 2004, *Technológia obrábania*. Bratislava: Slovenská technická univerzita (STU), pp. 288 s.

24. **Kalajdžić M.,** 2004, Tehnology of metalworking I (in Serbian language). 9th Edition. Belgrade: Faculty of Mechanical Engineering, pp. 407.

25. **Kalpakjian S.,** 1997, Manufacturing processes for engineering materials, 3rd Edition. Menlo Park (California): Addison Wesley Longman Inc., pp. 950.

26. **Kocman K., Prokop J.,** 2001, Technologie obrábění, Brno: Vysoké učení techické v Brně, Fakulta strojního inženýrství, pp. 270.

27. **Kopač J,** 2004, Cutting tool wear during high-speed cutting. *Strojniški vestnik – Journal of Mechanical Engineering*, Vol. 50, No. 4, pp. 195-205.

28. **Kopač J.,** 1991, Odrezavanje (in Slovenia language). Ljubljana: Univerza v Ljubljani, Fakulteta za strojništvo.

29. **Kuzin V.V., Dašić P.,** 2003, Prospects of coated ceramic cutting tools use, *Proc. of 3rd Int. Conf. "Research and Development in Mechanical Industy - RaDMI 2003"*, Herceg Novi, Serbia and Montenegro, Trstenik: High Technical Mechanical School, Kruševac: Institute IMK "14. October" and Podgorica: Institute of Faculty of Mechanical Engineering, pp. 289-292. (for Proc. Vol. 1 in hard copy, published in 2004 and for Proc. on CD-ROM).

30. **Momper J. F.,** 1985, *Untersuchung zum standvermogen keramischer werkzeugschneiden beim drehen unter besonderer berucksichtigung der schneideneingriffsverhaltnisse*. Dissertation. Kaiserslautern: Vom Fachbereich Maschinenwesen der Universitat Kaiserslautern, s. 157.

31. **Momper J. F., Friedrich K. M., Fripan M.,** 1987, Keramische Schnidstoffe, Entwicklungsstand - Tendenzen – Anwendungen. *VDI-Z Special* Bd. 129 (1987.), Nr. 4, s. 4-15.

32. **Radovanović M.,** 2002, *Metalworking technology, Cutting work.* Niš: Faculty of Mechanical Engineering, 328 s.

33. **Radovanović M., Dašić P., Ječmenica R.,** 2002, Advanced cutting tool materials, *Proc. of 2nd Int. Conf. "Research and Development in Mechanical Industy - RaDMI 2002"*, Vrnjačka Banja, Yugoslavia, Edited by Dašić P. and Radovanović M. Kruševac: Institute IMK "14. October", Trstenik: IHP "Prva petoletka" and High Technical Mechanical School, pp. 346-351. (Proc. Vol. 1 in hard copy) and (Proc. on CD-ROM).

34. **Soković M., Mikuła J., Dobrzański L. A., Kopač J., Koseč L., Panjan P., Madejski J., Piech A.,** 2005, Cutting properties of the Al2O3 + SiC(w) based tool ceramic reinforced with the PVD and CVD wear resistant coatings. *Journal of Materials Processing Technology*, Vol. 164–165, pp. 924–929.

35. **Stanić J.,** 1989, Method of engineering measuring, Basic of mathematical theory of experiment (in Serbian language). 5th Edition. Belgrade: Faculty of Mechanical Engineering, pp.250.

36. **Stanić, J.:** *Theory of metalworking I* (in Serbian language). 2nd Edition. Belgrade: Faculty of Mechanical Engineering, pp. 268.

37. **Старков К. В., Кузин В. В., Попов Ф. В., Исходжагов Р. Р.,** 1989, Повышение эксплуатационных характеристик изделий из керамических материалов методами механической и термической обработки. *Машиностроительное производство, Серия: Прогресивное технологические процессы в машиносроении, Обзорная информация*, Москва: ВНИИТЭМР, выпуск 4, 64 с.

38. **Tadić B.,** 1990, Contribution to analztical definition of wear curves (in Serbian language). *Journal of Tribology in Industry*, Vol. XII, No. 4, pp. 117-120.

39. **Tanović L.J.,** 1997, Production technology of modern cutting tools elements (in Serbian language). Belgrade: Faculty of Mechanical Engineering, pp. 99.

40. **Whitney E.D.,** 1994, Ceramic cutting tools, Materials, development and performance. Gainesville, Noyes Publications. pp. 352.