

Regression Models of Process Parameters Interdependence in Turning S12Mn2Si Metallized Coatings

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Abstract: - Statistical methods, such as experiments design and regression analysis, performed with special software, do represent successful means to be used in studying important aspects of real machining processes. This article points out the most relevant aspects of research carried out in order to determine new models of process functions specific to exterior cylindrical turning process parameters. The material studied was thermal sprayed S12Mn2Si, a Romanian produced one, with wide application in industry. "Steps" developed in this research could be considered "guidance lines", whenever process parameters relationships are worth to be determined.

Key-Words: - regression model, turning process, cutting tool durability, surface roughness, metallized coating

1 Introduction

It was in 1910 when Max Ubrich Schoop invented the metallizing process. Due to its importance in repairing worn parts and corrosion protection, the process has been imported to the USA (in 1920) and since then, it has known a continuous extend.

Metallizing, or thermal spraying, is defined as the process where pure or alloyed metal is melted in a flame and atomized, by a blast of compressed air into fine spray [2], [6]. A schematic representation of the process (for cylindrical part metallizing) is shown in figure 1.

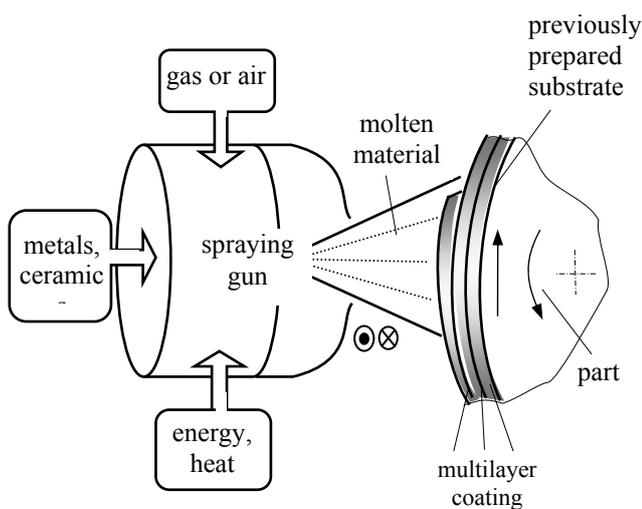


Fig. 1 Schematic representation of the metallizing process - for cylindrical part -

For good adherence of sprayed coating onto the part surface, this has to be carefully, previously prepared. Examples of how "it is done" for exterior cylindrical parts, by mechanical machining, are presented in figure 2.

Observation:

Research presented by this article is on exterior cylindrical turning process so, consequently, the samples were cylindrical ones, with thermal sprayed coating adhering on their exterior surface.

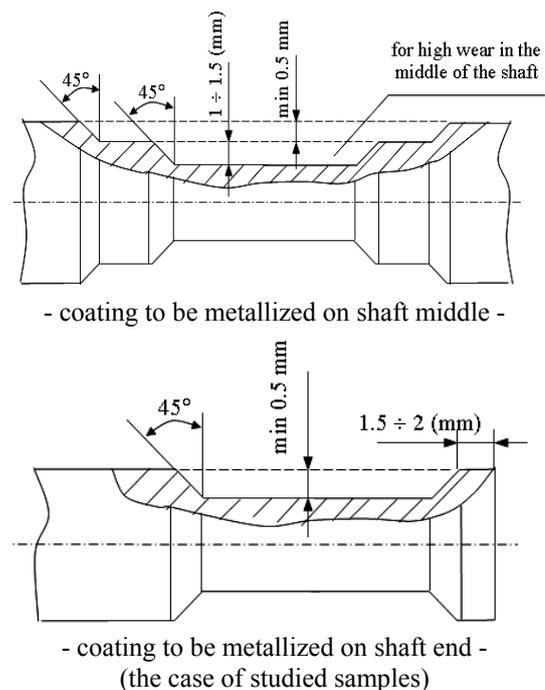


Fig. 2 Examples of prepared surfaces for metallizing

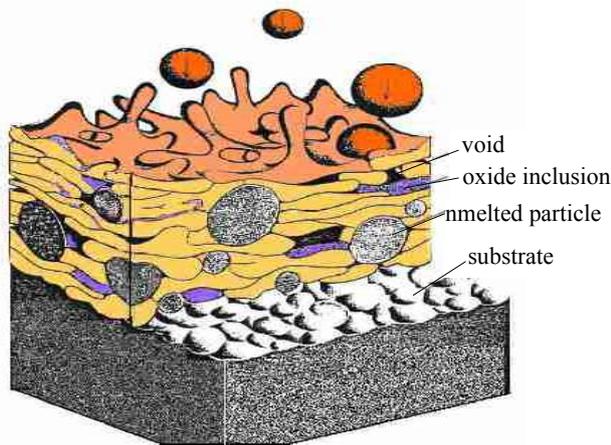


Fig. 3 Thermal sprayed coating structure [6]

Because of the fact that molten metal is “sprayed” by a large amount of air, the part being metallized does not heat up too much. Still, due to the high temperature and velocity of the metal drops, when impacting the previously prepared surface they do flatten and adhere to one another, forming a multilayer structure – see figure 3.

Researches on the phenomena developing while melting and spraying the material, as well as on the impact of metal droplets with the “target” surface are of great importance. Also, new materials suited for thermal spraying and, implicitly, new modern, efficient equipments are developing by producers specialized in thermal spraying processes.

Sources used for generating the energy and heat required can be either: combustion (a combination of hydro-carbides and oxygen) or, electric power (electric arc, plasma discharge). As for material’s initial state, there are two possibilities, meaning: powder form or, wire form.

What material type and, consequently, what energy source to be used, does represent an option depending on the metallised coating required characteristics and on the available equipment.

Even used for corrosion or, specially, for wear protection, the obtained thermal sprayed coatings do need further “preparation” – by machining, polishing or brushing. This is required in order to obtain the prescribed geometrical precision, meaning: dimensions, shape and relative position, as well as roughness of the metallized surfaces.

There are many procedures of machining thermal sprayed coatings, the most frequently used being turning and grinding. Whatever the procedure is, there is always the need for a correct set of machining parameters values, so that optimum machinability and quality conditions (ex.: cutting tool wear, optimum cutting speed, surface roughness) to be ensured.

Specific references studied by the author present recommendations for machining parameters values, when certain materials (usually made by thermal spraying equipments producers) and procedures are involved [1], [2]. Unfortunately, these data are poor quantitative ones and, seldom refer to Romanian produced metallizing steels – that are really of great interest for Romanian industry.

Determining regression models of process parameters interdependence in turning thermal sprayed coating, has been considered fit, thus it should be possible to ensure optimum machinability and quality characteristics for these multilayer structures [3]. The studied metallized material was S12Mn2Si, a Romanian made special steel, widely used in (reconditioning) industry for wear protection of parts.

Further more, the “steps” developed in this research could be considered “guidance lines”, whenever process parameters relationships are worth to be determined.

2 Applied Theoretic Method

The research presented by this article is focused on determining new, relevant regression models of process parameters interdependence relations in cylindrical exterior turning. [3], [4].

It is considered that a process “developing” within a certain technological system, can be defined by the interdependence relation (1):

$$Y = \Gamma(z_1, z_2, \dots, z_j, \dots, z_n) \quad (1)$$

called process function, where:

z_j , $j = 1, 2, \dots, k$ represents the independent process variables (controllable inputs);

Y – the dependent process variable (output);

Γ - the type of dependence relationship.

So, the variables studied are the ones that follow.

- a. Independent variables (controllable inputs), z_j :
 - cutting speed, v [m/min];
 - cutting feed, a_f [mm/rot];
 - cutting depth, f [mm];
 - cutting tool wear, VB [mm];
 - cutting tool nose radius, r [mm]

There are, also, uncontrollable (noise) inputs, like:

- Vickers micro-toughness, $HV_{0.05} = 290$, for the studied metallised coating;
- vibrations of the technological system, at constant speed exterior cylindrical semi-finishing turning, on SN type lathe.

As constant inputs, there can be mentioned the environment characteristics (temperature, humidity, etc).

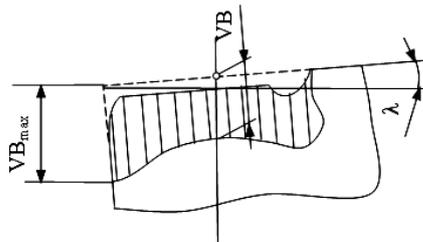


Fig. 4 Definition of the VB parameter – for cutting tool wear, U.

Table 1

Experiment Designs

Design Type	Run	x ₁	x ₂	x ₃		
	Fractional Factorial Design (P 1.2)	1	+1	-1	-1	
2		-1	+1	-1		
3		-1	-1	+1		
4		+1	+1	+1		
5		0	0	0		
6		0	0	0		
Fractional Factorial Design (P 2.1)	Run	x ₁	x ₂	x ₃	x ₄	
	1	-1	-1	-1	-1	
	2	+1	-1	-1	+1	
	3	-1	+1	-1	+1	
	4	+1	+1	-1	-1	
	5	-1	-1	+1	+1	
	6	+1	-1	+1	-1	
	7	-1	+1	+1	-1	
	8	+1	+1	+1	+1	
	9	0	0	0	0	
	10	0	0	0	0	
	11	0	0	0	0	
12	0	0	0	0		
Fractional Factorial Design (P 3)	Run	x ₁	x ₂	x ₃	x ₄	x ₅
	1	-1	-1	-1	-1	-1
	2	+1	-1	-1	-1	+1
	3	-1	+1	-1	-1	+1
	4	+1	+1	-1	-1	-1
	5	-1	-1	+1	-1	+1
	6	+1	-1	+1	-1	-1
	7	-1	+1	+1	-1	-1
	8	+1	+1	+1	-1	+1
	9	-1	-1	-1	+1	+1
	10	+1	-1	-1	+1	-1
	11	-1	+1	-1	+1	-1
	12	+1	+1	-1	+1	+1
	13	-1	-1	+1	+1	-1
	14	+1	-1	+1	+1	+1
	15	-1	+1	+1	+1	+1
	16	+1	+1	+1	+1	-1
	17	0	0	0	0	0
	18	0	0	0	0	0
	19	0	0	0	0	0
20	0	0	0	0	0	
Central Composite Design (CCD)	Run	x ₁	x ₂			
	1.	-1	-1			
	2.	-1	+1			
	3.	+1	-1			
	4.	+1	+1			
	5.	0	0			
	6.	0	0			
	7.	-1	0			
	8.	+1	0			
	9.	0	-1			
10.	0	+1				

b. Dependent variables, Y, as mentioned above, are both,

b1. machinability related variables, like:

- cutting tool wear, U [mm] – evaluated by the VB parameter – see figure 4;
- cutting tool durability, T [min];
- optimum cutting speed, v_{T₀} [mm]

and

b2. quality related variable, meaning:

- surface roughness, R_a [μm].

c. As for the type of dependence relationship – they are polynomial and exponential type ones.

In order to determine regression models for machinability related outputs, first there had to be determined the dependence relation of cutting tool wear, U, on machining time, t – see relation (2).

$$U = a + b \cdot t + c \cdot t^2 + d \cdot t^3 \tag{2}$$

Then, considering a certain wear criterion (VB = 0.28 mm – for the studied turning process type), interdependence relations as (3) had to be obtained.

$$T = A_0 v^{A_1} a_f^{A_3} f^{A_3} \tag{3}$$

Further, it was considered useful to determine the dependence relation of cutting tool durability, T, on all four independent variable specific to the process – see (4)

$$T = A_0 v^{A_1} a_f^{A_3} f^{A_3} \cdot VB^{A_4} \tag{4}$$

Once the most important two inputs influencing the output being evidenced, another kind of interdependence relation has been obtained, meaning a polynomial one (5)

$$T = a_0 + a_1 \cdot a_f + a_2 \cdot VB + a_{12} \cdot a_f \cdot VB + a_{11} \cdot a_f^2 + a_{22} \cdot VB^2 \tag{5}$$

When the number of independent variables studied was “equalling” three, the experiment design considered was conventionally called P 1.2, when it was four, the design was called P 2.1 and when it was two (the most significant ones), it was a central composite design (CCD) – see table 1.

In order to determine regression models for quality related output, first there was determined interdependence relation as (6), for $VB = 0$:

$$R_a = A_0 \cdot v^{A_1} \cdot a_f^{A_2} \cdot f^{A_3} \cdot A_4^r \quad (6)$$

while, the experimental design type was P2.1.

Another model considered fitted for surface roughness variable, is the one considering the fifth independent variable, meaning the VB wear parameter of the cutting tool – see (7).

$$R_a = A_0 v^{A_1} a_f^{A_2} \cdot f^{A_3} \cdot A_4^r \cdot A_5^{VB} \quad (7)$$

Determining this relationship involved an experimental design of P3 type (see table 1).

As for the polynomial type model, due to license rights limitation, there were considered only two variables (most significant two ones, for the studied output) – see relations (8) and (9).

The experiments design was, also, a CCD one.

$$R_a = a_0 + a_1 \cdot r + a_2 \cdot a_f + a_{12} \cdot r \cdot a_f + a_{11} \cdot r^2 + a_{22} \cdot a_f^2 \quad (8)$$

$$R_a = a_0 + a_1 \cdot VB + a_2 \cdot a_f + a_{12} \cdot VB \cdot a_f + a_{11} \cdot VB^2 + a_{22} \cdot a_f^2 \quad (9)$$

Observation:

The number of replicates, for each experience in P type experiments design (P 1.2, P 2.1, P 3) equaled three, while in CCD design, it equaled five.

As for the software used in regression analysis they were the ones that follow:

- CurveExpert 1.3 – for third order polynomial function, $U(t)$;
- REGS –for P 1.2, P 2.1 and P3 experiment designs [8];
- DOE KISS -for CCD design [5].

3 Experiments and Results

Research involved a Romanian made steel, for thermal spraying, S12Mn2Si. Its chemical structure and most important mechanical properties are presented in table 2.

The metallizing process was an electric arc one, with specific parameters values evidenced in table 3 Its schematic representation, as well as an image taken while performing the process, are shown in figure 5.

Metallographic structure of the metallized coating, sprayed on exterior cylindrical surface of OLC 45 (STAS 880-80) material sample, can be noticed in figure 6.

Table 2

Chemical structure and mechanical properties

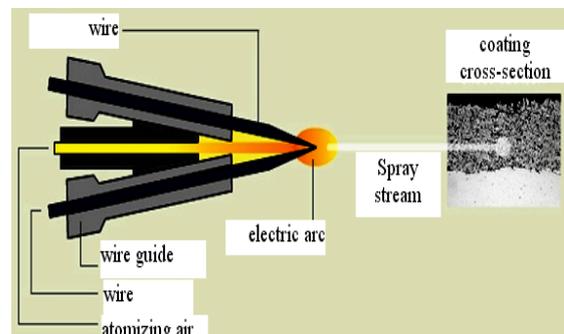
Material	Chemical Structure	HV .05	Porosity [% vol]	Wire Diameter [mm]
S12Mn2Si	max 0,12 % C (1,8 ÷ 2,2) % Mn, max 0,15 % Si	290	7 ÷ 8	$\phi 1,6 \pm_{0,04}$

Table 3

Electric arc metallizing process parameters

U [V]	I [A]	h [mm]	p _a [bar]
26	170	180	5,0

U – electric arc voltage; h – spraying distance
I - current intensity; p_a - pressure of compressed air



- process schematic representation [7] -



- process image -

Fig. 5 Electric arc metallizing process

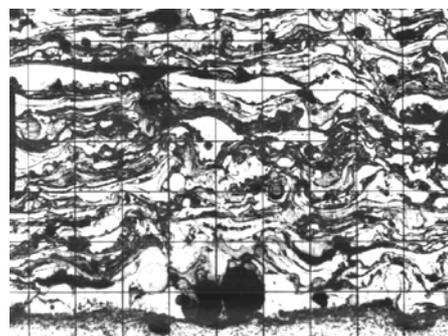


Fig. 6 Metallographic structure of the S12Mn2Si metallized coating

Table 4

Independent variables values								
	Coded values	Real values, for P 1.2, P 2.1 and P 3 designs	Real values, for CCD design					
v [m/min]			-1	23	0.20	0.257	0.315	
			0	36				
			+1	57				
a _f [mm/rot]			-1	0.20				
			0	0.25				
			+1	0.315				
f [mm]			-1	0.25				0.375
			0	0.35				
			+1	0.50				
VB [mm]			-1	0				0
			0	0.14				
	+1	0.28						
r [mm]	-1	0.40	0.40					
	0	0.80						
	+1	1.20						

In order to carry out experiments, there were considered, both, limited variation domains and certain well defined values of the independent variables studied, as shown in table 4. All of these do represent the results of a lot of preliminary experimenting work.

The turning procedure fitted for the studied material, was exterior cylindrical semi-finishing turning and the cutting tool used was conventionally called K20 (based on its mechanic and geometric characteristics).

A. So, experiments done in order to determine regression models for machinability related outputs, “started” with the first set (P 1.2 design), aimed to determine the cutting tool wear, U, dependence on machining time, t.

An image taken while turning the sample is shown in figure 7, while the VB wear of cutting tool is evidenced by figure 8.

For each experience, the process was on and, from time to time (usually every 2 minutes), it stopped and measurements of the tool wear were performed.



Fig. 7 Turning experiments – for machinability related outputs



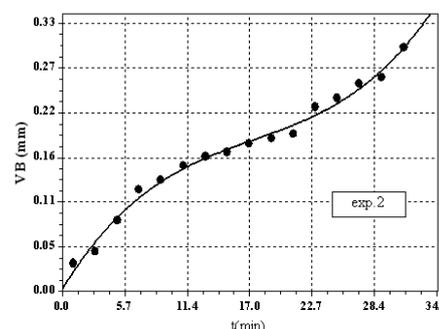
Fig. 8 Cutting tool VB wear

An example of the obtained results is presented in table 5 and, consequently, the plotted graphs are shown in figure 9. The adequate regression models (obtained with CurveExpert 1.3 software) are also mentioned.

Table 5

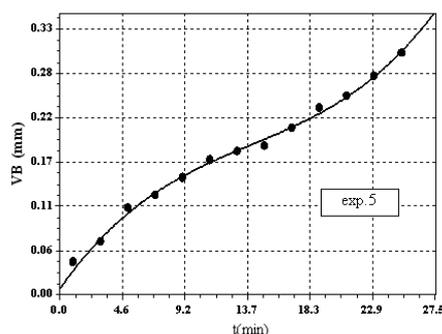
Examples of VB wear experimental results

Experience number (P 1.2 design)			
2		5	
t [min]	VB [mm]	t [min]	VB [mm]
0	0	0	0
1	0,035	1	0,042
3	0,049	3	0,066
5	0,087	5	0,109
7	0,125	7	0,124
9	0,137	9	0,147
11	0,154	11	0,169
13	0,166	13	0,179
15	0,172	15	0,186
17	0,181	17	0,208
19	0,188	19	0,234
21	0,193	21	0,248
23	0,227	23	0,273
25	0,238	25	0,301
27	0,255		
29	0,263		
31	0,299		



$$U = 3.5 \cdot 10^{-3} + 22 \cdot 10^{-3} \cdot t - 10^{-3} \cdot t^2 + 1.9 \cdot 10^{-5} \cdot t^3$$

Fig. 9 Examples of cutting tool wear curves



$$U = 8.3 \cdot 10^{-3} + 24.2 \cdot 10^{-3} \cdot t - 1.2 \cdot 10^{-3} \cdot t^2 + 2.89 \cdot 10^{-5} \cdot t^3$$

Fig. 9 Examples of cutting tool wear curves - continued -



Fig 10 Turning sample in surface roughness experiments

Table 6

Experiments Results – for REGS

P 1.2 design	Cutting tool durability, T [min]						
	Exp. no.	1	2	3	4	5	6
		25.410	29.670	28.550	15.150	23.530	24.080

Once determined the $U(t)$ dependence relations, for the $VB = 0.28$ mm durability criterion (established based on specific references and author’s experience – for the semi-finishing turning process studied) it has been possible (due to software characteristics) to determine the values of output variable, T (cutting tool durability), for each experience – see table 6.

B. Experiments done in order to determine regression models for quality related outputs, referred first to P 2.1 design. They were aimed to determine the surface roughness, R_a , parameter values dependence on process specific parameters (v , a_f , f , r). The obtained experimental results are shown in table 7. An image taken while turning the samples is presented in figure 10.



Fig. 11 Surface roughness values measurements

On the sample, there can be noticed the "rings" (corresponding to each experience of the experiments design program), each about 2 cm width, for R_a roughness measurements. The measurements were taken with a portable instrument, Rugomas, as evidenced by figure 11.

Table 7

Experiments Results – for REGS

P 2.1 design	Surface roughness, R_a [μm]						
	Exp. no.	1	2	3	4	5	6
		4.00	2.40	3.04	8.66	2.26	6.62
Exp. no.	7	8	9	10	11	12	
	7.97	4.96	4.28	4.33	4.44	4.30	

4. Regression Models

A. The regression models related to machinability outputs, of exponential type, have been determined with REGS software.

So, the first obtained dependence relation of cutting tool durability, T, and optimum cutting speed, v_{T_o} , on turning process specific parameters (v , a_f , f) are presented below – see relations (10) and (11).

$$T = e^{3,587} \cdot v^{-0,434} \cdot a_f^{-0,527} \cdot f^{-0,401} \tag{10}$$

$$v_{T_o} = e^{8,265} \cdot T^{-2,304} \cdot a_f^{-1,214} \cdot f^{-0,924} \tag{11}$$

Observation:

The relation (10) model was determined based on experimental results shown in table 6.

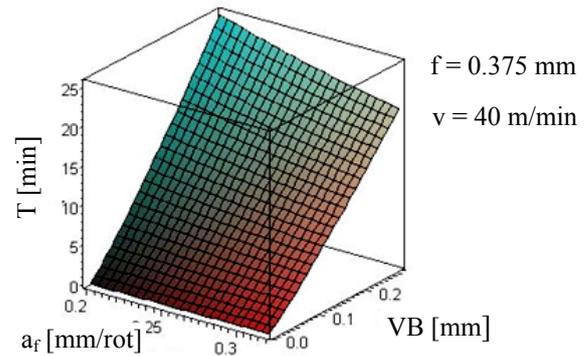
Relation (11) was obtained by "extracting" the v variable from relation (10)

Further experiments were done (as P 2.1 design), in order to determine regression model of fourth independent variable, VB. The results of REGS regression analysis are presented by relations (12) and (13).

$$T = e^{5,050} \cdot v^{-0,440} \cdot a_f^{-0,525} \cdot f^{-0,406} \cdot VB^{1,124} \quad (12)$$

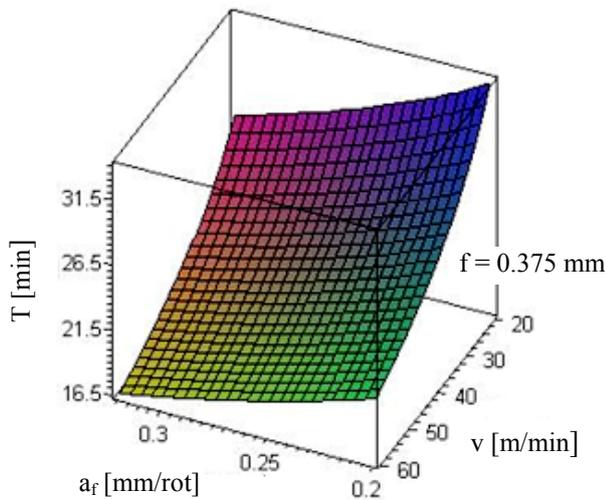
$$v_{T_o} = e^{11,477} \cdot T^{-2,273} \cdot a_f^{-1,193} \cdot f^{-0,923} \cdot VB^{2,555} \quad (13)$$

Some plotted graphs for the above presented regression models are shown in figure 12.



- graph of cutting tool durability dependence on both cutting feed and cutting tool wear - relation (12) -

Fig. 12 Graphical representations of T models



- graph of cutting tool durability dependence on both cutting feed and cutting speed - relation (10) -

Table 8

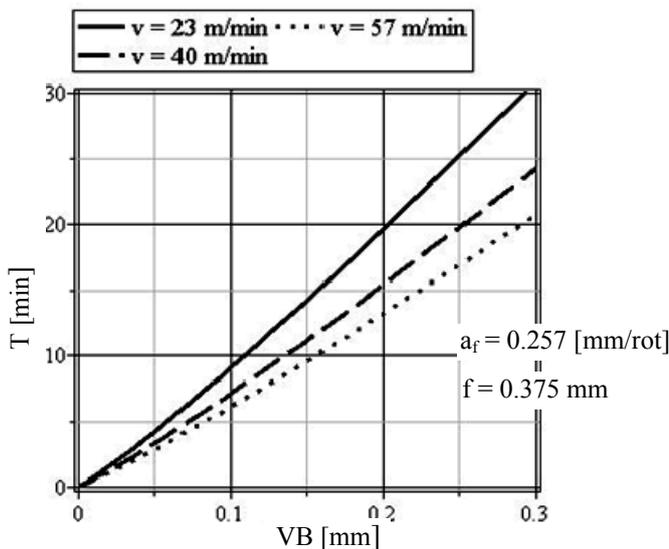
q_i Coefficients Values

	Relation (10)	Relation (12)
$q_v = \left(\frac{v_{max}}{v_{min}} \right)^{a_1}$	0.674	0.671
$q_s = \left(\frac{a_{f_{max}}}{a_{f_{min}}} \right)^{a_2}$	0.787	0.788
$q_t = \left(\frac{f_{max}}{f_{min}} \right)^{a_3}$	0.757	0.755
$q_{VB} = \left(\frac{VB_{max}}{VB_{min}} \right)^{a_4}$	-	3.181

There have been “computed” the q_i coefficients - for evidencing how strong the influence of each independent, on the output, really is- see table 8.

Studying relation (12) and the q_i coefficients values, one can notice that the two most important factors influencing cutting tool durability are the VB wear and the cutting feed a_f. So, a detailed study on their influence has been considered appropriate – and it was done with DOE KISS software. It was determined a polynomial type model and, as mentioned above, due to license rights limitation, there were considered only two variables (the most significant two ones, for the studied output), each with three variation levels.

In order to do the new set of experiments, the values of the independent variables v and f were set to their medium (see table 4), while independent variables a_f and VB were varied according to the CCD of experiments. The obtained experimental results, are presented in table 9.



- graph of cutting tool durability dependence on cutting tool wear - relation (12) -

Fig. 12 Graphical representations of T models – to be continued

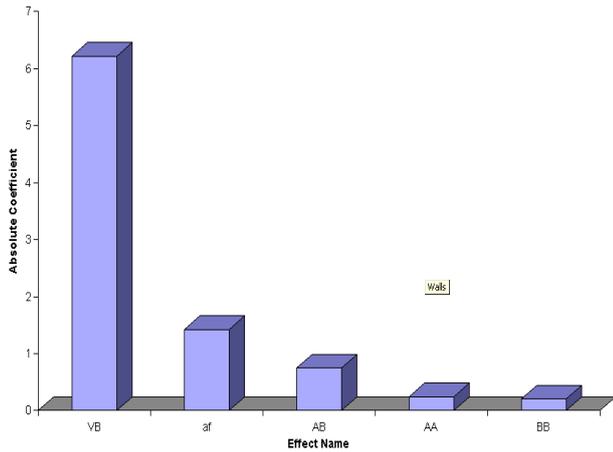


Fig. 14 DOE KISS software - Pareto chart of coefficients – for T model

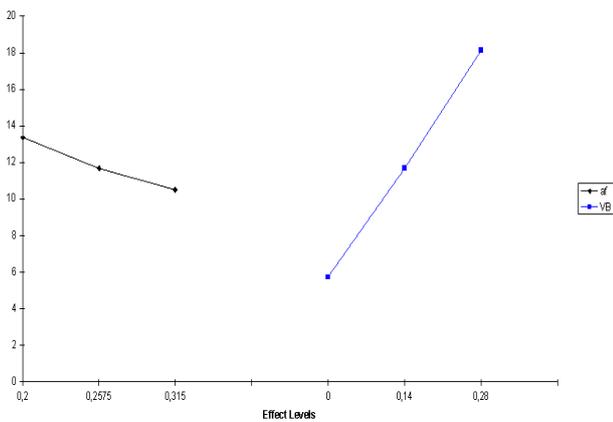
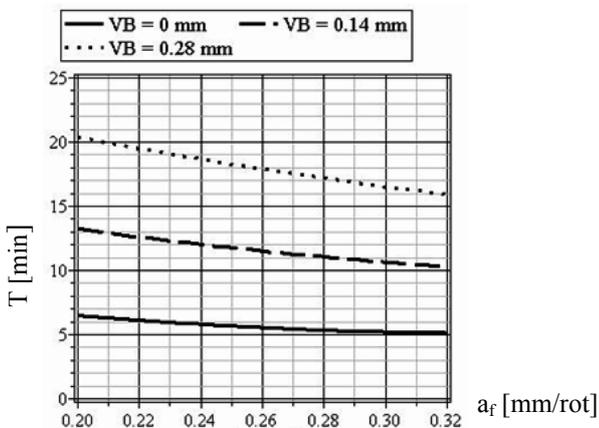


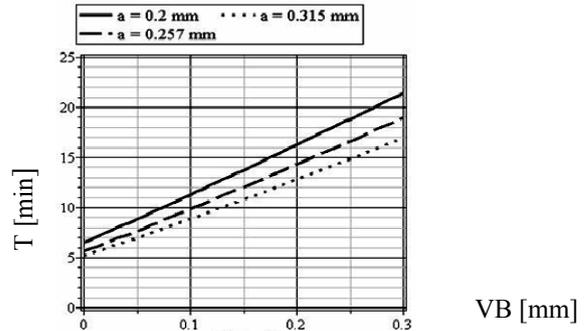
Fig. 15 DOE KISS software - Marginal means plot – for T model

Examples of graphs plotted (with Maple software) for better evidencing the influence of independent variables studied on cutting tool durability are shown in figure 16.

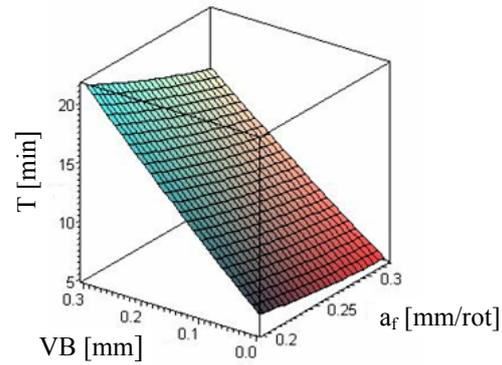


- graph of cutting tool durability dependence on cutting feed - relation (16) -

Fig. 16 Graphical representations of T model – to be continued



- graph of cutting tool durability dependence on cutting tool wear - relation (16) -



- graph of cutting tool durability dependence on both cutting tool wear and cutting feed - relation (16) -

Fig. 16 Graphical representations of T model

B. The exponential type regression models, related to quality outputs, have been determined with REGS software.

First, based on experimental results, presented in table 7, there were determined regression models of surface roughness, R_a . The independent variables considered were the ones specific to turning process, meaning: v (cutting speed); a_f (cutting feed); f cutting depth and r (cutting tool nose radius) – see, also, table 4.

The obtained regress model is the next one:

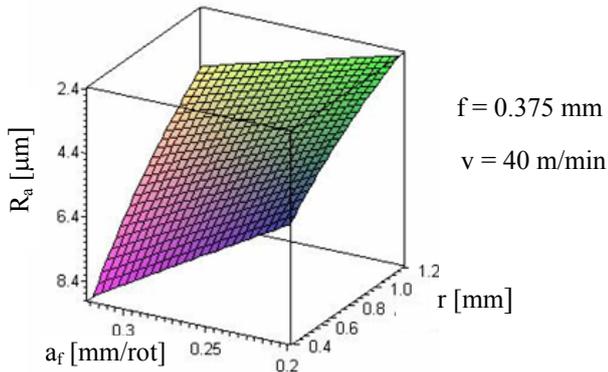
$$R_a = e^{2,960} \cdot v^{0,313} \cdot a_f^{1,090} \cdot f^{0,307} \cdot (0,379)^r \quad (17)$$

and a relevant plotted graph is shown in figure 17.

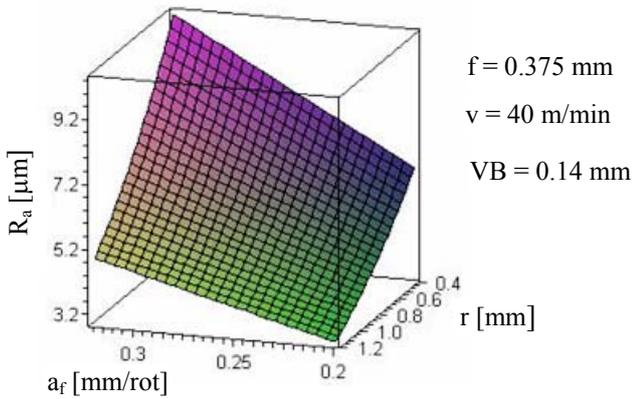
Based on data mentioned by references, as well as on author's experience, it has been considered fit to determine dependence relation of surface roughness on another cutting tool specific element, meaning on cutting tool wear (the VB parameter). So, further experiments were done (according to P 3 experiments design) and the obtained results were "analyzed" so that the regression analysis "estimated" in model that follows:

$$R_a = e^{3,023} \cdot v^{0,276} \cdot a_f^{1,054} \cdot f^{0,285} \cdot (0,391)^r \cdot (3,108)^{VB} \quad (18)$$

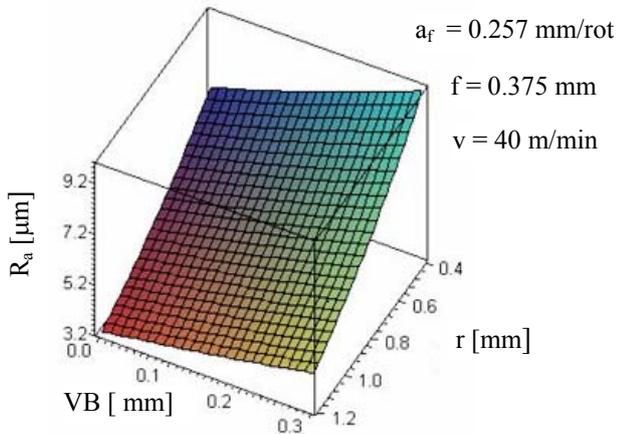
Table 10



- graph of surface roughness dependence on both cutting feed and cutting tool nose radius - relation (17) -



- graph of surface roughness dependence on both cutting feed and cutting tool nose radius - relation (18) -



- graph of surface roughness dependence on both cutting tool wear and nose radius - relation (18) -

Fig. 17 Graphical representations of R_a models

For these models, using Maple software, there have been plotted some graphs, evidencing the way independent variables studied do influence the outputs variable of interest – see figure 17.

The q_i coefficients pointing out (quantitative), how strong the influence of each independent, on the output, really is, have also been calculated – see table 10.

q_i Coefficients Values

	Relation (17)	Relation (18)
$q_v = \left(\frac{v_{\max}}{v_{\min}} \right)^{a_1}$	1.329	1.285
$q_s = \left(\frac{a_{f\max}}{a_{f\min}} \right)^{a_2}$	1.641	1.614
$q_t = \left(\frac{f_{\max}}{f_{\min}} \right)^{a_3}$	1.237	1.218
$q_r = (A_4)^{r_{\max} - r_{\min}}$	0.460	0.472
$q_{VB} = (A_4)^{VB_{\max} - VB_{\min}}$	-	1.374

Due to the fact that, at least theoretically, when starting the turning process, the cutting tool is a new one ($VB = 0$), some “special” attention has been given to relation (17). So, it can be noticed that two important factors influencing surface roughness, R_a , values are the cutting tool nose radius, r , and the cutting feed a_f .

A detailed study on their influence has been done with DOE KISS software and a polynomial type model was determined. As already mentioned above, due to license rights limitation, there were considered only two variables, each with three variation levels.

In order to do the new set of experiments, the values of the independent variables v and f were set to their medium (see table 4), while independent variables r and a_f were varied according to the CCD of experiments. The obtained experimental results for surface roughness, R_a parameter, are presented in table 11.

Table 11

Experiments Results – for DOE KISS

		Cutting tool durability, T [min]					
		Exp. no.	1	2	3	4	5
CCD		4.00	2.40	3.04	8.66	2.26	6.62
	Exp. no.	7	8	9	10		
		7.97	4.96	4.28	4.33		

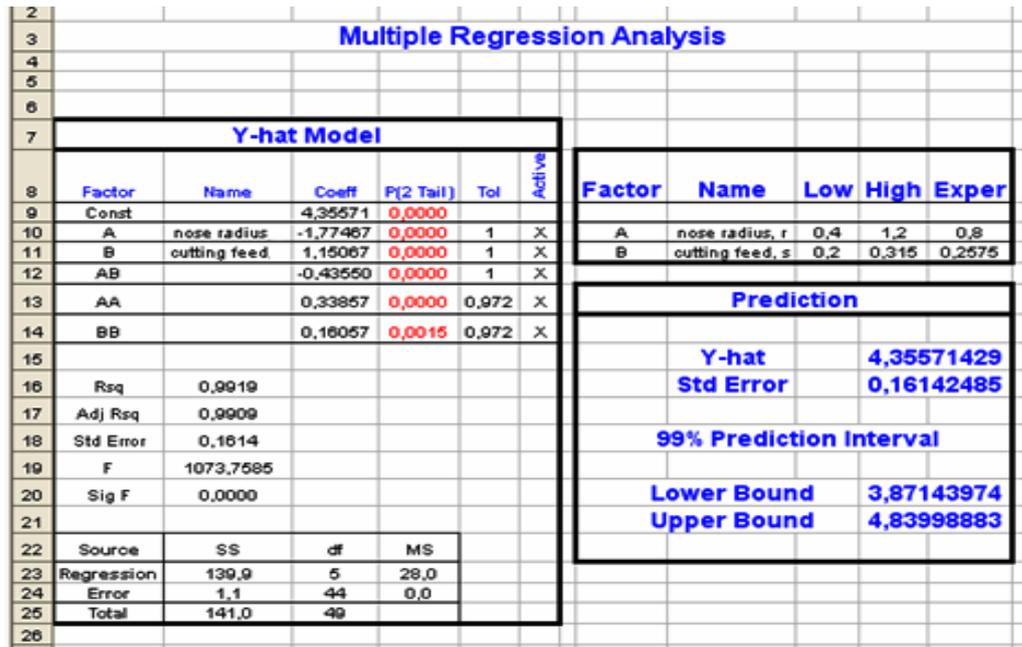


Fig. 18 DOE KISS software - regression analysis results - surface roughness model -

DOE KISS software regression analysis results are presented in figure 18.

There should be mentioned the aspects that follow:

→ a factor is considered to have significant influence on the output as long as the P (2 Tail) value is less. or equal, to 0,05;

→ when using the software, the initial results do consider the coded values (x_j) for the variables studied

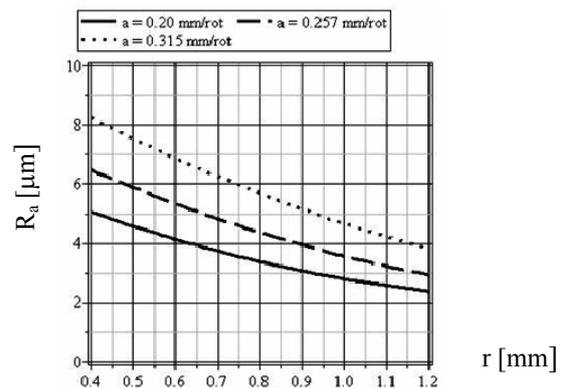
→ the relationship of real and coded variables values (r , a_f and, respectively, x_1 , x_2) is given by relation (19).

$$x_1 = \frac{r - 0.8}{0.4}; \quad x_1 = 2 \cdot \frac{a_f - 0.257}{0.115} \quad (19)$$

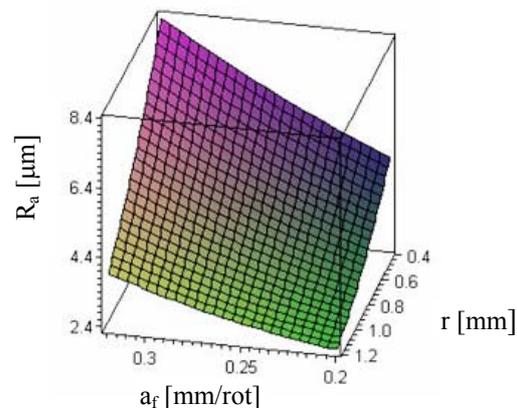
So, the resulting regression model of surface roughness, depending on r and a_f process parameters is the next one:

$$R_a = 3.437 - 2.956 \cdot r + 10.152 \cdot a_f - 18.957 \cdot r \cdot a_f + 2.119 \cdot r^2 + 48.696 \cdot a_f^2 \quad (20)$$

Examples of graphs plotted (with Maple software) for better evidencing the influence of independent variables studied on surface roughness are shown in figure 19.



- graph of surface roughness dependence on cutting tool nose radius - relation (20) -



- graph of surface roughness dependence on both cutting feed and cutting tool nose radius - relation (20) -

Fig. 19 Graphical representations of R_a models

Further research on surface roughness, should consider relation (18). So, it can be noticed that the cutting tool wear, evaluated by the VB parameter does significantly influence the R_a parameter values.

With DOE KISS software, a polynomial type model is determined. For the new set of experiments, the values of the independent variables v , f and r were set to their medium, while independent variables VB and a_f were varied according to the CCD of experiments (see table 4).

Observation:

The relationship of real and coded variables values (VB, a_f and, respectively, x_1 , x_2) is:

$$x_1 = \frac{VB - 0.14}{0.14}; \quad x_2 = 2 \cdot \frac{a_f - 0.257}{0.115} \quad (21)$$

while the resulting regression model is the one that follows:

$$R_a = -12.514 - 74.951 \cdot VB + 71.027 \cdot a_f + 235.435 \cdot VB \cdot a_f + 68.724 \cdot VB^2 - 351.758 \cdot a_f^2 \quad (22)$$

The marginal means plot, evidencing how the two independent variables considered do influence the output is presented in figure 20.

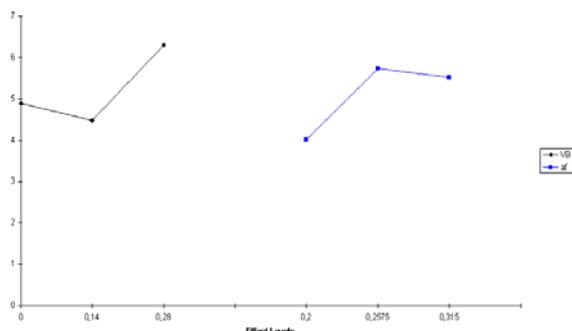


Fig. 20 DOE KISS software - Marginal means plot – for R_a model

5 Conclusion

Due to its importance in repairing worn parts and corrosion protection, the metallizing has known a continuous extend

Machining procedures of thermal sprayed coatings are often used in order to obtain the prescribed geometrical precision, meaning: dimensions, shape and relative position, as well as roughness of the metallized surfaces.. One of the most frequent is turning.

Applied statistics methods – such as experiments design and regression analysis have proved to be

adequate when studying turning process parameters interdependence.

There were used three statistics specific software and so, regression models of process parameters interdependence have been determined. More specifically, the models refer to some turning process important aspects, like: cutting tool wear, cutting tool durability, optimum cutting speed, and surface roughness.

As consequence, all the models obtained can be used to determine the estimated values of the above mentioned outputs, when the values of inputs – meaning machining parameters (speed, feed, depth) and cutting tool characteristics (nose radius, wear) are previously known.

All the steps carried in order to obtain the regression models can be considered as parts of a “procedure” to be followed / applied for any materials type and different machining procedures, whenever dependence relations of machining parameters are worth to be determined.

Further research development does involve other process parameters and / or metallised coating materials to be studied, as well as application of the obtained models on real time control of the process.

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