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Optimization of Cutting Parameters during Machining of Fine Grained Cemented Carbides

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Abstract**—**The group of progressive cutting materials can include non-traditional, emerging and less-used materials that can be an efficient use of cutting their lead to a quantum leap in the field of machining. This is essentially a "superhard" materials (STM) based on polycrystalline diamond (PCD) and polycrystalline cubic boron nitride (PCBN) cutting performance ceramics and development is constantly "perfecting" fine coated cemented carbides. The latter cutting materials are broken down by two parameters, toughness and hardness. A variation of alloying elements is always possible to improve only one of each parameter. Reducing the size of the core on the other hand doing achieves "contradictory" properties, namely to increase both hardness and toughness.

Keywords**—**Grained cutting materials difficult to machine materials, optimum utilization.

I. Introduction

CONSIDERING that the current method of classifying materials into different classes machinability and choice of cutting conditions in relation to national normative has a number of inaccuracies [1] is the determination of effective, let alone optimal cutting conditions for a new, as yet unknown combination of innovative cutting material - Difficult material for specific technological environment, complicated, time consuming and relatively expensive.

Therefore article discusses the economical way of determining efficient (up to optimal) cutting conditions, on the particular front profile turning difficult to machine rotary cladding coated fine grained cemented carbides .

II. Considering Before Optimizing Cutting Conditions

Before performing a complex experiment optimization of cutting conditions is desirable, based on a deeper understanding of the theoretical patterns, to identify areas suitable chip and determine the critical component (or component) forces due to the turning machining kinematics. Furthermore, estimating the timing of tool wear (durability of the blade) for cutting power previously unknown - workability of the analysis technological environment, as elaborated technical and organizational constraints. Whenever a certain quality finish, it is necessary to respect the range of roughness values achieved within the "expected intervals" cutting conditions.

Equally important is the ability to finely experimentalist approach to determine the optimum cutting conditions for conventional machine tools and manufacturing equipment with a high degree of automation, which is increasing the price of NC machines and overhead costs, are increasing much traffic for an hour of work machines [2]. The true variance of the machined material and machinability of cutting tools can then determine technologist force cutting conditions due to the extreme conditions, which then determine the optimal cutting conditions for automated machines not reach such values that are commonly applied to conventional machine tools.

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III. Experimental Determination of Optimal Cutting Conditions

Investigation of optimal cutting conditions usually always requires a certain ideological, material and financial potential. This potential is growing especially in the implementation of new cutting materials into production, when it is not based on the "table or catalog values" nor operational experience. Too additionally machine difficult to machine surfaces, the complexity and cost of the experiment is then multiplied.

The optimum cutting conditions are closely related with optimal durability of the cutting tool. Generally cannot be separated from each other to determine the optimal durability and optimum cutting conditions. This can be done only under certain circumstances. Therefore, it is preferable to use a complex optimization calculation, the solution is the optimal value and durability of cutting conditions, respectively. Also the optimum values of other variables [3].

IV. Experimental Planning

Since acquiring the necessary exponents and constants for determining Fc and Ra (for our case, the essential parameters) often used the "classic way" is costly and laborious, it is the time and economically preferable to use the method of regression analysis. Implementation of the proposed experiment; however, is responsible to plan in advance. Planning shortened by a factorial experiment can be divided into three basic parts:

1. **How many points (lines) n** is needed to determine (measure)?

The larger the number of rows or attempts is suitable for the experimenter - a statistic experiment itself, but not for the economist. The larger number of measurements than is absolutely necessary, experiment cost and time burden (especially for small batch and unit production).

2. **Which points x** (parameters) is appropriate and effective to apply?

It is mainly about the selection of the "dominant" cutting conditions (parameters) that must be relatively easy to reach (measurable) .

3. **How many parameters** (cutting conditions) to be measured (examine or monitor)?

It is that small or too large number of parameters can be simultaneously analyzed experiment not only economic disadvantage, complicate, and the "skew". Therefore, it is necessary to properly estimate the "correct" number of monitored variables. For decades various plans experiments was chosen for this case truncated factorial experiment which minimizes the number of rows (attempts), and hence it becomes economically advantageous .

V. Using Regression Analysis for Determining the Parameters FC and RA

If one accepts the generally valid, normally used, and in this case sufficiently precise hypothesis that the mathematical relationships between the output values and cutting conditions are exponential and the corresponding equations in general form

$$F_c = c_o \cdot a_p^{c_1} \cdot f^{c_2} \cdot v_c^{c_3} \quad , \qquad (1)$$

then after linearization equation

$$\log F_c = \log c_0 + c_1 \log a_p + c_2 \log f + c_3 \log v_c \qquad (2)$$

You can experiment to evaluate the use of statistical methods of multivariate regression analysis of independent variables [4].

TABLE I
THE GENERAL EXPRESSION OF MATRIX FACTORIAL TYPE $\frac{2^3}{2}$ CALCULATION OF FC

M.	x_1	x_2	x_3	x_1	x_2	x_3	y_i
1	$a_{p,min}$	f_{min}	$v_{c, max}$	-1	-1	1	F_{c1}
2	$a_{p,min}$	f_{max}	$v_{c, min}$	-1	1	-1	F_{c2}
3	$a_{p,max}$	f_{min}	$v_{c, min}$	1	-1	-1	F_{c3}
4	$a_{p,max}$	f_{max}	$v_{c, max}$	1	1	1	F_{c4}

To deal with cases applies

$$y = f\,(x_1, x_2, x_3,), \qquad (3)$$

where the three factors (parameters) x_1, x_2 and x_3 are the cutting conditions investigated technological environment, cutting depth (the discard thickness of the weld), displacement of the cutting tool and the cutting speed.

TABLE II
RANGE INTERVALS SELECTED CUTTING CONDITIONS

Variable Value	Code	The level of variation -1	The level of variation 1	Dimensions variable
Cutting depth a_p	x_1	1	2	mm
Feed f	x_2	0.1	0.4	mm
Cutting speed v_c	x_3	80	170	$m.min^{-1}$

When considering the case of three "core" parameters (cutting conditions a_p, f and v_c, then the number of required trials (rows) according to the following formula will be

$$N = \frac{2^n}{2} = \frac{2^3}{2} = 4, \qquad (4)$$

where n is the number of considered cutting conditions.

VI. Determination of Functional Relationships for Fc and Ra

Suitable election minima and maxima of the individual parameters (i.e. specific to the environment of "acceptable values" intervals selected cutting conditions) are crucial for the success of the experiment. Generally, the intervals are smaller; the more implemented method corresponds to the accepted hypothesis. For this case were based on an analysis of several variants of design requirements and the technical and organizational constraints, the following intervals:

Experimental measurements depending cutting component $F_c = f$ (p, f, v_c) three-component dynamometer and depending roughness Ra = f (p, f, v_c) Surface roughness HOMMEL TESTER, for the addition of depth of cut $a_p = 1 \div 2$mm, feed f = 0 1 ÷ 0.4mm and cutting speed $v_c = 80 \div 170$m.min^{-1} cutting material PRAMET TNMM 22 04-24FR-58, 525 P and machined steel cladding on die corresponding to its composition and physical properties of the tool die steel ČSN 41 9663 19 663.3 annealing, the hardness of 225 HB max and tensile strength of 1275 MPa, once in factorial matrix type (4) through a computer program (e.g. MATLAB) for Fc receive the following constants for the functional relationships (5) and (6).

TABLE III
RANGE INTERVALS SELECTED CUTTING CONDITIONS

Value	x_1	x_2	x_3	y_i
Row number	a_p [mm]	f [mm]	v_c [$m.min^{-1}$]	$F_{c,i}$ [N]
1	1	0.1	170	520
2	1	0.4	80	1 550
3	2	0.1	80	1 060
4	**2**	**0.4**	**170**	**2 115**

For general use, the mathematical power law relationship, obtained on the basis of four measurements, it is possible, through the factor matrix and a computer program MATLAB, determine the constants c0 = 8 973.2; c1 = 0.7379, c2 = 0.6431, c3 = -0, Substituting in 2663 and then calculate the cutting force component machining

$$F_c = 8\,973 \,.\, a_p^{0,738} .\ f^{0,643} .\ v_c^{-0,266} . \quad (5)$$

Especially for the determination of optimal cutting conditions by the statistical method of regression analysis was modeled new mathematical relationship that predetermined spatial region "allowable solutions" (Fig. 1) for the technological environment are described more precisely which states and proves Literature [5].

$$F_c = (c_0 - c_1 . v_c) . (c_2 . f + a_p)^{c_3}, \quad (6)$$

where $c_0 = 291.86$; $c_1 = -0.1316$; $c_2 = 6.0805$; $c_3 = 1.3838$.

TABLE IV
THE GENERAL EXPRESSION OF MATRIX FACTORIAL TYPE $\frac{2^3}{2}$ CALCULATION RA

M.	x_1	x_2	x_3	x_1	x_2	x_3	y_i
1	$a_{p,min}$	f_{min}	$v_{c\ max}$	-1	-1	1	R_{a1}
2	$a_{p,min}$	f_{max}	$v_{c\ min}$	-1	1	-1	R_{a2}
3	$a_{p,\ max}$	f_{min}	$v_{c\ min}$	1	-1	-1	R_{a3}
4	$a_{p,max}$	f_{max}	$v_{c\ max}$	1	1	1	R_{a4}

Substituting into (6) is then calculated value of the cutting force components equal to turning

$$F_c = (291,86 - 0,1316\, v_c) . (6,0805\, f + a_p)^{1,3838} . \quad (7)$$

can be expressed in a similar way to the arithmetical mean deviation Ra.

Roughness Ra can be economically established so that the surface resulting from the measurement of Fc will be used for roughness measurement device HOMMEL TESTER. Provided, however, that they are accessible for measurement and long enough. The values in the table are average No.5, obtained by repeated measurements.

TABLE V
THE MEASURED AND PROCESSED VALUES BY FACTORIAL

Value	x_1	x_2	x_3	y_i
Row number	a_p [mm]	f [mm]	v_c [m.min^{-1}]	R_a [μm]
1	1	0.1	170	1.9
2	1	0.4	80	2.9
3	2	0.1	80	2.4
4	2	0.4	170	3.1

The arithmetical mean deviation of the profile function is expressed by a power law relationship

$$R_a = 0,966\, a_p^{-0,205} .\ f^{0,705} .\ v_c^{0,398} . \quad (8)$$

Through factor matrix is a power law function is written

$$R_a = c_o . a_p^{c_1} . f^{c_2} . v_c^{c_3}, \quad (9)$$

where $c_0 = 5.8959$; $c_1 = 0.2166$; $c_2 = 0.2448$; $c_3 = -0.1107$.

Substituting the shape

$$R_a = 5,896\ a_p^{0,217} .\ f^{0,245} .\ v_c^{-0,111} . \quad (10)$$

Like (6) has been created a new relationship (11) for ***R_a***

$$R_a = (c_0 - c_1 . v_c) . (c_2 . f + a_p)^{c_3} . \quad (11)$$

Substituting the constants receive shape

$$R_a = (1,5318 - 0,0005046\, v_c) . (8,0909\, f + a_p)^{0,4646} . \quad (12)$$

VII. SPATIAL REPRESENTATION OF THE TWO METHODS OF MEASUREMENT POINTS

Fig. 1 shows the spatial region of admissible solutions (estimated prevalence of optimal solutions) with measured points using both methods. While the points measured normal "classical method" Probe (cut) a specified area approximately the middle of each axis system, the points set out factor matrix are extreme (boundary) points of this region placed diagonally.

The spatial area of the postulated optimal solution has been limited (intended) intervals for a particular technological environment critical cutting conditions (v_c , p, f) based on the following findings:

1. The measurements, it was found that the cutting speed is limited within a certain interval (v_c = 80-170 m.min^{-1}). The lower limit restriction cutting speed results from the occurrence of brittle fracture (with decreasing cutting speed increasing specific cutting resistance , which can occur when a certain value to the Chipping - chipping smaller parts on the blade) and the upper limit is determined by a sharp decline as a result of cutting tools the plastic deformation.
2. Interval allowable displacement (f = 0.1 to 0.4 millimeters) practically limited upper value above which is already achieved inadmissible roughness (Ra > 3.2μm). The lower limit is determined by the minimum allowable productivity of the sector operations and also no longer decreasing, but rather increasing Ra.
3. The thickness of the machined layer a_p (depth of cut) is given by (limited) machining allowance.

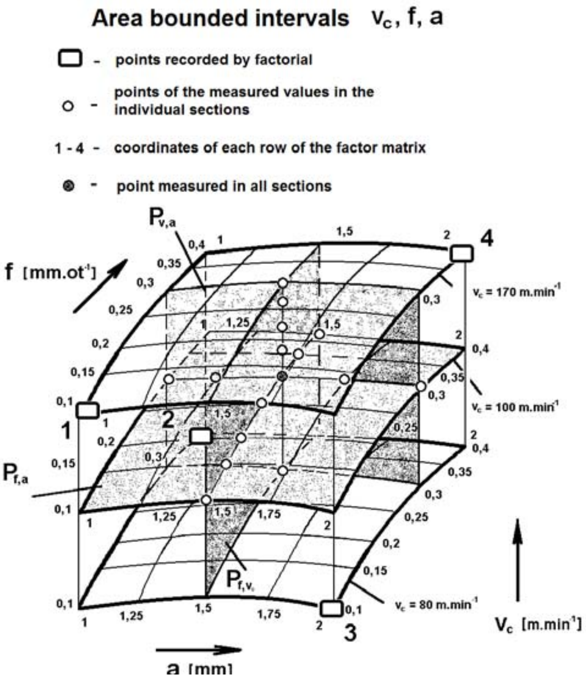

Fig. 1 Spatial representation of the coordinates of the measured points

VIII. Conclusion

Optimization of cutting conditions (understood in relation machined material - cutting material - technological environment); therefore, requires not only the identification of the region of feasible solutions through appropriate determination of the scope of basic intervals of cutting conditions, but of course also to determine the optimal durability Toptech in terms of the criteria considered.

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