

A Method to Determine the Cutting Regime Parameters for the Turning Operation

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Abstract

The methodology for establishing the parameters of the cutting regime has steadily improved. They studied and applied calculation methods and relationships that allow optimizing the cutting regime parameter values.

In practice, setting the parameters of the cutting regime involves a laborious algorithm working with complicated analytical calculations.

They are also frequently used information obtained experimentally.

Once, the transition to computer-aided manufacturing, have developed computer programs automatically using various databases.

This paper presents a comparison of how to determine the values of the parameters of the cutting regime for turning operation using classical algorithm work - the analytical method of calculation - and automatic calculation algorithm, developed by Sandvik Coromant company.

Key words: *cutting data, the parameters of the processing regime, algorithm*

General Aspects

Of particular importance is the management of technological process parameters setting the cutting regime. Setting a cutting regime parameters depend on: the type of operation [1, 2, 3] (turning, drilling, milling, grinding etc.) preform material [4, 6] (steel, bronze alloys, plastics etc.) and dimensional characteristics of processing (length, diameter, etc.), the material and geometric characteristics of the active part of the cutting tool [9, 14, 15, 16] (plaques carbide, minerals and ceramic plaques, plaque type, the length of the active peak radius etc.), other processing conditions [10, 11, 12] (coolant-lubricating etc.).

The parameters of the cutting regime are defined by [2]: cutting speed v_c (m/min), the feed work f (mm/r) cutting depth a_p (mm), plus and establishing other elements of mechanical processing – spindle speed n (rpm), N_c power consumption (kW) etc.

The literature [5, 13] recommends connecting relations between durability T (min) of the cutting tool and the cutting regime parameters: v_c (m/min), f (mm/r) and a_p (mm).

In this context, methods for determining the parameters of the cutting regime have evolved with the technical progress achieved in machine building: machine tool numerical control machining centers, robots handling and service lines, flexible manufacturing, cutting tools performing intensive work schemes etc.

In practice, two methods are used to establish the parameters of the cutting regime: the analytical method of calculation [6, 7] and automated method [17].

The paper performed analysis methods used to determine the parameters of the cutting regime, with the objectives: accuracy and speed calculations working method.

Presentation of the Methods Used to Determine the Parameters of the Cutting Regime

Further, it presented how to determine the cutting data parameter values used in practice by two methods: the analytical method of calculation [6,7] and automated method [17].

Analytical method of calculation allows setting the parameters of the cutting regime based on an algorithm that uses analytical computation relations and working coefficients determined experimentally.

Calculation stages of the analytical method are:

- a) Establishing the cutting scheme used (turning outer cylindrical, internal, cone).
- b) The choice of the technical characteristics of the cutting tool (material active part, geometry active part, of the body section and fixation etc.)
- c) Setting the cutting depth a_p (mm).
- d) Establishing the feed work f (mm/r).
- e) Determination of the cutting speed v_c (m/min) (existing in literature [6, 7], the calculation for determining the relationship of the cutting speed for different cutting schemes used in practice).
- f) Determination of the spindle speed n (rpm).
- h) Determining the effective power N_e (kW).

The automated method. For setting the parameters of the cutting regime, companies in the construction machinery, realized on the basis of its own data obtained in machining, specialized software database type. Sandvik Coromant Company has developed specialized software CoroGuide [17] which allows setting the parameters of the cutting regime: the cutting speed, actual spindle speed, productivity processing machine of effective power, time base, machined surface roughness etc.

Workflow in the cutting regime obtaining parameter values are:

- selecting the operating range (machining) - turning, milling, drilling etc.;
- selection of used cutting scheme;
- selecting working technical characteristics;
- determination (by viewing the respective dialog windows) of the cutting regime parameter values: cutting depth a_p , feed work f , cutting speed v_c , spindle speed n , effective power N_e .

Application

The proposed application is to determine values for the processing parameters of the cutting regime by turning an internal cylindrical surface. It will determine the values of the parameters of the cutting regime through two methods: the analytical method of calculation and automated method.


A) *Determination of cutting regime parameters by analytical method of calculation*

- a) *Scheme of cutting* used in turning the internal cylinder having typical dimensions, the diameter $D = \Phi 40 \pm 0.8$ mm and the cutting length, $L = 70$ mm. Type of material to be

processed is 42CrMo4 according to EN 10083 (DIN 17200), and the operation of the machining is finish machining of the internal cylinder.

- b) *The choice of cutting tool:* machining area is used for internal corner cutter ISO 4974 9 (STAS 6385-80), with the characteristics indicate in Table 1 [15].

Table 1. Features of the cutting tool

Cutting tool name	Technical specifications
Inside corner cutter DIN 4974 ISO 9 (STAS 6385-80)	$h \times b$ is the cutter body section; $h \times b = 32 \times 32$ (mm) L - cutter length; $L = 150$ mm r - radius peak cutters; $r = 0.8$ mm α - place angle; $\alpha = 5^\circ$ γ - release angle; $\gamma = 5^\circ$ χ_r - principal angle of attack; $\chi_r = 90^\circ$ χ_r' - secondary angle of attack; $\chi_r' = 15^\circ$ P10 plaque, 10 mm thick. Body material: OLC45
Sketch of the cutting tool	
	

- c) *Setting the depth of cut:* cutting depth is adopted: $a_p = 0.8$ mm.
- d) *Establish feed work.* According to [6, p. 342], the size of the feed work is recommended: $f = (0.15 \dots 0.30)$ mm/r. According range of machine tools used advances (normal lathe SN 320 [5]) shall be adopted: $f_a = 0.16$ mm/r.
- e) *Determination of cutting speed:* In the case of longitudinal turning, cutting speed is determined by the relation [6, p. 359]:

$$\begin{aligned}
 v &= \frac{C_v}{T^m \cdot a_p^{x_v} \cdot f^{y_v} \cdot \left(\frac{220}{200}\right)^n} \cdot K_1 \cdot K_2 \cdot K_3 \cdot K_4 \cdot K_5 \cdot K_6 \cdot K_7 \cdot K_8 \cdot K_9 = \\
 &= \frac{150}{90^{0.125} \cdot 0.8^{0.18} \cdot 0.16^{0.45} \cdot \left(\frac{220}{200}\right)^{1.75}} \cdot 1.003 \cdot 0.66 \cdot 1.0 \cdot 0.912 \cdot 1.0 \cdot 0.9 \cdot 1.0 \cdot 0.9 \cdot 1.0 = 87.1 \text{ m/min}
 \end{aligned} \quad (1)$$

in which: C_v is a coefficient which depends on the characteristics of the material to be processed and the material of the cutting tool [6]: $C_v = 150$;

T – durability cutting tool [6]: $T = 90$ min;

m, x_v, y_v, n – exponents: $m = 0.125$; $x_v = 0.18$; $y_v = 0.45$; $n = 1.75$;

K_1 – influence coefficient depends on the section of the cutter [6]:

$$K_1 = \left(\frac{q}{20 \cdot 30}\right)^\xi = \left(\frac{32 \cdot 32}{20 \cdot 30}\right)^{0.08} = 1.04 ; \quad (2)$$

q – the cutter body surface: $q = h \times b = 32 \times 32$ mm² (see table 1);

ξ – coefficient that depends on the workpiece [6]: $\xi = 0,08$;

K_2 – coefficient that depends on the angle of the principal attack ($\chi_r = 90^\circ$) [6]:

$$K_2 = \left(\frac{45}{\chi_r} \right)^\rho = \left(\frac{45}{90} \right)^{0.6} = 0.66; \quad (3)$$

ρ – exponent that depends on the nature of the material to be machined [6]: $\rho = 0.6$;

K_3 – coefficient that depends on the angle of the secondary attack ($\chi'_r = 15^\circ$) [6]:

$$K_3 = \left(\frac{a}{\chi'_r} \right)^{0.09} = \left(\frac{15}{15} \right)^{0.09} = 1.0; \quad (4)$$

$a = 15$ for cutting with carbide inserts [6];

K_4 – coefficient which takes into account the radius of the tip of cutter [6]:

$$K_4 = \left(\frac{r}{2} \right)^\mu = \left(\frac{0.8}{2} \right)^{0.1} = 0.912; \quad (5)$$

r – the cutter tip radius $r = 0.8$ mm (see table 1);

μ – coefficient which depends on the type of processing and material to be machined [6]:

$$\mu = 0.1;$$

K_5 – coefficient which depends on the material from which it is made the active part of the cutting tool [6]: $K_5 = 1.0$;

K_6 – coefficient that depends on the workpiece [6]: $K_6 = 0.9$;

K_7 – coefficient that depends on the production of the preform material [6]: $K_7 = 1.0$;

K_8 – coefficient that depends on the layer superficial of the preform material [6]: $K_8 = 0.9$;

K_9 – coefficient depends on the shape of the surface clearance [6]: $K_9 = 1.0$.

- f) *Determination of the spindle speed*: Speed main shaft of the machine tool is determined by the relation [5]:

$$n = \frac{1000 \cdot v}{\pi \cdot D} = \frac{1000 \cdot 87.1}{\pi \cdot 40} = 6931 \text{ rpm} \quad (6)$$

The range of the machine tools (lathe normal SN 320 [5]) shall be adopted: $n_a = 700$ rpm.

- g) *Determining the effective cutting speed*: effective speed cutting is determined using the relation [5]:

$$v_{ef} = \frac{\pi \cdot D \cdot n_a}{1000} = \frac{\pi \cdot 40 \cdot 700}{1000} = 87.9 \text{ m/min} \quad (7)$$

- h) *Determination of the effective turning*: Effective power is determined by the relation [5]:

$$N_e = \frac{F_z \cdot v_{ef}}{60000 \cdot \eta} = \frac{367.58 \cdot 87.9}{60000 \cdot 0.9} = 0.599 \text{ kW} \quad (8)$$

where: F_z the principal component of the cutting force [6]:

$$F_z = C_4 \cdot a_p^{x1} \cdot f_a^{y1} \cdot HB^{n1} = 357 \cdot 0.8^{1.0} \cdot 0.16^{0.75} \cdot 220^{0.35} = 367.58 \text{ N} \quad (9)$$

C_4 – coefficient that takes account of the workpiece and the cutting tool material active part [6]: $C_4 = 275$.

i) *The calculation of basic time:* Time base determined by the relation [8]:

$$t_b = \frac{L}{n \cdot s} \cdot i = \frac{l + l_1 + l_2}{n \cdot s} \cdot i \text{ (min)}, \quad (10)$$

where: l_1 is the length of the cutting input [8]:

$$l_1 = \frac{a_p}{\operatorname{tg} \chi_r} + (0,5 \dots 2) \text{ (mm)}; \quad (11)$$

l_2 – length of the exit of the cutting: $l_2 = (1 \dots 5)$ mm; l – the length effective processed; i – the number of passes.

By replacing known dates, in the equation (10), it is obtained:

$$t_b = \frac{L}{n \cdot s} \cdot i = \frac{70}{700 \cdot 0.16} \cdot 1 = 0.62 \text{ min.} \quad (12)$$

The calculated values of the parameters of the cutting regime with the software Mathcad are shown in Table 2.

The notations used in Table 2 are in accordance methodology presented.

Table 2. Establishing the values of the cutting regime parameters

$C_v := 150$ $k_1 := 1.04$ $k_2 := 0.66$ $k_3 := 1.0$ $k_4 := 0.912$ $k_5 := 1.0$ $k_6 := 0.9$ $k_7 := 1.0$
 $k_8 := 0.9$ $k_9 := 1.0$
 $T := 90 \text{ min}$ $a_p := 0.8 \text{ mm}$ $f := 0.16 \text{ mm/r}$ $HB := 220$ $C_4 := 275$ $\eta := 0.9$ $D := 40 \text{ mm}$

$$v := \frac{(C_v \cdot k_1 \cdot k_2 \cdot k_3 \cdot k_4 \cdot k_5 \cdot k_6 \cdot k_7 \cdot k_8 \cdot k_9)}{T^{0.125} \cdot a_p^{0.18} \cdot f^{0.45} \cdot \left(\frac{HB}{200}\right)^{1.75}} = 87.101 \text{ m/min} \quad n := \frac{1000 \cdot v}{3.14 \cdot D} = 693.475 \text{ rpm}$$

$n_a := 700 \text{ rpm}$

$$v_{ef} := \frac{(\pi \cdot D \cdot n_a)}{1000} = 87.965 \text{ m/min} \quad F_z := C_4 \cdot a_p^{1.0} \cdot f^{0.75} \cdot HB^{0.35} = 367.587 \text{ N}$$

$$N_e := \frac{(F_z \cdot v_{ef})}{60000 \cdot \eta} = 0.599 \text{ kW} \quad N := \frac{(F_z \cdot v)}{60000 \cdot \eta} = 0.593 \text{ kW}$$

B) Determining the cutting regime parameters by automatic method

For determining the amounts parameters of the cutting regime to use specialized software type database (developed by the company Sandvik Coromant CoroGuide [5]) which enables the

optimal values work: speed principal cutting, effective speed work, productivity processing, power effective machine tool, time base, machined surface roughness.

To obtain optimal values of the parameters of the cutting regime following steps are recommended:

- Determination of the operation (machining) - turning (fig. 1);
- Establishing cutting scheme used - turning internal cylinder (fig. 2);

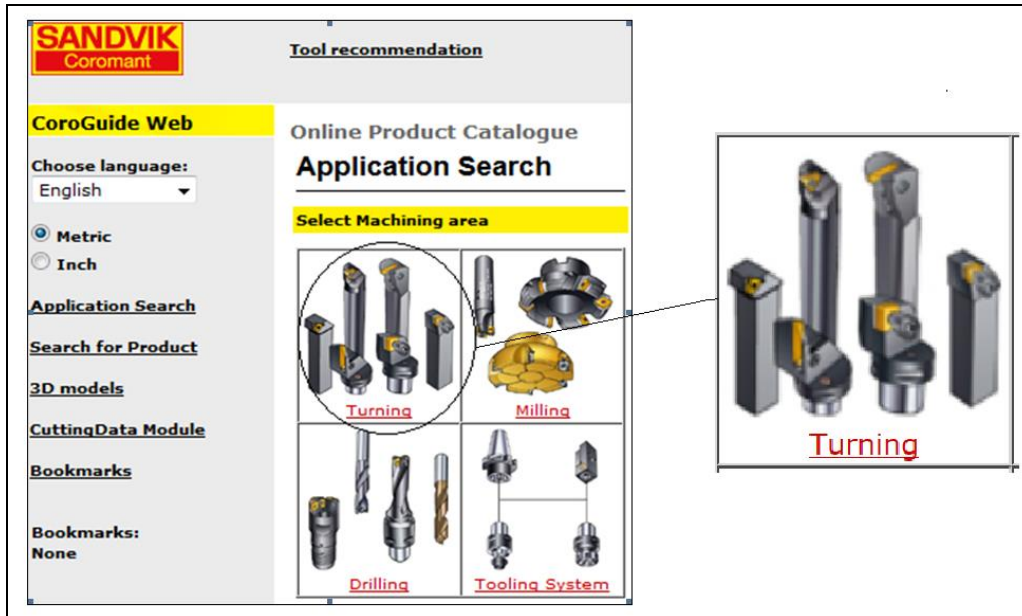


Fig. 1. Establish the operating range (machining) - Turning [17].

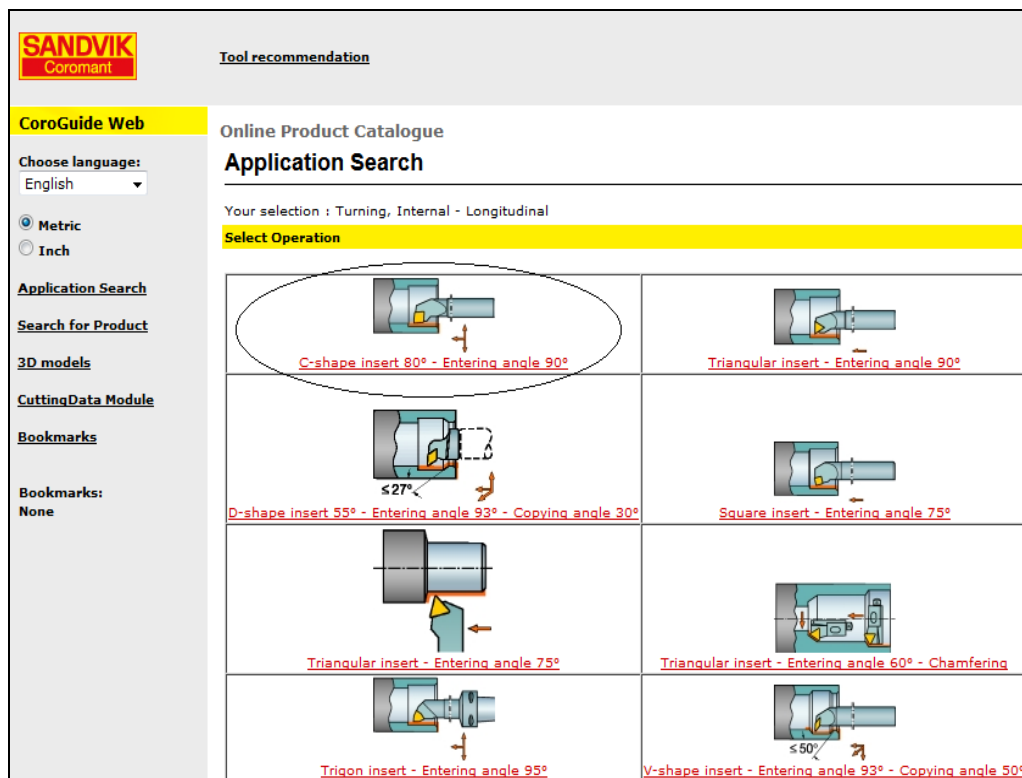


Fig. 2. Selecting cutting scheme used [17]

- Selecting the type of cutting tool used (fig. 3);
- Selection of cutting tool characteristics (fig. 4);
- Selection of feed work values (f) and cutting depth (a_p) – Figure 5;
- Determining the amounts feed work for f , the principal cutting speed v_c , spindle speed n , processing length L , the power consumed N_e , while basic t_b (fig. 6).

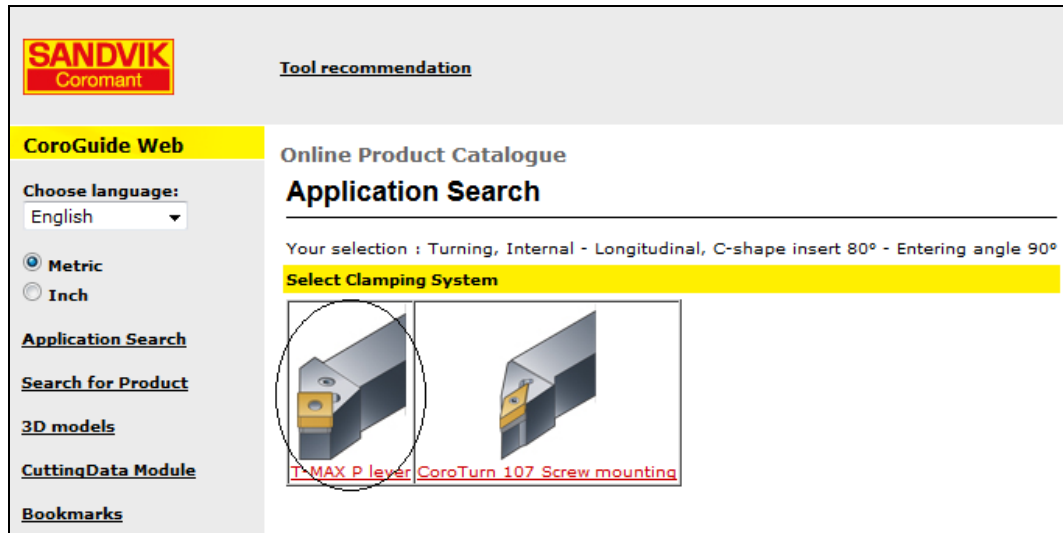


Fig. 3. Selecting cutting tool used [17].

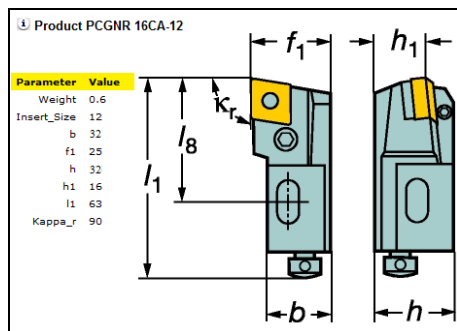


Fig. 4. Selecting cutting tool characteristics [17]



Fig. 5. Selection of feed work values (f) and cutting depth (a_p) [17]

Determining the parameters of the cutting regime through two methods (analytical method and automatic method) indicate the correlation between the sizes calculated (table 3).

Comments and Discussions

Choosing cutting regime at cutting machining operations is performed depending on the work, cutting tool and the preform material, precision cooling-lubrication conditions etc.

This paper presents how to determine the cutting data parameter values used in practice by two methods: the of analytical calculation method and automated method.

Table 3. Comparative analysis of analytical calculation method and automated method in order determining the parameters of the cutting regime

Crt. No.	Operation	Method	i	a_p (mm)	f_a (mm/r)	v_c (m/min)		n (rpm)		t_b (min)
						Calculated	Effective	Calculated	Effective	
1	Turning internal cylindrical	Analytical	1	0.8	0.16	87.1	87.9	700	700	0.62
2		Automatic	1	0.8	0.16	85		676...705		0.63

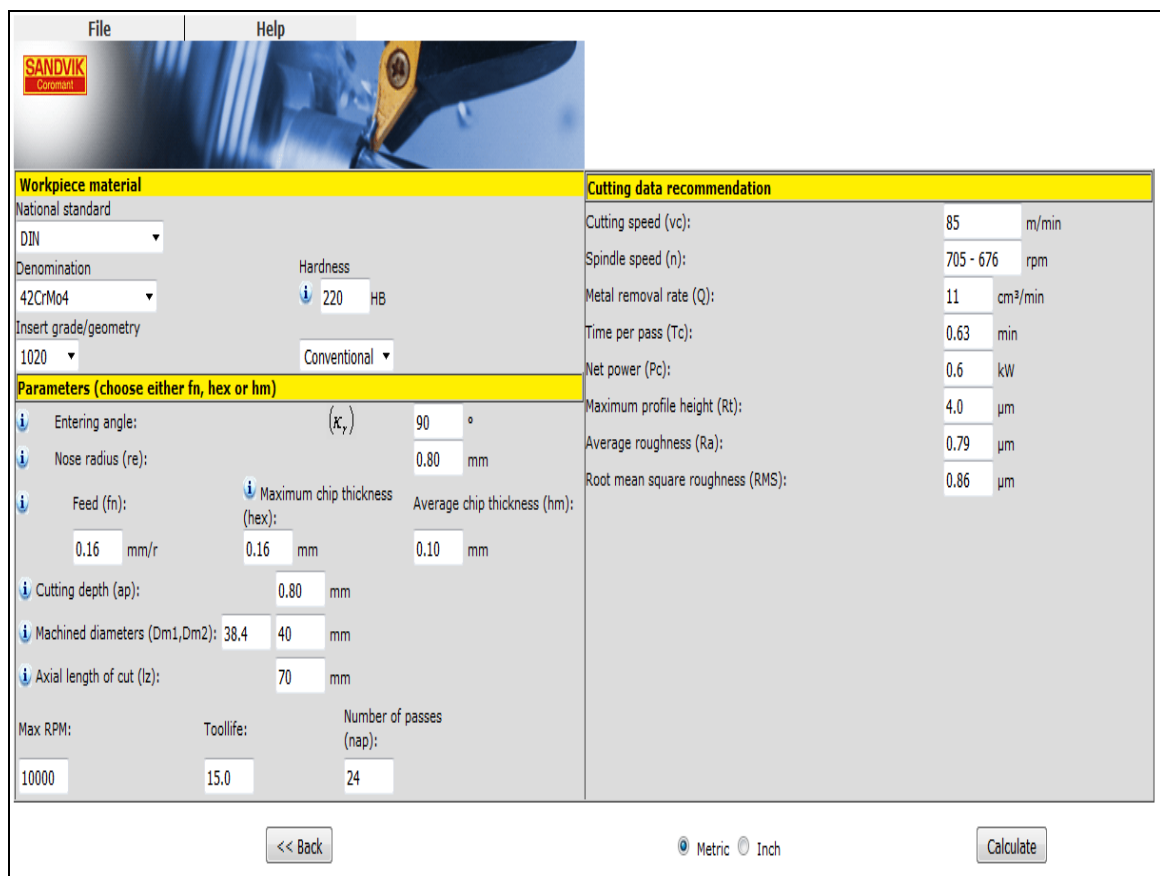


Fig. 6. Setting values for the principal cutting speed v_c , spindle speed n , processing length L , power consumed N_e , time per pass t_c , machined surface roughness [17].

According to the methods of determining the values of the parameters of the cutting regime, analyzed in the paper, there is a correlation between very good analytical method for calculation and automatic method (table 3).

There is a difference that is specific to that classic machine tools working speed range of speeds shall be adopted in accordance with existing (according gearbox).

Also, the discrepancy can be explained by the different values of intervening weightings used in calculation relations.

Using the automated method allows rapid calculation of the parameter values cutting regime to the analytical method of calculation that is more laborious.

The analysis carried out to establish the limits of the analytical method of calculation under a modern fabrication - aided manufacturing.

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Metodă pentru stabilirea parametrilor regimului de așchiere la operația de strunjire

Rezumat

Metodologia de stabilire a valorilor parametrilor regimului de așchiere s-a îmbunătățit continuu. S-au studiat și aplicat metode și relații de calcul care să permită optimizarea valorilor parametrilor regimului de așchiere.

Din practica curentă, stabilirea valorilor parametrilor regimului de așchiere comportă un algoritm de lucru laborios, cu calcule analitice complicate.

De asemenea, sunt utilizate frecvent informații obținute experimental.

Odată, cu trecerea la fabricația asistată de calculator, s-au dezvoltat programe de calcul automat ce utilizează diverse baze de date.

Lucrarea prezintă o comparație între modul de determinare a valorilor parametrilor regimului de așchiere pentru operația de strunjire utilizând algoritmul clasic de lucru – metoda analitică de calcul – și algoritmul de calcul automat, elaborat de firma SANDVIK Coromant.