BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LIX No. 3/2007	7 - 17	Seria Tehnică

Comparative Analysis of the Methods Used for the Determination of the Mechanical Working Cutting Regime Parameters

Ion Nae, Marius Gabriel Petrescu

Petroleum and Gas University of Ploieşti, Bd. Bucureşti 39, Ploieşti, România
e-mail: inae@upg-ploiesti.ro

Abstract

The technological process as part of the fabrication process represents an ordered succession of the operational systems that involves a decisional approach on each work stage.
The ordering and the processing data in the technological system have as final purpose the adoption of some decisions concerning the design, the fabrication and the maintenance of the technological processes.
The paper presents the way of determining the cutting regime parameters values for the turning operation; there is made a comparative analysis of the values determined by using the analytical calculus method and the automatic one.

Keyword: *technological process, comparative analysis, technological system*

The technological decisional process

In the technological process of an engine part manufacturing, the technologist elaborates the decisional problem starting from the basic documentation (the engine part manufacturing design) and the technical conditions handed by the designer [1], [4].
The technical decisions adopted by the technologist contain the following distinct stages[1], [4], [3], [5]: the definition of the problem, the analysis of the problem, the research of different possible solutions, the choice of the criteria concerning the selection of the possible solutions, the adoption of the best working variant, the transformation of the decision in efficient action.
An important stage in the design of the mechanical working technological process is the establishment of the cutting regime parameters values. The working conditions and the establishment of the cutting regime parameters are presented in the figure 1.

The establishment of the cutting regime parameters values

The calculus analytical method, the cutting regime calculus at the turning operation $\Phi 130{,}5 \pm 0{,}8$ mm, $L = 700$ mm

a) The choice of the cutting tool: for the surface working it is used a lateral cutter STAS 6381-80, having the characteristics presented in the table 1.
b) The establishment the cutting depth

The cutting depth is adopted: a_p = 2,0 mm

c) The establishment of the working forward flow

In the case of the turning operations, the forward flow value depends on: the resistance of the cutter corpus, the resistance of the metal carbide plate, the efforts admitted by the forward flow mechanisms of the machine tool, the torsion moment admitted by the main movement mechanism of the machine - tool.

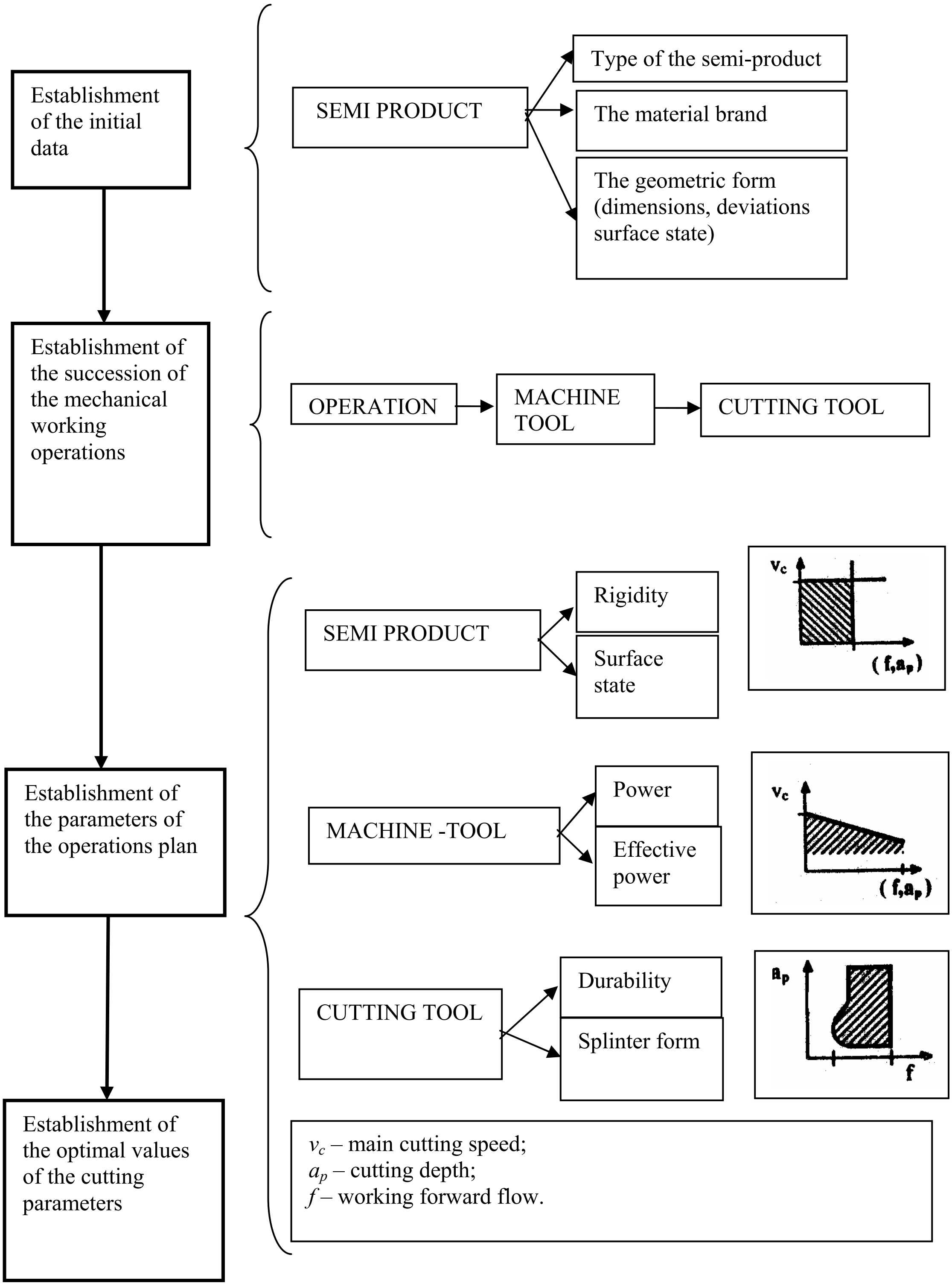
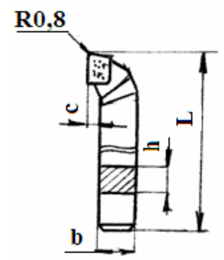


Fig. 1. Work conditions and establishment of the cutting regimes parameters

Table 1. The characteristics of the cutting tool

Name of the cutting tool (STAS)	The cutting tool draft	The technical characteristics
Lateral cutter STAS 6381-80 [2], p. 504		h x b = 32x32 (mm) L = 150 mm R = 0,8 mm c = 15 mm $\alpha = 5^0$; $\gamma = 5^0$; $\chi_r = 90^0$; $\chi_r' = 15^0$ Plate P10, having the thickness of 10 mm Shaft material: OLC45

According to [1] p. 341, tab. 10.7, it is recommended: f = (0,2 ... 0,4) mm/rot
According to the forward flow gamut of the machine - tool it is adopted: f_a = 0,2 mm/rot (table 2).

Table 2. The establishment of the technical characteristics of the machine - tool

Name of the machine tool	Technical characteristics	
Normal lathe SN 320 [4], p.132, tab. 5.1.	Turning maximum diameter	D_{max} = 320 mm
	Distance between tops	L_{max} = 500…750 mm
	Number of rotations steps	n = 18 steps
	Gamut of number of rotations of the main axle (rot/min)	79; 100; 124; 155; 194; 242; 302; 377; 471; 590; 736; 800; 920; 1150; 1433; 1792; 2240; 2800.
	Number of forward flow steps	n = 36 steps
	Gamut of longitudinal forward flows (mm/rot)	0,045; 0,051; 0,058; 0,066; 0,076; 0,086; 0,098; 0,112; 0,128; 0,146; 0,167; 0,19; 0,216; 0,247; 0,281; 0,32; 0,36; 0,42; 0,48; 0,54; 0,62; 0,7; 0,8; 0,92; 1,04; 1,2; 1,35; 1,54; 1,75; 2,0; 2,3; 2,6; 3,0; 3,4; 4,0; 4,5; 5,0.
	Gamut of transversal forward flows (mm/rot)	0,015; 0,017; 0,019; 0,022; 0,025; 0,028; 0,033; 0,037; 0,042; 0,048; 0,055; 0,063; 0,072; 0,082; 0,094; 0,107; 0,122; 0,140; 0,158; 0,180; 0,200; 0,235; 0,28; 0,30; 0,35; 0,40; 0,45; 0,52; 0,58; 0,67; 0,76; 0,87; 1,0; 1,14; 1,30; 1,47; 1,66.
	Power of the main engine	P = 3 kW
	Net weight	m = 1100 kg

c.1) *The verification of the forward flow from the point of view of cutter shaft resistance*
For the cutters with rectangular section, the forward flow is determines with the relation:

$$f = \sqrt[y_1]{\frac{b \cdot h \cdot \left(\frac{h}{L}\right) \cdot R_{a,i}}{6 \cdot C_4 \cdot HB^{n_1} \cdot a_p^{x_1}}} = \sqrt[0,75]{\frac{32 \cdot 32 \cdot 0,67 \cdot 55}{6 \cdot 35,7 \cdot 148^{0,35} \cdot 2^{1,0}}} = 38 \text{ mm/rot} > f_a = 0,2 \text{ mm/rot}$$

[1] p. 348, rel. 10.8

where: h x b represents the section of the cutter shaft: h x b = 32 x 32 mm^2 (tab. 1); L – the length in console of the cutter, in mm; it is recommended: $L = 1,5 \cdot h$ [1] p. 345

It is obtained: $\frac{h}{L} = \frac{h}{1,5h} = 0,67$; $R_{a,\,i}$ - unitary tensions admissible to the bending of the cutter shaft material. For OLC 45, $R_{a,\,i}$ = 55 daN/mm² = 550 N/mm² [6] p. 97, tab. 3.6; C_4 – coefficient that takes into account the worked material and the material of the active part of the cutting tool: C_4 = 35,7 [1]p. 347, tab. 10.15; HB – Brinell hardness of the worked material: HB = 148

x_1, y_1, n_1 – exponenți: $x_1 = 1,0$; $y_1 = 0,75$ [1]p.353, tab. 10.21

$n_1 = 0,35$ [1]p.353, tab. 10.22

*c.*2) *The verification of the forward flow from the point of view of the metal carbide plate resistance*

The verification relation is determined:

$$f = \frac{8,3 \cdot C^{1,8}}{a_p^{0,3} \cdot R_m} = \frac{8,3 \cdot 10^{1,8}}{2^{0,3} \cdot 35} = 12,1 \text{ mm/rot} > f_a = 0,2 \text{ mm/rot}$$ [1] p.348, rel. 10.12

where: C represents the thickness of the metal carbide plate: C = 10 mm tab. 1; R_m fracture resistance to traction of the worked material: R_m = min. 350 N/mm²

*c.*3) *The verification of the double torsion moment admitted by the main movement mechanism of the machine tool*

The calculus relation is:

$$2M_t^* = \frac{F_z \cdot D}{1000} = \frac{122,7 \cdot 130,5}{1000} = 16\, N \cdot m$$ [1]p. 355, rel. 10.26

where: F_z represents the main component of the cutting force:

$$F_z = C_4 \cdot a_p^{x_1} \cdot f_a^{y_1} \cdot HB^{n_1} = 35,7 \cdot 2^{1,0} \cdot 0,2^{0,75} \cdot 148^{0,35} = 122,7 \text{ N} = 12,27 \text{ daN}$$

[1]p.347, rel. 10.7

D – cutting diameter: D = 130,5 mm

The double torsion moment that may be realized to the machine tool is determined with the relation:

$$2M_t = \frac{19500 \cdot N_m \cdot \eta}{n} = \frac{19500 \cdot 3 \cdot 0,9}{590} = 89,2\, N \cdot m > 2M_t^* = 16 \text{ N·m}$$ [1] p. 355

where: N_m represents the engine power: N_m = 3 kW (tab. 2); η - the machine tool efficiency: η = 0,85…0,95 [1] p. 355, it is adopted η = 0,90; n – the main shaft number of rotations: n = 590 rot/min according to pct. e)

d) The determination of the cutting speed

In the case of the longitudinal turning, the cutting speed it is determined with the relation:

$$v = \frac{C_v}{T^m \cdot a_p^{x_v} \cdot f_a^{y_v} \cdot \left(\frac{HB}{200}\right)^n} \cdot K_1 \cdot K_2 \cdot K_3 \cdot K_4 \cdot K_5 \cdot K_6 \cdot K_7 \cdot K_8 \cdot K_9 =$$

$$= \frac{285}{90^{0,125} \cdot 2^{0,18} \cdot 0,2^{0,45} \cdot \left(\frac{148}{200}\right)^n} \cdot 1,04 \cdot 0,66 \cdot 1,0 \cdot 0,912 \cdot 1,0 \cdot 0,9 \cdot 1,0 \cdot 0,9 \cdot 1,0 = 253,9\, m/\min$$

[1]p.359, rel. 10.29

where: C_v represents a coefficient that depends on the material characteristics that is worked and of the cutting tool material: C_v = 285 [1]p. 361, tab. 10.30; T – cutting tool hardness:

T = 90 min [1]p. 335, tab. 10.3; m, x_v, y_v, n – exponents: m = 0,125 [1]p. 359, tab. 10.29, x_v = 0,18; y_v = 0,45 [1]p. 361, tab. 10.30, n = 1,75 [1]p. 361; K_1 – coefficient that takes into account the influence of the cutter transversal section:

$$K_1 = \left(\frac{q}{20x30}\right)^{\xi} = \left(\frac{32 \cdot 32}{20 \cdot 30}\right)^{0,08} = 1,04$$ [1] p. 361, rel. 10.30

q - surface of the cutter shaft transversal section: q =32 x 32 mm^2 tab. 1

ξ - coefficient that takes into account the worked material:

$$\xi = 0,08$$ [1]p. 361

K_2 – coefficient that takes into account the influence of the main attack angle ($\chi_r = 90^0$):

$$K_2 = \left(\frac{45}{\chi_r}\right)^{\rho} = \left(\frac{45}{90}\right)^{0,6} = 0,66$$ [1]p. 361, rel. 10.31

ρ - exponent depending on the nature of the worked material:

$$\rho = 0,6$$ [1]p. 362

K_3 – coefficient that takes into account the secondary attack angle ($\chi'_r = 15^0$):

$$K_3 = \left(\frac{a}{\chi'_r}\right)^{0,09} = \left(\frac{15}{15}\right)^{0,09} = 1,0$$ [1]p. 362, rel. 10.32

a = 15 for the cutting tools with metal carbide plates; [1]p. 362

K_4 – coefficient that takes into account the influence of the cutter top connection ray:

$$K_4 = \left(\frac{r}{2}\right)^{\mu} = \left(\frac{0,8}{2}\right)^{0,1} = 0,912$$ [1]p. 362, rel. 10.33

R – cutter top of the connection ray: R = 0,8 mm tab. 1

μ - coefficient that takes into account the working type and the worked material: μ = 0,1 [1]p. 362; K_5 – coefficient that takes into account the influence of the material from which it is made the active part of the cutting tool: $K_5 = 1,0$ [1]p. 362, tab. 10.31; K_6 – coefficient that takes into account the worked material: $K_6 = 0,9$ [1]p. 363, tab. 10.32; K_7 – coefficient that takes into account the obtaining way of the semi - product: $K_7 = 1,0$ [1] p. 363; K_8 – coefficient that takes into account the semi - product superficial layer state: $K_8 = 0,9$ [1]p. 363; K_9 – coefficient that takes into account the evolving surface form: $K_9 = 1,0$ [1]p. 364.

e) The determination of the work number of rotations

The number of rotations of the main shaft of the machine tool is determined with the relation:

$$n = \frac{1000 \cdot v}{\pi \cdot D} = \frac{1000 \cdot 253,9}{\pi \cdot 130,5} = 619,3\ rot/\min \qquad (1)$$

From the gamut of the machine tool number of rotations it is adopted: n_a = 590 rot/min, tab. 2

f) The determination of the cutting effective speed

The cutting effective (real) speed is determined with the relation:

$$v_{ef} = \frac{\pi \cdot D \cdot n_a}{1000} = \frac{\pi \cdot 130,5 \cdot 590}{1000} = 241 m/\min \tag{2}$$

g) The determination of the cutting tool effective hardness
The cutting tool effective hardness is determined with the relation:

$$T = T_{ec} \cdot \left(\frac{v}{v_{ef}} \right)^{\frac{1}{m}} = 90 \cdot \left(\frac{253,9}{241} \right)^{\frac{1}{0,125}} = 136 \text{ min} \tag{3}$$

h) The determination of the effective power at turning
The effective power is determined with the relation:

$$N_e = \frac{F_z \cdot v_{ef}}{6000 \cdot \eta} = \frac{12,27 \cdot 241}{6000 \cdot 0,9} = 0,547 \text{ kW} < N_m = 3 \text{ kW} \qquad [1]\text{p. } 365$$

i) The calculus basic time
The basic time is determined with the relation [7, p. 345, tab. 12.1]:

$$t_b = \frac{L}{n \cdot f} \cdot i = \frac{l + l_1 + l_2}{n \cdot f} \cdot i \text{ (min)} \tag{4}$$

where: l_1 represents the in-put length in the cutting:

$$l_1 = \frac{a_p}{tg\, \chi} + (0,5...2) \quad (mm) \tag{5}$$

a_p– cutting depth; χ – main attack angle; l_2 – the out-put length from the cutting: l_2 = (1…5) mm; l – the worked effective length; i – the number of pulls; n – the work number of rotations; f – the work forward flow.
Replacing the known data, the basic time is determined:

$$t_b = \frac{L}{n \cdot f} \cdot i = \frac{700}{590 \cdot 0,2} \cdot 1 = 5,93 \text{ min} \tag{6}$$

The automatic method

In order to establish the cutting regime parameters values it was used a specialized soft type data base (made by the company SANDVIK Coromant CoroGuide) that allows establishing the optimal work values for: the work forward flow, the cutting tool hardness, the cutting main speed, the working productivity, the effective power of the machine tool. The study is made with the help of the company Max-Muller from Germany using cutting tools produced by the company Koromant Sandvik.

The work stages for obtaining the optimal values of the cutting regime parameters are:
- the establishment of the mechanical - turning working operation (fig. 2);
- the selection of the application field (fig. 3);
- the selection of the work conditions (fig. 4);
- the selection of the turning conditions, of the forward flow values gamut, of the cutting depth (fig. 5);
- the establishment of the values for the work forward flow f, the main cutting speed v_c, the number of rotations of the engine part n, the working length L, the consumed power P_c, the basic time t_b (fig. 6).

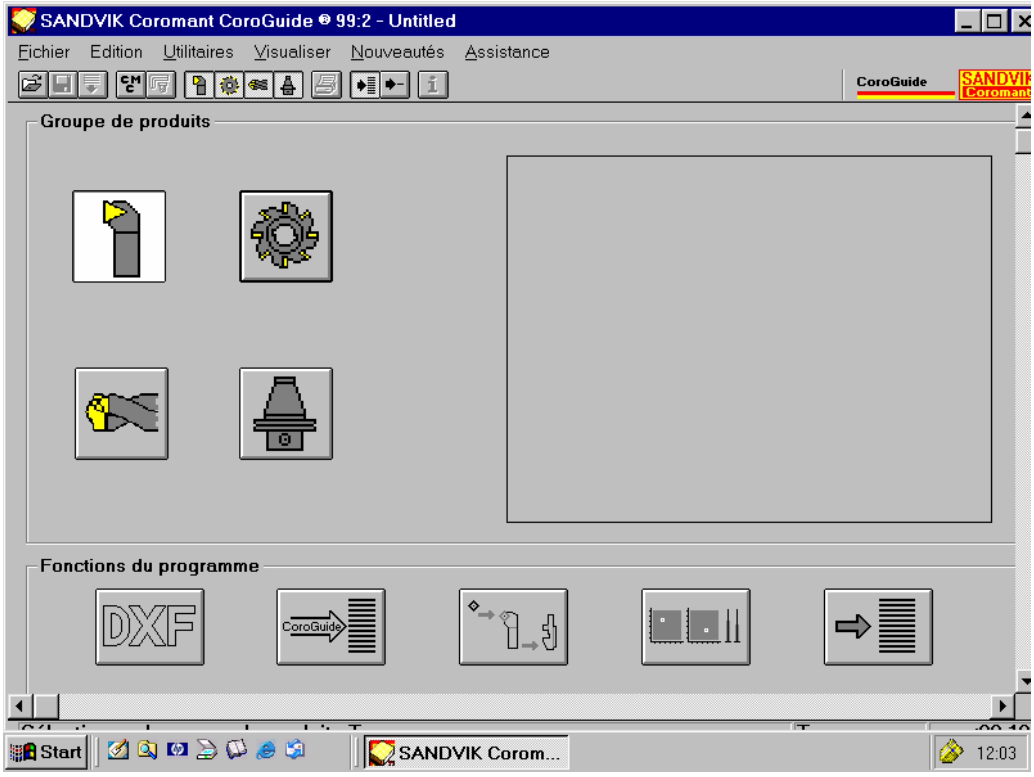


Fig. 2. The establishment of the mechanical (turning) working operation

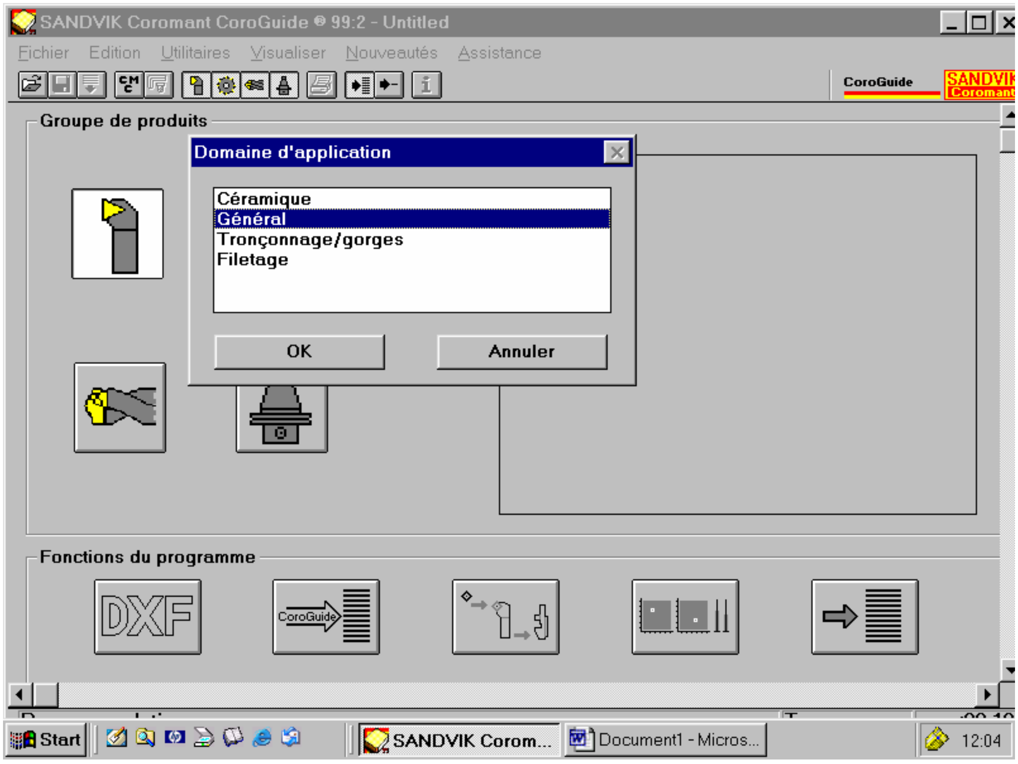


Fig. 3. The selection of the application field

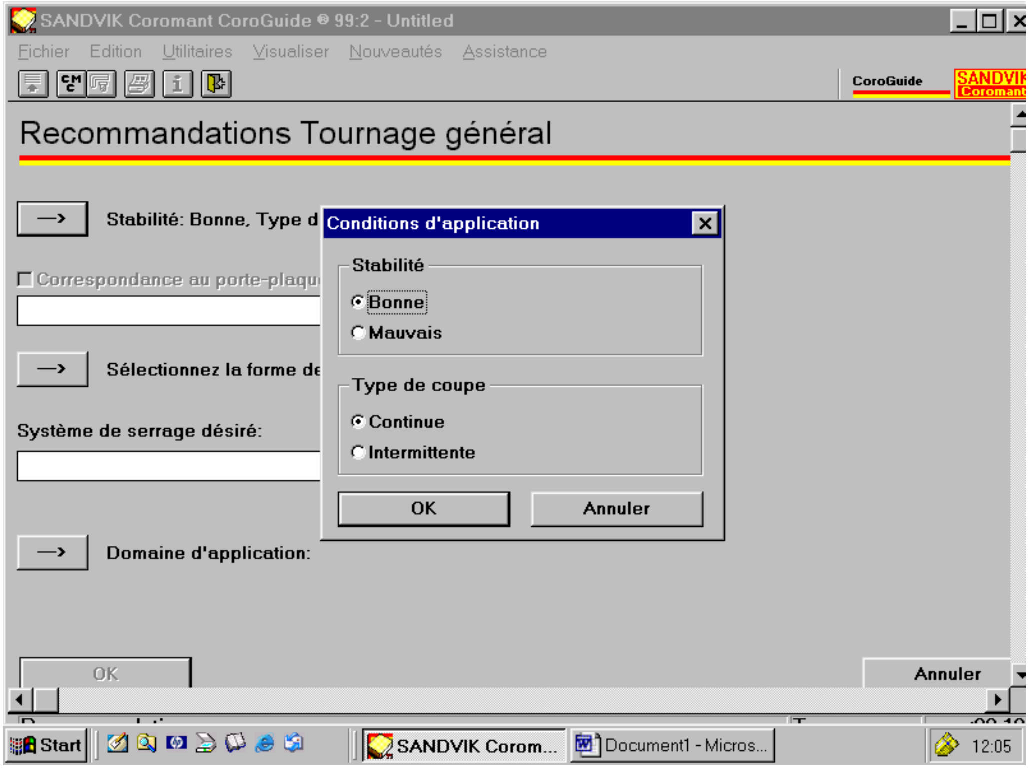


Fig. 4. The selection of the work conditions

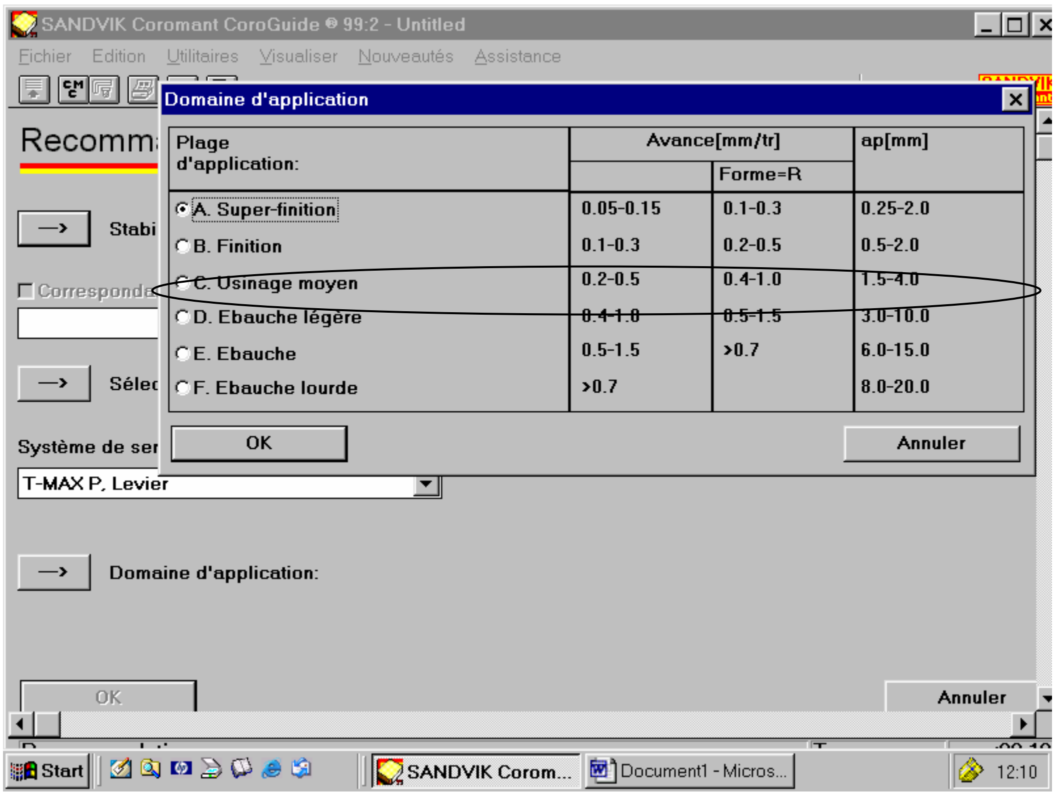


Fig. 5. The selection of the turning conditions, of the forward flow values gamut, of the cutting depth

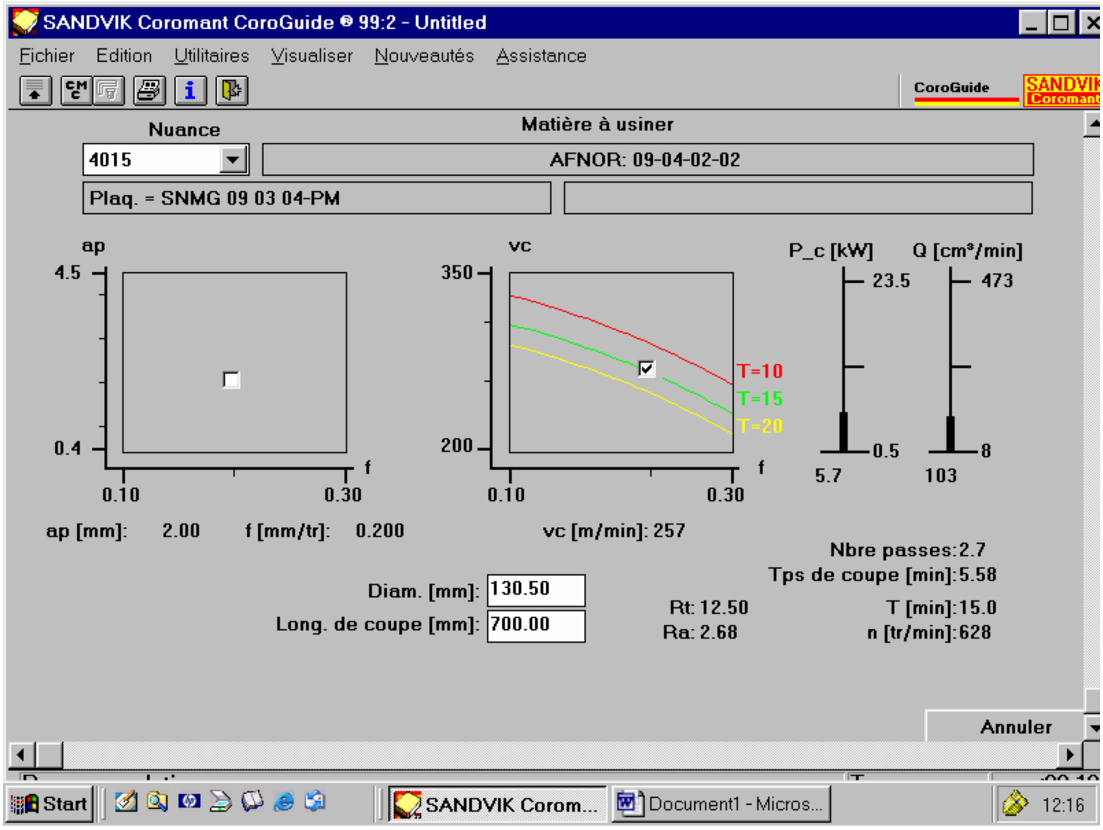


Fig. 6. The establishment of the values for the work forward flow *f*, the main cutting speed v_c, the number of rotations of the engine part *n*, the working length *L*, the consumed power P_c, the basic time t_b.

Comments, Discussions

The choice of the cutting regime to the cutting working of the engine parts is realized depending on the work conditions (the cutting draft), on the cutting tool and semi - product material, on the precision, on the available equipments etc.
The determination of the cutting regime parameters values by the two methods (calculus analytical and automatic method) shows the correspondence between the calculated sizes (table 4).

Table 4. Comparative analysis of the analytical calculus method and the automatic one in order to determine the cutting regime parameters

No.	Operation	Work method	*i*	*t* (mm)	*f* (mm/rot)	v_c (m/min)		*n* (rot/min)		t_b (min)
						calculated	real	calculated	real	
1	Turning	Analytical calculus	1	5	0,20	253,9	241	619,3	590	5,93
2		Automatic	1	5	0,20	257	257	628	628	5,58

The analytical method presents the following disadvantages:

- Is laborious requiring a great volume of calculus, that is why it is justified by the application to the production in series;
- Need a great number of information (work data) requiring the quantification of the sizes that intervene in the calculus relations.

Remark: in order to reduce the calculus volume there may be used the work monograms that group the main calculus sizes defined for the exploitation normalized conditions and then to particularize the final calculus by the multiplication with specific correction coefficients.

The automatic method presents the following advantages:

- An accessible work interface;
- Quick access of the work data;
- Economical work way;
- Optimization possibilities of the work values.

The disadvantages of the calculus automatic method:

- the relative high cost for the acquisition of the data base and its maintenance.

In conclusion, the utilization of the automatic method allows the rapid calculus of the cutting regime parameters values toward the analytical calculus methods which is more laborious.

References

1. Picoş, C. Pruteanu, O., ş.a., *Proiectarea tehnologiilor de prelucrare mecanică prin aşchiere*, Manual de proiectare, vol. I, Editura „Universitas", Chişinău, 1992
2. * * * *Scule aşchietoare şi portscule pentru prelucrarea metalelor*, vol. I, Colecţie STAS, Editura Tehnică, Bucureşti, 1987
3. Georgescu, S., *Îndrumător pentru ateliere mecanice*, Editura Tehnică, Bucureşti, 1978
4. Ivan, M., Antonescu, N. N., ş.a., *Maşini–unelte şi control dimensional*, Editura Didactică şi Pedagogică, Bucureşti, 1980
5. Picoş, C., ş.a., *Proiectarea tehnologiilor de prelucrare mecanică prin aşchiere*, Manual de proiectare, vol. II, Editura „Universitas", Chişinău, 1992
6. Minciu, C., ş.a., *Scule aşchietoare – îndrumător de proiectare*, vol. I, Editura Tehnică, Bucureşti, 1995
7. Vlase, A., ş.a. *Regimuri de aşchiere, adaosuri de prelucrare şi norme de timp*, vol 1., Editura Tehnică, Bucureşti, 1983

Analiza comparativă a metodelor utilizate pentru determinarea parametrilor regimului de aşchiere la prelucrarea mecanică

Rezumat

Procesul tehnologic ca parte a procesului de fabricaţie, reprezintă o succesiune ordonată de sisteme operaţionale care implică o abordare decizională pe fiecare etapă de lucru în parte.
Ordonarea şi prelucrarea informaţiilor în sistemul tehnologic are ca scop final adoptarea unor decizii privind proiectarea, fabricaţia şi mentenanţa proceselor tehnologice.
Lucrarea prezintă modul de determinare a valorilor parametrilor regimului de aşchiere pentru operaţia de strunjire; se efectuează analiza comparativă a valorilor determinate utilizând metoda de calcul analitică şi metoda automată.