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The Damage of the Cutting Tools out of Carbide Metallic During the Turning of a Soaked and not Hardened Steel XC38

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Abstract: The purpose of this study to widened knowledge on the use of the cutting tools out of metal carbide and to define of it the influence of the elements of the mode of cut on the behaviour of these tools during the machining of treated steel XC38 and untreated. This study aimed at evolution determined in experiments of the wear of a cutting tool out of metal carbide with plate reported of P30 nuance for an operation of slide-lathing in turning on soaked and not hardened steel XC38 test-tubes. This research is based on the model of Taylor to determine the lifespan of the cutting tool according to the various parameters of cut, like the cutting speed Vc, the advance of cut a, the depth of cutting P. In order to express the operational limits of the tool for slide-lathing in a preventive way. The model makes it possible to determine the time of change of the tool and to regard it as constraint for the respect of the roughness of the work piece during a work of series in conventional machining.

Key words: Machining, wear, lifespan, model of Taylor, cutting tool, carburize metal

INTRODUCTION

The industrialists need to optimize their production processes in order to increase the productivity, to reduce the wear of the cutting tools (Ben Salem *et al*., 2003). The improvement of the quality of the production will remain always one of the paramount concerns for the industrial development. Technological progress in the machining of metals is related to the improvement of the behavior of materials to the cut. The increase in the performances on the machine tools influences directly over the lifespan of the cutting tools engaged in production. The selection of material of the tool is a delicate phase, taking into account the conditioning of feasibility of the operation of machining. Consequently the rational choice of a nuance of tool can be done only with experiments quite specific to material given (Shultz and Moriwahim, 1992).

The materials of cut out of high speed steel, carburizes and cermet are largely used in turning for the majority of machined materials (Schneider, 2002; Brandt *et al*., 1990). However, their behaviour is limited and their use is sometimes impossible when certain work pieces are characterized by a very great hardness and an abrasion resistance very high (Fallböhmer *et al*., 2000; Chou, 2003). It is the case mainly special steels, pig iron and cast iron soaked, alloys refractory containing nickel and of composite materials with metal matrix. We can also add the sintered materials whose hardness's exceed easily the 70 HRc. Technical progress reveals new materials likely to be used to produce cutting tools answering these requirements. The rational choice of these materials of cut can be done only with experiments specific to each nuance. Thus their implementation requires a sufficient control of the course of the process of cut, in particular the evolution of the wear of the tools and required roughness. During the machining of the materials whose hardness exceeds the 45 HRc, at cutting speeds raised, the mechanical and thermal requests on the edge of cut of the tool, which constitutes the active element carrying out the work of deformation, become significant. Frictions and the high constraints which are exerted with the interfaces between the part and the tool cause various forms of wear on the active part of tool (Bauer *et al*., 2003; Luo *et al*., 1999; Boulanouar and Andonov, 1996; Maamar *et al*., 1994).

Morphologies of wear depend primarily on the nature of the tool, machined material, the cutting conditions and the type of machining. According to standard NF E66-505, the principal forms of wears met are characterized primarily by wears in skin Vb and crater K_T. Wear in skin or frontal wear is due to the friction of the part on the face in skin of the tool (Remadna, 2001; Gelin and Vincent, 1995). From the point of view practises, frontal wear is most significant to consider since it determines the surface quality of the part machined as well as dimensional accuracy (Kaufeld and Torbaty, 1999). On the other hand, wear in

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crater is characterized by a basin formed on the cutting face of the tool following frictions of the chip (Remadna, 2001; Gelin and Vincent, 1995). This form of wear is allotted to the presence of strong pressures and the release of a great quantity of heat in the zone of contact between the chip and the tool. Consequently, the temperature rises and causes a significant thermal diffusion process. The shape of the crater is defined by its depth K_T. Wear notches some occurs under certain cutting conditions following wrenching of particles.

Several work (Amri, 1987; Gelin and Vincent, 1995; Roumesy, 1975a-c) proposed mathematical relations which express the lifespan of the tool T according to the parameters of cut (Boulanouar *et al*., 2006).

Today hard machining is in full rise and the applications of hard turning include/understand the gears (30%), the bearings (25%), the trees (20%), the casings (5%) and more particularly those intended for the car industry which call upon the semi-completion and the completion of the transmissions, the axles, the discs of brakes, etc. (Poulachon *et al*., 2002; Defretin and Levaillant, 1999). The turning of the chilled steels by hardening requires the use of component materials having excellent properties of hardness at high temperatures, wear resistance and chemical stability.

The latter had relatively high performances in turning for their substitution for the operations of correction (Schultz, 1997; Schneider, 2002; Poulachon and Moison, 2003). The more of time, the hard turning products of surfaces of qualities, minimizes the number of operations and the rejected parts (Benchiheub and Boulanouar, 2006).

In end of this study is devoted to the comprehension of the damage mechanisms of the cutting tools in service.

MATERIALS AND METHODS

Materials

Machined material: The cylindrical test-tubes of diameter Ø 80 mm and length L = 500 mm machined are out of steel XC38, of which a first series of test-tubes not soaked and a second series of test-tubes soaked. This steel is selected as material to be machined because it roughly presents 47% of thermically treated materials used in the manufacture of the parts (Table 1).

Materials of the tools: The cutting tool used is a turning tool with removable plate brought back square, fixed on the tool by fastening. The square brought back plates are out of metal carbide of nuance P30 having the following geometry: Xr = 75°, α = 6°, γ = -6E, λ = -6E, whose the radius of the nozzle used is Rε = 0.8 mm. The chemical composition of the plates is: WC = 82%, TiC = 8%, Co = 10%.

Table 1: Physical and chemical properties of the test tube XC38

Properties	Values
C (%)	0.35-0.46
Mn (%)	0.5-0.8
Si (%)	0.1-0.4
Rm (Mpa)	580-670
Re (Mpa)	350
Rp0.02 (Mpa)	335
A_{min} (%)	21

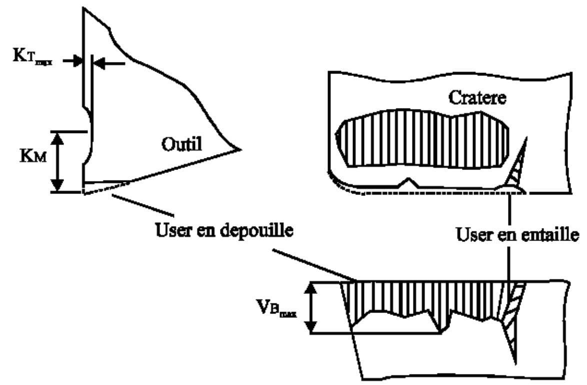

Fig. 1: Schematic of wear to the specimen and the cutting tool

Methods

Models of lifespan and models of wear: The lifespan of a tool is the time of cut total necessary to reach a criterion of specific lifespan. To evaluate the lifespan, we refer to a limiting value of a direct criterion (Vb, K_T). The analysis of the damage is very often done by considering wear on the face of skin because the latter influences directly the surface quality of the part (Fig. 1). For a tool out of carbide, the following criterion is recommended by the ISO standard: average height Vb = 0.3 mm

From the criteria of wear, we establish models of lifespan. Oldest and the most used is that of Taylor (Eq. 1). Taylor was the first to be proposed a mathematical model connecting the effective duration of cut T of a tool to the parameters of modified cut or Taylor (Eq. 2) (Menegaux, 2004; Lelong-Ferrand and Arnaudiès, 1977):

$$T = C_1 . V_c^n \quad (1)$$

$$T = C_2 . P^x . a^y . V_c^n \quad (2)$$

C_1 = Constant depends on the nuance of the tool and machined material
V_c = Cutting speed (m min^{-1})
n = Constant

C_2 = Constant depends on the nuance of the tool and machined material
P = Depth of cut (mm)
a = Advance (mm tr^{-1})
x, y = Exhibitors depending on the nuance of the tool

These equations describe the relation between the lifespan T and the parameters of cut like the cutting speed V_C the advance a and the depth of cut P they utilize constants (C_1, C_2, n, x, y) which must be identified in experiments for each couple tool/matter considered and each process of machining. Contrary to the models of lifespan, the models of wear describe the volume of matter lost in the zones of contact of the tool by connecting them to physical parameters like the temperature or the pressures applied to the tool (Roumesy, 1975a-c; Roumesy and Bedrin, 1981, 1984).

PRESENTATION OF THE RESULTS

Case of the operations of slide-lathing of steel XC38 not hardened

Test 1: Test 1 consists to evaluate wear (Vb) and to determine the behaviour of the tool out of metal carbide according to time for various cutting speeds (Vc_1 = 36 m min^{-1}, Vc_2 = 100 m min^{-1}) with an advance a = 0.08 mm tr^{-1} and a depth of cut p = 0.5 mm (Fig. 2, 3).

Figure 2 presents the variation of the wear of the tool on the surface of skin Vb according to time for different cutting speeds (Vc_1= 36 m min^{-1}, Vc_2 = 100 m min^{-1}), with a depth of constant cutting p = 0.5 mm and an advance of constant cut a = 0.08 mm tr^{-1}. It is noted that the value cutting speed influences the value of the wear of the Vb tool for example with one 50 min duration of machining, with Vb = 0.28 mm and Vc_2 = 100 m min^{-1}. These two curves of wear have three parts. The first part is that of wear of grinding with a time of cut between 0 and 10 min. The second part presents a fair wear and tear of a time of cut between 10 and 90 min. The third part starts to 90 min is the part of catastrophic wear (Fig. 2). It is noticed that these three parts are not identical, because their zones are different.

The statistical processing of the results of the behaviours according to the cutting speed (Fig. 3) allowed the deduction of mathematical model, expressing the functional relation between the lifespan and the cutting speed according to the Eq. 3:

$$T = e^{8.19} \times V_c^{-0.91} \quad (3)$$

Figure 3 shows the behaviour T of the experimental tool for the two different modes of cut (Vc_1= 36 m min^{-1}, a = 0.08 mm tr^{-1}, p = 0.5 mm) and (Vc_2 = 100 m min^{-1}, a = 0.08 mm tr^{-1}, p = 0.5 mm). The first mode of cut gives a behaviour T = 140 min, on the other hand the behaviour of the sec mode of cut is T = 56 min.

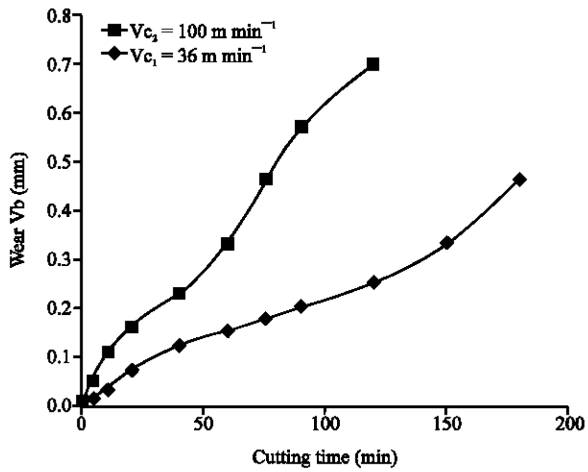

Fig. 2: Variation of cutting tool wear (Vb) according to time for different cutting speed (a = 0.08 mm tr^{-1}, p = 0.5 mm)

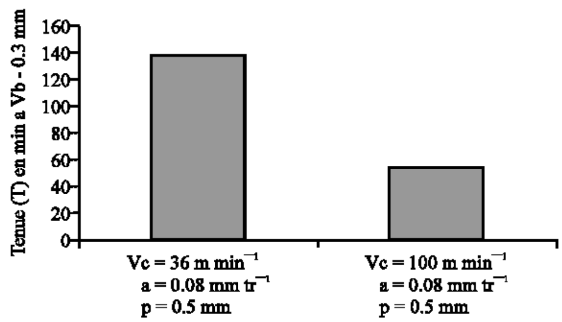

Fig. 3: Experimental behaviour for different cutting speed, Vb = 0.3 mm

The form and the shape of the curves of Fig. 2 and 3 resemble the curves obtained by other research tasks to work out by other researchers (Schultz, 1997; Schneider, 2002; Poulachon and Moison, 2003) but they are not identical because the working conditions are not the same ones, in particular the mode of cut (Vc, a, P), the matter with machined, the nature of the reported plates of the cutting tools, the machine tools used are not identical. We can say that the cutting speed Vc is a significant parameter influencing the damage and the behaviour of the tool.

Test 2: Evolution of wear (Vb) and determination of the behaviour of the tool out of metal carbide according to time for various depths of cut (Fig. 4, 5):

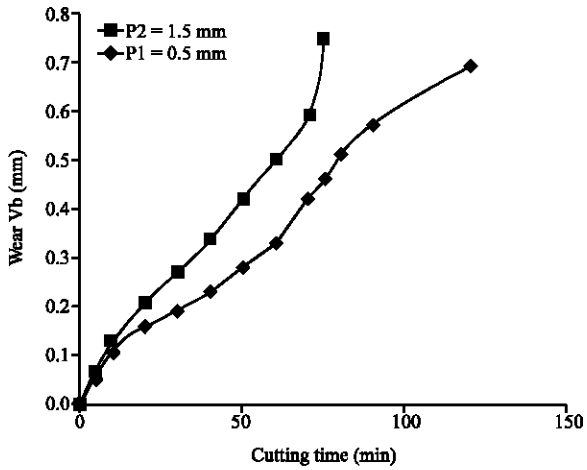

Fig. 4: Variation of cutting tool wear (Vb) according to time for different depth of feed (Vc = 100 m min^{-1}, a = 0.08 mm tr^{-1})

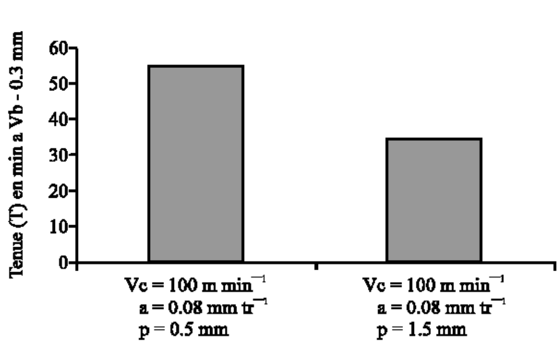

Fig. 5: Experimental behaviour for different depth of feed, Vb = 0.3 mm

For a cutting speed and advance constants, one varies the depth of cut. The advance a = 0.08 mm tr^{-1}, the cutting speed Vc = 100 m min^{-1} and the depths of cuts (p_1 = 0.5 mm, p_2 = 1.5 mm).

Figure 4 presents the wear of the tool according to the depth of cutting (p_1 = 0.5 mm and p_2 = 1.5 mm), on the other hand the cutting speed (Vc) and advance (a) are constant. If the depth of cutting increases the wear of the tool example increases if we takes t = 50 min of machining, we obtains the wear of the tool equal to Vb = 0.4 mm for p = 1.5 mm but if we takes p = 0.5 mm, the wear of the tool is of Vb = 0.28 mm.

It is noted that the increase the depth of cutting increases the wear of the tool.

The statistical processing of the results of the behaviours according to the depth of cut (Fig. 5) allowed the deduction of mathematical model, expressing the functional relation between the lifespan and the depth of cut given by the Eq. 4:

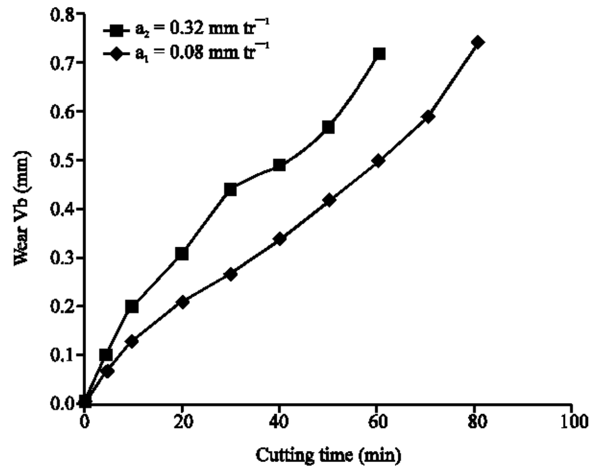

Fig. 6: Variation of cutting tool wear (Vb) according to time for different cutting advancement (a)

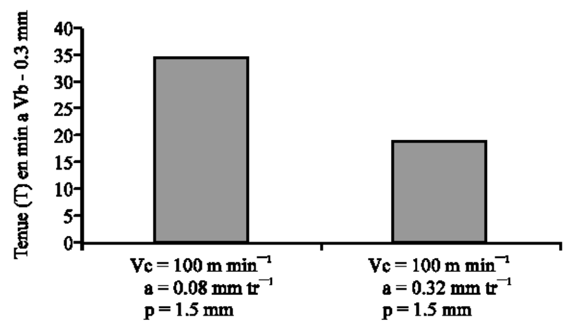

Fig. 7: Experimental contains for different advancement, Vb = 0.3 mm

$$T = e^{3.7} \times P^{-0.41} \quad (4)$$

Test 3: Evolution of wear Vb and determination of the behaviour of the tool out of metal carbide according to time for various advances of cut (Fig. 6, 7):

For a cutting speed and a depth constants, we varies the advance of cut (a = 0.08 mm tr^{-1}, a = 0.32 mm tr^{-1}) with a cutting speed Vc = 100 m min^{-1} and a depth p = 1.5 mm.

Figure 6 allows even influence of the variation of the parameter of the advance of cut on wear Vb of the tool. It is noted that if the value of the advance of cut increases the value of wear also increases, for example, for one duration of machining of 20 min, Vb wear is 0.2 mm with an advance of 0.08 mm tr^{-1}, on the other hand for a value in advance of 0.32 mm tr^{-1}, wear increases with 0.3 mm.

The statistical processing of the results of the behaviours according to the advance (Fig. 7) allowed the deduction of the mathematical model expressing the functional relation between the lifespan and the advance in the form Eq. 5:

$$T = e^{2.47} . a^{-0.42} \quad (5)$$

The behavior T of the tool according to the advance according to the deduction of the mathematical model connecting the behaviour of the tool compared to the advance Eq. 5. It is noted that the behaviour of the tool decreases when we increases the advance (Fig. 7).

Multifactorielle method: The tests carried out allowed the follow-up of the evolution of wear according to time for the various combinations (Fig. 2, 4, 6).

The curves of the Fig. 8 have the results of different experimental combinations from the modes of cut (cutting speed, advances, depth of cutting) according to time. Following these results, we notices the same experimental results of the tests previously presented. For two identical experiments, if we increases the cutting speed (Vc_1 = 36 m min^{-1}, Vc_2 = 100 m min^{-1}), the wear of the tool increases. Same manner if we increases the advance of cut (a_1 = 0.08 mm tr^{-1}, a_2 = 0.32 mm tr^{-1}), the wear of the tool increases also even for the increase the depth of cutting (P_1= 0.5 mm, P_2 = 1.5 mm).

With the tests of Fig. 8, we could deduce the life spans from the cutting tools represented by the Fig. 9 according to the model of Taylor. The graphic treatment of these results led to the determination of the life spans corresponding to the various conditions of tests. The statistical processing of the behaviours allowed the deduction of mathematical model of the modified equation of Taylor 2. The latter express the functional relation between the lifespan and the elements of mode of cut in the form of Eq. 6 (Lelong-Ferrand and Arnaudiès, 1977).

$$T = e^{6.85} . V_c^{-0.9} . a^{-0.4} . P^{-0.41} \quad (6)$$

Figure 9 is a histogram which recapitulates the various experiments realized previously according to the various combinations of the parameters of cut (cutting speed, advances, depth of cutting). We notes that the greatest behaviour (lifespan of the tool) is according to the parameter cutting speed smallest (Vc = 36 m min^{-1}), then that of the smallest advance (a = 0.08 mm tr^{-1}) and in end the depth of the smallest cutting (p = 0.5 mm).

Micrography of wear Vb of the plates P30 after machining on a steel XC38 not hardened according to time: Figure 10a-d show the various wears Vb recorded on plates out of metal carbide P30 according to time on steel XC38 test-tubes not hardened.

The photographs on the Fig. 10 they is images made with the MEB of stop work of the plates of the tools for each test carried out in order to even the degree of wear. The micrographic one of the wear of the plates to pay out of metal carbide according to variation of the time of machining of steel XC38 not soaked shows that the wear of the plate is not significant and that the tools resisted the criteria of wear well.

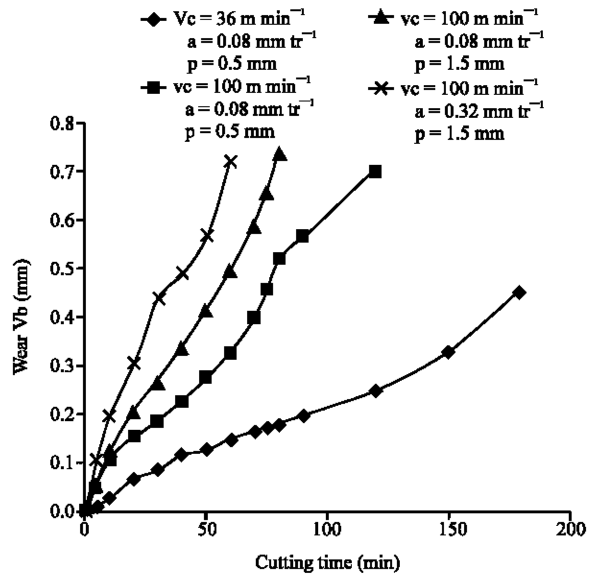

Fig. 8: Variation of cutting tool wear (Vb) according to time for different combinations

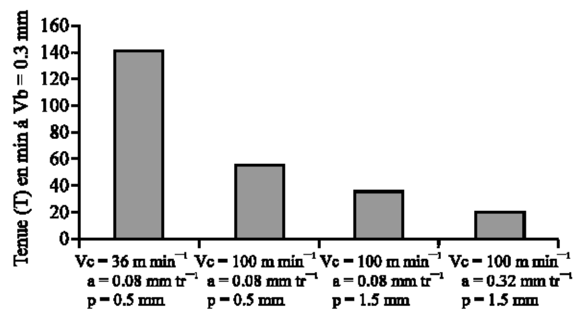

Fig. 9: Experimental behavior for different combinations, Vb = 0.3 mm

Case of the operations of slide-lathing of hardened steel XC38

Heat treatment (Hardening, Returned): According to the percentage out of carbon and their volume, the steel XC38 test-tubes have were put in a furnace heated until a temperature of 850EC, after 2 h, the parts are soaked in water. Then, the test-tubes have undergoes an income to know: we gives the test-tubes in the furnace, at the temperature of 250EC left we them during 2 h with the furnace then cooled with the free air with 20EC. The

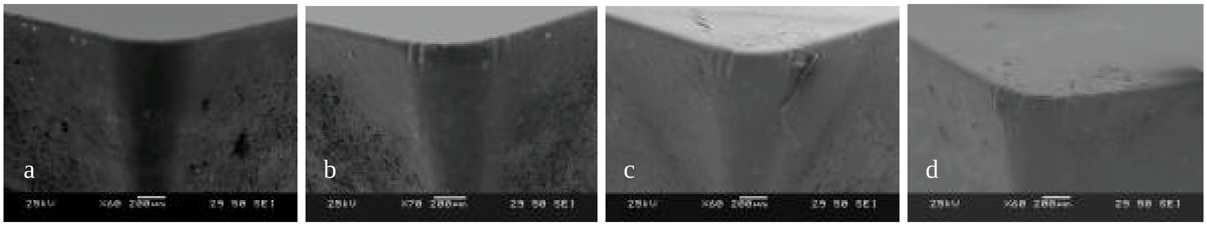

Fig. 10: Micrographics of wear Vb for metallic carbide layer to P30 nuance at Vc = 100 m min^{-1}, a = 0.32 mm tr^{-1} and p = 1.5 mm. (a) : tc = 10 min, (b) : tc = 20 min, (c) : tc = 40 min, (d) : tc = 60 min

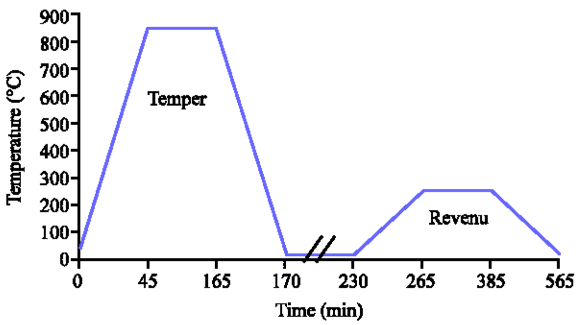

Fig. 11: Cycle heat treatment of the test-tubes

conditions of the heat treatment are presented in the Fig. 11. The average hardness of the test-tubes obtained at the end of the operations is of 112 HRB.

We take again the same tests carried out for the case of the operations of slide-lathing of the steel soft centre, respectively.

The first test consists in varying the cutting speed (Vc_1 = 36 m min^{-1}, Vc_2 = 100 m min^{-1}) and to keep the advance a = 0.08 mm tr^{-1} and the depth of cut p = 0.5 mm constant.

One on the other hand notices on the Fig. 12 that for a time of 2 min machining, wear strips Vb of them is 0.18 mm for a cutting speed of 36 m min^{-1}, Vb = 0.34 mm for a cutting speed of 100 m min^{-1}. Also, the increase cutting speed influences the value of wear. The value of wear is larger with that of the test of the Fig. 2 because of the hardness of the machined part (the soaked part).

From Fig. 12, we deduces the histogram from the behaviours (lifespan) (Fig. 13) the functional relation between the lifespan and the cutting speed is given by Eq. 7:

$$T = e^{6.26} . V_c^{-1.36} \qquad (7)$$

We notes on the Fig. 14, a much reduced time of cut compared to the case of the parts not soaked with almost identical values of wear.

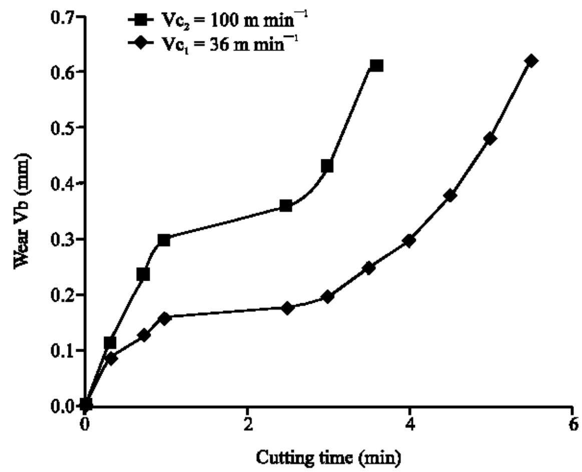

Fig. 12: Variation of cutting tool wear (Vb) according to time, (a = 0.08 mm/tr, p = 0.5 mm)

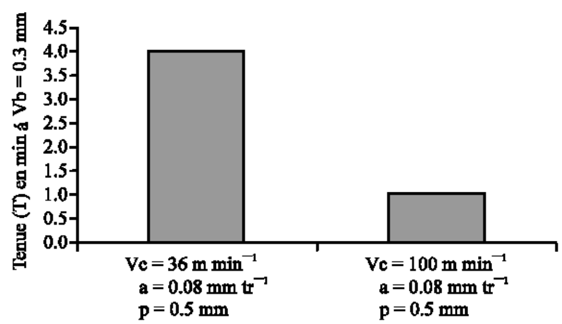

Fig. 13: Experimental behaviour for different cutting speed, Vb = 0.3 mm

The functional relation between the lifespan and the depth of cut is in the form Eq. 8:

$$T = e^{0.082} . P^{-0.88} \qquad (8)$$

The experimental behaviours with various depths of cut for the soaked parts do not exceed 4 min (Fig. 15) compared to those of the parts not soaked which exceeds the 50 min (Fig. 5).

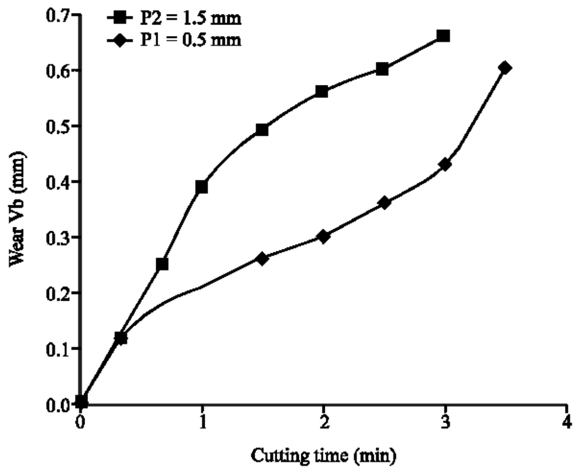

Fig. 14: Variation of cutting tool wear (Vb) according to time and depth of feed, a = 0.08 mm tr^{-1}, Vc = 100 m min^{-1}

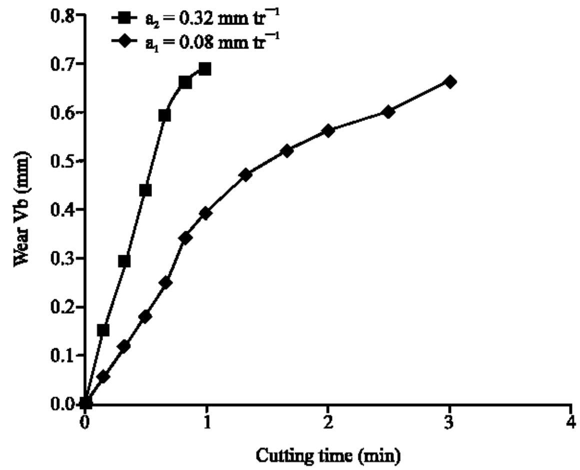

Fig. 16: Variation of cutting tool wear (Vb) according to time and advancement. Vc = 100 m min^{-1}, p = 1.5 mm

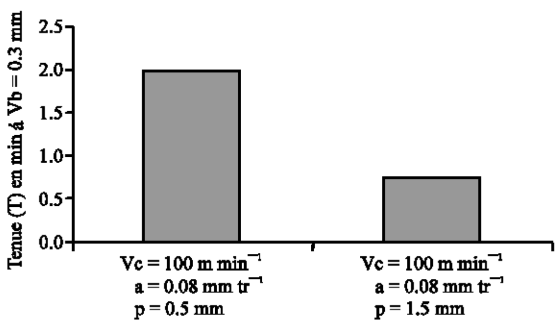

Fig. 15: Experimental behaviour for different depth of feed, Vb = 0.3 mm

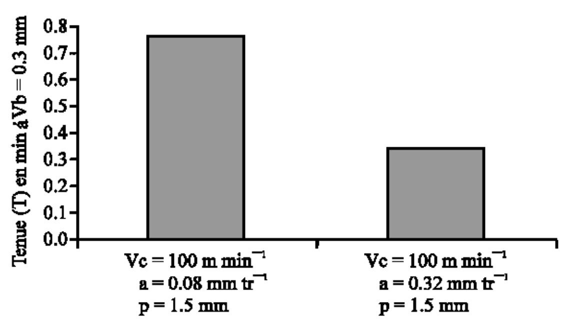

Fig. 17: Experimental behaviour for different advancement, Vb = 0.3 mm

Figure 16 shows the influence of the variation of the parameter of the advance of cut on wear Vb of the tool, we notes that if the value of the advance of cut increases the value of wear also with a time of cut does not exceed the 3 min increases a much reduced time of cut.

The functional relation between the lifespan and the advance is represented by Eq. 9:

$$T = e^{-1.74} . a^{-0.58} \tag{9}$$

The behaviour T of the tool according to the advance according to the deduction of the mathematical model connecting the behaviour of the tool compared to the advance Eq. 9. It is noted that the behaviour of the tool decreases when the advance at cutting speed and constant depths of cut are increased, do not exceed 1 min (Fig. 17).

Multifactorielle method: The tests carried out allowed the follow-up of the evolution of wear according to time for the various combinations of the experimental design (Fig. 12, 14, 16).

The functional relation between the lifespan and the elements of mode of cut is in the form:

$$T = e^{4.2} . V_c^{-1.36} . a^{-0.57} . P^{-0.89} \tag{10}$$

The curves of Fig. 18 have the results of different combinations experimental from the mode of cut (cutting speed, advances, depth of cutting) according to time. We note the checking of the various experimental results (curved) to find previously with knowing: for two experiments identical, if we increase the cutting speed (example Vc_1 = 36 m min^{-1} and Vc_2 = 100 m min^{-1}), the wear of the tool increases. Same manner, if we has two experiences identical but with different advances of cut (example a_1 = 0.08 mm tr^{-1} and a_2 = 0.32 mm tr^{-1}), the wear of the tool Vb_1 is an inferior with Vb_2. It is the same case to note for various depth of cutting (example p_1 = 0.5 mm and p_2 = 1.5 mm). In end, for three tests identical relatively,

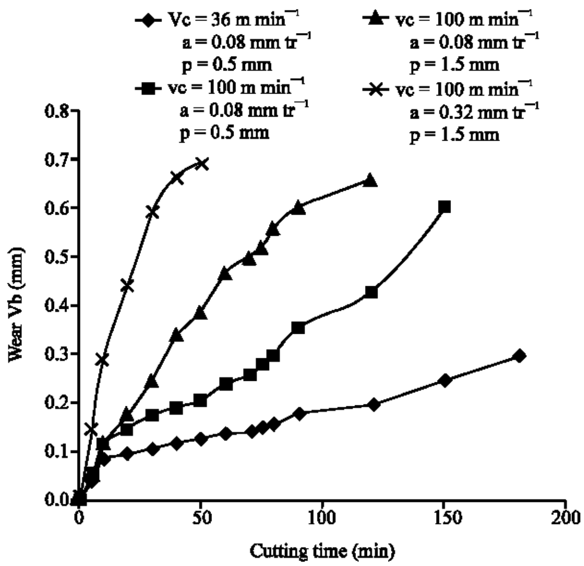

Fig. 18: Variation of cutting tool wear (Vb) according to time and different combinations

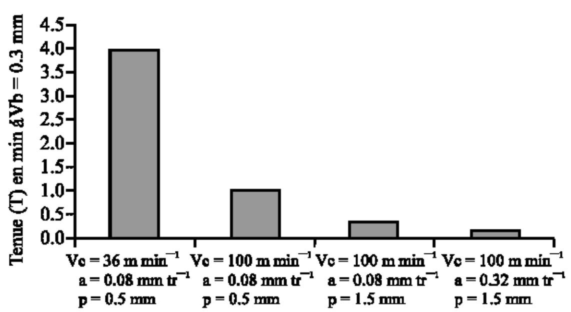

Fig. 19: Experimental behaviour for different combinations of experiences plan, Vb = 0.3 mm

we notes that the value of wear is according to the cutting speed initially, then of the value of the advance in second and end of the value the depth of cutting.

By comparison of Fig. 8 and 18, the value of wear is different following the increase from the hardness of the soaked test-tube. It is noticed that the values of the wear of the tool are definitely higher than those with the experiments ridges with a test-tube not hardening.

The behaviour of the tool for the various experiments realized according to the various combinations of the parameters of cut (cutting speed, advances, depth of cutting), shows that the greatest lifespan of the tool is according to the parameter cutting speed smallest, then that of the smallest advance and in end the depth of the smallest cutting.

In end, if we compare the results of the behaviour tool presenting it on Fig. 19 with those obtained and presenting on Fig. 9, we notice that the behaviour of the tools for these experiments is not the same bus the hardness of the test-tubes is not the same one, although the mode of cut is the same one.

Micrography of wear V B of the plates P30 after machining on a steel XC 38 hardened of hardness 112 HRB: Figure 20a-d show, the micrographic variation of the wear of the plate out of metal carbide is according to the variation of the time of machining initially, the mode of cut and the hardness of the work piece. We notice that wear is significant as the time of machining increases is that the hardness of the test-tube increases.

DISCUSSION

The analysis of these results shows that the cutting speed has a significant influence on wear, indeed with the increase in the latter; wear increases in a remarkable way (Fig. 2, 12).

It comes out from this analysis that the effect the cutting speed over the lifespan is more pronounced for speeds high (Fig. 3, 13) it is explained by the fact why when one works with higher cutting speeds:

- The machining system becomes unstable because of the great vibrations recorded during machining
- The temperature in the zone of cut increases (in particular with the interfaces chip surfaces of attack and part surfaces of principal skin, which results in a loss of hardness as well as the manifestation of the various mechanisms of wear of the tool

As the Fig. 4, 6, 14 and 16 show it that it is in the case of the machining of steel XC38 hardened or not, it is noted that wear increases with the increase in advance and the depth of cut. This rise in wear induced to a degradation of the surface quality of the part machined according to time. The increase in the advance enormously decreases the behaviour of the tool which does not exceed 1 min (Fig. 17). Amongst other things, the wear of the tool presented by the Fig. 10 and 20 show the variation of the damage of the tool according to time with selected modes of cuts.

These results are similar to those published by Schultz (1997), Schneider, (2002) and Poulachon and Moison (2003), whose authors prove that the parameters of cut play a very significant role in the surface quality of the parts more the surface quality of the tool after machining.

After having evaluated wear Vb for procedures of tests which take into account the variation of the various parameters of cut (Vc, a and P), we noted that:

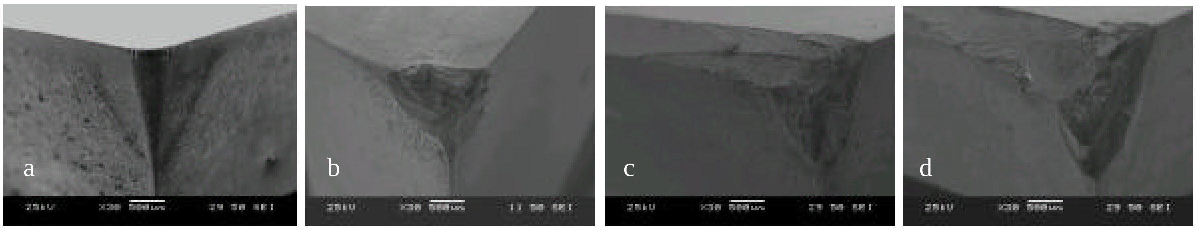

Fig. 20: Variations Micrographiques de l=usure Vb du carbure métallique de nuance P30, à Vc = 100 m min, a = 0.32 mm/tr, et p = 1.5 mm pendant l = usinage de l = éprouvette en acier XC38 trempée : (a) : tc= 10s, (b) : tc = 20s, (c) : tc = 30 sec, (d) : tc = 1 min

- The tool out of metal carbide of nuance P30 resists wear for the machining of half-hard steel XC38, to reach acceptable wear Vb = 0.3 mm. It him took a time of cut T = 60 min for a cutting speed Vc = 100 m min^{-1} and T = 140 min for Vc = 36 m min^{-1}
- Hardened steel XC38 of hardness 112 HRB is very difficult to machine, the tool of nuance P30 to reach acceptable wear very quickly (T = 1 min for Vc = 100 m min^{-1} and T = 4 min for Vc = 36 m min^{-1})
- The surface quality obtained in the case of the machining of hardened steel XC38 is better compared to that obtained during the machining of steel XC38 not hardened

The modes of wear observed are those of abrasion and diffusion which appears on surface in skin and the surface of attack.

The analysis of the curves of follow-up of wear according to time shows that the pace of the latter obeys the universal law of the wear of any machine element.

The influence of the advance and that the depths of cut on the behaviour are not very significant compared to the cutting speed.

The mathematical model suggested expresses the qualitative and quantitative relation between the wear and the elements of the mode of cut. It is necessary for optimization and the industrial exploitation.

Following the experiments carried out on the soaked test-tubes, we noted and checks the same observations quoted in the references (Schultz, 1997; Schneider, 2002; Poulachon and Moison, 2003) that the surface quality is better and does not ask for an operation of correction.

This comparative study made it possible to establish the variations of performance of the tool out of metal carbide of nuance P30 during the machining of two series of hardened steel XC38 test-tubes and not soaked with the same modes of cut.

NOMENCLATURE

L	= Length (mm)
Ø	= Diameter (mm)
% C	= Percentage of carbon
% Mn	= Percentage of manganese
% Si	= Percentage in silicon
Rm	= Maximum resistance to traction (MPa)
Re	= Normal load with the elastic limit (MPa)
$Rp_{,0.02}$	= Conventional load with the elastic limit (MPa)
Amin	= Elongation at the fracture of the sample (%)
α	= Clearance angle (°)
γ	= Angle of attack (°)
λ	= Angle of inclination of edge (°)
$R\varepsilon$	= Radius of nozzle (mm)
WC	= Carbon of tungsten
TiC	= Carbon of titanium
Co	= Cobalt
Vb	= Cutting tool wear (mm)
K_T	= Wear in crater (mm)
T	= Behaviour of the tool (lifespan) (min)
C1	= Constant depends on the nuance of the tool and machined material
n	= Constant
Vc	= Cutting speed (m min^{-1})
C_2	= Constant depends on the nuance of the tool and machined material
P	= Depth of cut (mm)
a	= Advance (mm tr^{-1})
tc	= Time of cut (min)
x, y	= Exhibitors depending on the nuance of the tool
P30	= Nuance of carbide of the tool
XC38	= Steel XC38

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