WEAR BEHAVIOR OF CUTTING TOOLS IN HARD TURNING

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Abstract: In large-scale machining, one often imposes a tool duration corresponding to a working session; tools in use are systematically exchanged for new tools at the end of the series. Alternatively, a tool duration is determined by the importance of the series of workpieces; the tool is then systematically exchanged at the end of each series. By thus working at "imposed duration", one voluntarily abandons the economic regime or the regime of maximum production; it is thus agreed to increase the cost of machining or/and/or a loss of production to benefit, in return, the distribution facilities, assembly, and maintenance of tools. It is, however, advisable to ensure that this counterparty is globally sufficient to justify the loss and, accordingly, to agree on the machining cost. CBN content (vol. %) plays a crucial role in machining applications. Varieties of CBN grades with different CBN contents ranging from 45% to 95%. In machining hardened steels, a higher CBN content increases resistance to fracture and thermal shock, whereas a lower CBN content provides greater wear resistance.

Keywords: machining, tool, series, regime, production.

INTRODUCTION

The maximum production regime demonstrates the importance of tool life in relation to machining time in the practical planning of costs and productivity of a machining operation. While machining time is readily estimated from programming parameters, a tool's lifespan depends on multiple physical wear mechanisms. Only experimental models can be used to estimate this lifespan based on the cutting parameters. This article describes the evolution of wear generally observed for a cutting tool, as well as the type of model that can be implemented for the tool life [1, 4, 5, 8].

CUTTING TOOL WEAR

Tool wear mainly manifests itself in two aspects, as shown in Figure 1:

- "Crater" wear on the cutting face of the tool, due to chip friction. During wear, the depth "KT" and the position of the crater change and influence, in particular, the radius of the chip wrap; the rear flank of the crater can play the role of a natural chip breaker.

- Frontal wear on the flanks, by friction on the part. It is manifested by the appearance of a shiny and streaked band, parallel to the edge. In zone B, the width "VB" of this band evolves (in time) parallel to the depth "KT" of the crater until the tip is destroyed by the conjunction of these two effects.

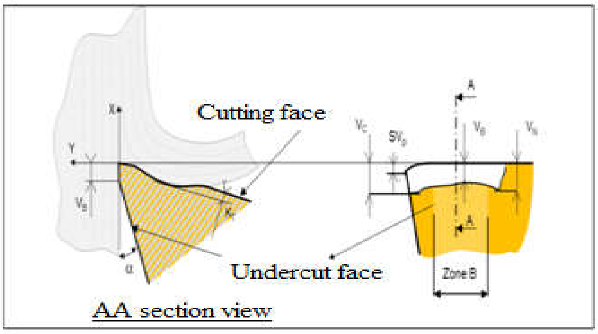

Figure 1: Definition of the main parameters characteristic of wear (Following NF and ISO Standards).

Please note, however:

- The increase in the width of the wear band at its ends, due to the machining of the surface areas of the part, which gives rise to particular phenomena;
- Under severe cutting conditions, the appearance of plastic deformation of the tool tip is characterized by its sagging "SVp";
- In the case of repeated shocks or periodic variations in forces (discontinuous cutting, vibrations), there is the possibility of crumbling of the cutting edge.

Measurements of frontal wear "VB" as a function of cutting time (Fig. 2) generally make it possible to follow the evolution of wear [3, 6, 7, 8]. This evolution is not strictly continuous, and irregularities may appear around the curve reflecting the average trend. In the case of carbide tools, the evolution of this wear is explained by the superposition of two main types of wear:

- wear by adhesion favored by local pressures and high temperatures,
- Wear by diffusion, the transfer of certain constituents of the tool into the chip, is favored by the high temperatures at the tool/chip interface. We observe 3 zones:

Zone 1: period of adaptation of the cutting edge to the cutting regime.

Zone 2: stabilization of the wear gradient, substantially linear evolution as a function of time.

Zone 3: rapid growth of wear which precedes the collapse of the edge; in this area, the risk of tool breakage is significant.

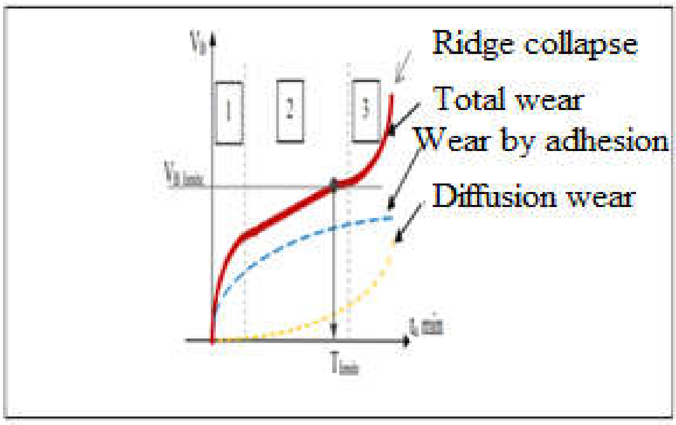

Figure 2: Evolution of frontal wear.

PLANNING OF EXPERIMENTS AND EQUIPMENT USED

This series of experiments concerns the machining of X155CrMoV12 steel treated at 62 HRC, using ceramic and CBN tools. Tool wear tests were carried out, taking the cutting speed as a variable in order to determine the corresponding Taylor models. The trials were planned using unifactorial and multifactorial methods.

In these tests, it is a question of studying the variation in the wear of the cutting tool and the roughness of the machined surface as a function of time for different cutting speeds, by carrying out machining with a CBN, following the plan in Table 1.

Table 1: Variation of cutting speed Vc.

Vc, [m/min] Ceramic	Vc, [m/min] CBN	f, [mm/rev]	ap, [mm]
127	125	0,3	1
145	150	0,3	1
164	320	0,4	1
_	450	0,4	1

Table 2: Variation of feed per revolution f.

f, [mm/rev] Ceramic	f, [mm/tr] CBN	Vc, [m/min]	ap, [mm]
0,08	0,08	118	0.5
0,14	0,14	118	0.5
0,20	0,20	118	0.5
0,24	0,24	118	0.5

Table 3: Variation of depth of cut.

ap, [mm] Ceramic	ap, [mm] CBN	Vc, [m/min]	f, [mm/rev]
0 ,25	0 ,25	118	0,8
0,50	0,50	118	0,8
0,75	0,75	118	0,8
1	1	118	0,8

EQUIPMENT USED

The machining was carried out without lubrication on a TOS universal lathe, model SN40C in the technological hall of the University of Abou Bekr Belkaid, Tlemcen, Algeria, whose electric motor power is 6.8 kW (Figure 3).

Figure 3: General view of the machining.

The material used is high alloy steel X155CrMoV12, having a hardness of 62 HRC after undergoing quenching at 940°C followed by tempering at 280°C to achieve a hardness of 55 HRC, in order to work under the duration of filming. The pieces are in the form of solid logs with a diameter D = 57 mm and a length L = 240 mm.

The chemical composition is given in Table 4.

Table 4: Chemical composition of the part.

% C	%Mn	%Si	%Cr	%Mo	%V	%P	%S
1 ,55	0,51	0,22	3	0,80	0,34	0,032	0,035

Two types of cutting tools were used: a ceramic tool and another in CBN, formed of an irreversible triangular insert of type TNGA 16 04 08 01020 CC650 for ceramic and type TNMG 16 04 08 for CBN and a tool holder designated SOGIMO 9020W3K10 with the following geometry:

$\psi = 90^\circ$; $\alpha = 6^\circ$; $\gamma = -6^\circ$; $\lambda = -6^\circ$; $r\varepsilon = 0.8$mm.

Pad wear is measured on a W-AD workshop microscope (Figure 4). To allow measurement, this microscope is equipped with a cross-displacement table with an accuracy of 1µm

Figure 4: Microscope used [2].

EXPERIMENTAL ANALYSIS OF SURFACE STATES

Continuous monitoring of the nature and roughness of the materials in contact indicates that the initial roughness significantly affects the location and evolution of the initial contact. The discrete contacts condition the local stress field and therefore the thickness of the damaged zones [76]. Finally, the nature and roughness of the materials in contact produce wear particles, part of which, under the action of flows and pressures in the contact, adheres to the tool to form the transfer film. This film acts as a condition or limit and completely controls the flow of third bodies inside the contact. We give examples of the evolution of the RZ roughness of the machined material as well as the cutting tool in Figures 5, 6, 7, and 8.

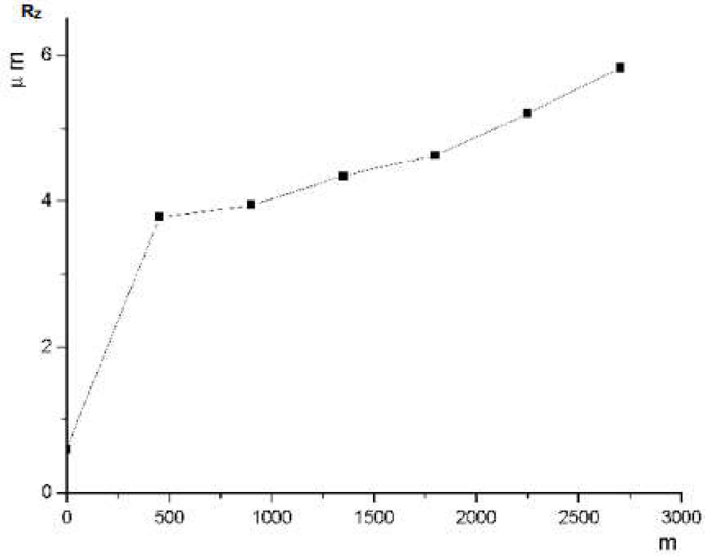

Figure 5: Evolution of the roughness RZ of the TiN cutting tool CBN on half axis, as a function of the cutting length V = 450m/min, f = 0.4mm/rev, ap = 1mm.

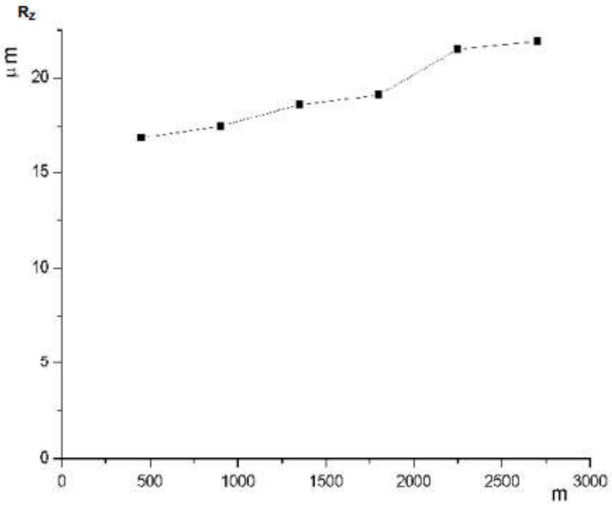

Figure 6: Evolution of the roughness RZ of the machined material half-axis on the cutting tool Vc = 450m/min, f = 0.4mm/rev, ap = 1mm.

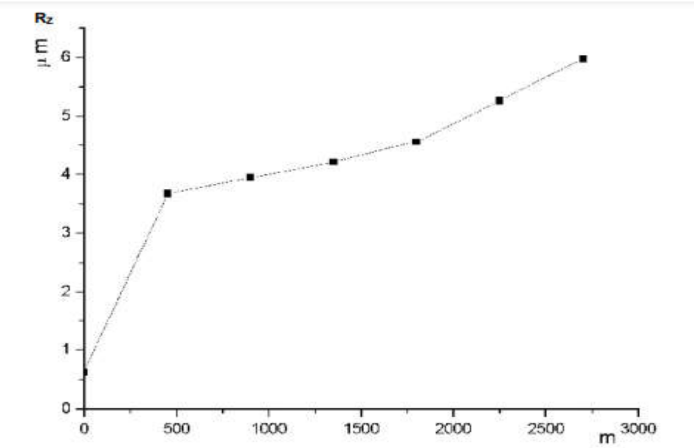

Figure 7: Evolution of the roughness RZ of the TiC cutting tool CBN on half axis as a function of the cutting length Vc = 150m/min, f = 0.3mm/rev, ap = 1mm.

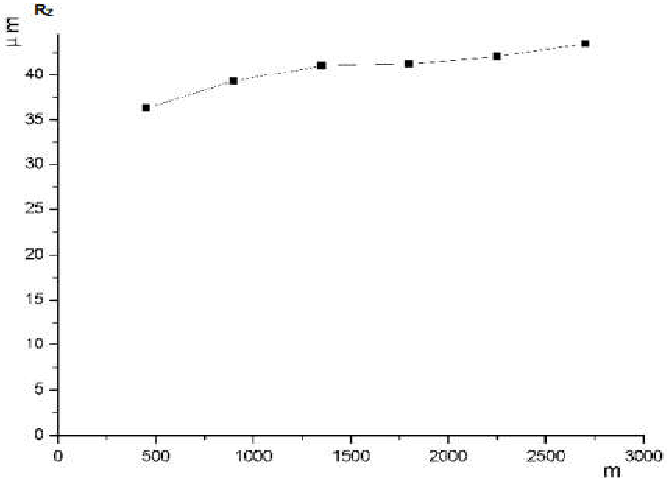

Figure 8: Evolution of the roughness RZ of the machined material half-axis on the cutting tool as a function of the cutting length Vc = 150m/min, f = 0.3mm/rev, ap = 1mm.

RESULTS AND DISCUSSIONS

The tests carried out made it possible to monitor the evolution of frontal wear as a function of machining time. The experimental results are shown in Figures 9 and 10.

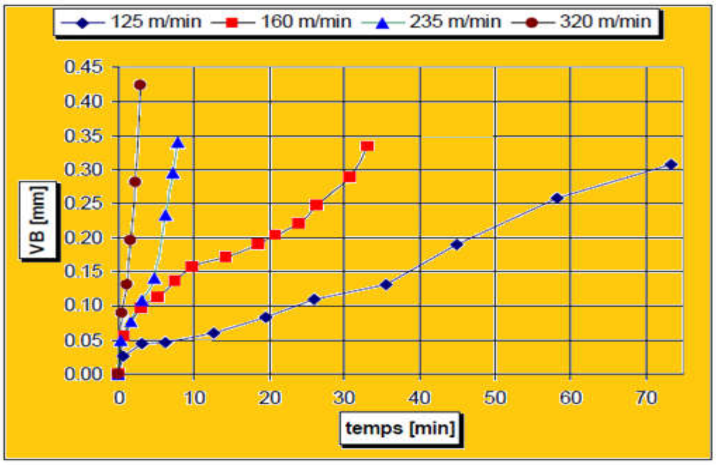

Figure 9: Evolution of CBN flank wear as a function of time at different cutting speeds (f=0.08mm/rev and ap=0.5mm) [9].

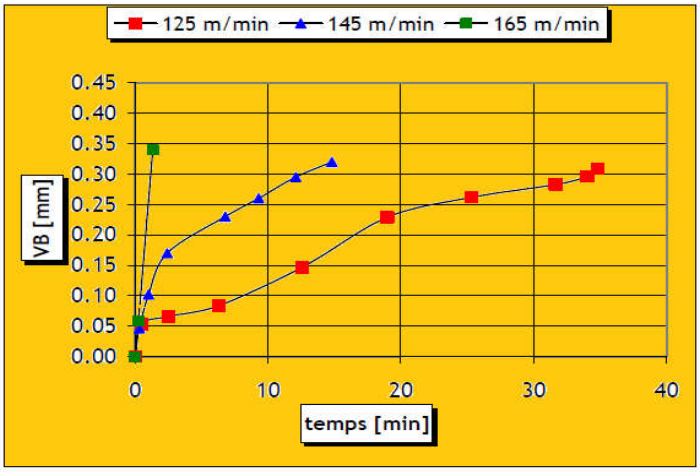

Figure 10: Evolution of flank wear of CC650 ceramic as a function of time for different cutting speeds (f=0.08mm/rev and ap=0.5mm) [9].

- The life pan of the tool corresponds to the admissible wear criterion adopted, [VB]adm = 0.3 mm. They are determined graphically; from the points of intersection of the line VB = 0.3 mm with the wear curves VB = f (t), we draw vertical lines which give the values of the resistance on the time axis.

- The optimization of machining operations using cutting tools constitutes the concrete purpose of studies on the cutting process, the interest of which is justified on an industrial level. This is increased with the development of automation, which results in an increase in the relative share of chip removal time in the time spent using the workstation.

- In practice, the wear law of a cutting tool results in a relation of the type: T = F (Vc, f, ap).

- The determination of the coefficients of the model of the law of wear of cutting tools can only be done correctly by exploiting the results of traditional so-called long-term tests, which are closer to industrial reality.

- However, these must be chosen judiciously to reduce their number while allowing maximum information to be obtained. The cutting tool wear law defines the variation of the effective cutting time T (min) as a function of the main machining factors:

1- Cutting speed Vc (m/min);
2- Feed f (mm/rev);
3- Depth of cut ap (mm).

- The nature and roughness of the materials in contact produce wear particles, part of which, under the action of flows and pressures in the contact, adheres to the tool to form the transfer film.

CONCLUSION

The results obtained in this study lead to the following conclusions:

- The most distinguished phenomenon of wear is wear by abrasion. This phenomenon is manifested by the appearance of flutes (ridges) on the flank face of the tool. Abrasive wear is due to the tearing of particles of the tool by the hard particles constituting the workpiece material.

- Cutting speeds above 240 m/min are not recommended due to rapid tool wear. This has the effect of giving too short lifespans, which are not industrially interesting. Consequently, the speed domain between [85 and 240] m/min can be considered as an optimal operating range for CBN tools when machining high alloy steel X200Cr12 treated at 60 HRC.

- Wear is one of the factors to consider, since its evolution damages and degrades the state of the surface of parts. Despite the evolution of VB up to 0.3 mm, the majority of recorded values of Ra have not exceeded the value of 1 µm.

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