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INFLUENCE OF THE MAGNETIC FIELD ON THE MORPHOLOGY OF THE WEAR OF THE INSERT IN P25 CARBIDE WITHOUT LUBRICATION

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ABSTRACT

This paper reports the study of the influence of a magnetic field on the morphology of the wear of the cutting tool as a function of the cutting speed during the cutting operation, and observed the weight losses (wear) and their morphologies. The wear of the cutting tool was quantified by weight loss during cutting. While carrying out experiments, we have noticed the existence of a critical value of the magnetic field intensity H = 16.5 $kA.m^{-1}$, for which the depth of the crater wear of cutting is minimal and the cutting edge of the cutting tool is preserved. The presence of the magnetic field in the manufacturing contact modifies completely the morphology of cutting, shape of chips of manufacturing, and quality of the surface state of the cutting edge. Moreover, the increasing of the magnetic field was found to change the cutting temperature. In the present manuscript we presented the different behaviours of manufacturing observed with and without magnetic field.

KEYWORDS: Cutting Tool, Cutting Speed, Magnetic Field, Surface Quality, Wear

INTRODUCTION

Manufacturing by chip removal, designates the set of techniques that enable to obtain a surface via removing material using a cutting tool. This old technique is often described as a costly cutting technique due to the fact that the shaping of the material piece leads to the transformation of the noble material into waste (chips). However; it is still an important and widespread manufacture technique. In shaping the metals by cutting, the turning process, the subject of our study, represents on its own for 33 % of the field of manufacturing by chips removal. Turning plays an important role in the engineering industry, where manufacturers seek to increase production with minimum possible cost. These two objectives are limited by several parameters including the cutting tool lifetime. This has prompted researchers to improve, firstly, the quality of the material of the cutting tool, and secondly, to minimize the negative effect of the cutting speed [1]. For this, we sought to optimize the cutting tools life by a fairly new industry, which involves applying to the contact piece-tool, a magnetic field during manufacturing. Reduction of wear of a cutting tool can be obtained either by choosing the geometry and hardness of the active part of the tool, or via using a machined material that has been polished by a thermal treatment.

The latter must satisfy two constraints: on one hand, a quantitative constraint which leads to the reduction of the manufactured parts cost. On the other hand, a qualitative constraint which consists in obtaining surfaces possessing optimal geometries and micro-geometries. In 1987, V. J. Al Shits [2] studied the effect of a magnetic field applied to metal pairs and showed that its application results in a considerable modification of the plasticity of metals; that is the magnetoplastic effect. Moreover, he showed that the magnetic field can lead to the hardening of metal crystals; therefore a magnetoplastic positive effect. Nevertheless, it can lead to the softening of crystals; which is the magnetoplastic negative effect. In addition, the nature of the magnetoplastic effect depends mainly on the magnetic properties of metals [2].

In 1970 and 1971, Bagchi and Ghosh [3, 4] were the first to have studied the effect of an external electromotive force (EMF) created by a magnetic field on the wear characteristics of cutting tools in HSS on mild steel. Their results revealed an important reduction in wear and a permanent positive gain factor. In 1975 and 1977, Muju and Ghosh [5, 6, 7] presented a physical model in order to explain some obtained results during experiments carried out with a magnetized tool HSS (tool running on mild steel and brass). In their observations, they confirmed that this technique allows an increase in the lifetime of tools by about 40% as well as a reduction of the size of wear particles [5]. Furthermore, El Mansori [8, 9, 10] showed that the effect of the magnetic field on the mechanisms of friction tool-chip (position, morphology of the primary zone and of the contact tool-chip) is the reduction of the wear of the cutting tool. In 2003, O. Batainch [11] showed that this technique leads to a longer lifetime of the cutting tool of 10%, despite an increase in the interfacial temperature during manufacturing.

These recent studies showed that the application of the magnetic field is concentrated at the superficial layer of material, which can modify its mechanical behavior at the tribology of the contact tool-chip. The main objective of this paper is to determine the influence of a magnetic field on the wear morphology of a cutting tool. In addition, we seek to link the damage mechanisms of the cutting tool with the thermo-mechanical stress at the interface tool-chip-piece in the case of manufacturing with and without magnetic field (the mechanical and thermal stress undergone by the tool are very important).The discussion of results is mainly based on microscopic observations of the active tip of the tool and the different forms of chips collected during testing, as well as on the state of the surface of the cutting tool.

EXPERIMENTAL PROCEDURE

Description of Tests and the Experimental

The international standard DIN ISO 3685 [1] was used for wear tests of long duration carried out to assess the lifespan of tools in P25 at different cutting speeds. By using a microbalance accurate to 100µg, weight difference before and after each cutting operation allowed evaluation of the weight loss (W). Longitudinal turning operations relative to the different tests were realized on round specimens of non-alloy steel of grade XC38, 65 mm diameter, 500 mm in length (the machined length is lc = 300 mm) and hardness 52 HRC. An 8 mm in diameter centering hole is made to ensure rigid fixation of the part (piece) between the two points. A lathe (Figure 1), of a power of 9.5 kW, mounted on a pin, was used for the cutting operations. The inserts used (Figure 2) are removable of a rhombic form made of metallic carbide of grade P25 (type CCMT09T308E-73) with a ray of rounding corresponding to 80°. The insert tightening torque is fixed at 3 Nm. The insert holder, of reference SCLC2020K09 (D4010T) [12] and designation SCLCR/L2525M12 is fitted with a tightening screw of the insert.

The experimental setup shown schematically in Figure 1, includes mainly:

- An infrared camera
- A metallic carbide removable insert of a rhombic form (cutting tool)
- The part to be manufactured (the workpiece)
- An Ammeter
- A regulator of a voltage to an alternative courant used to vary the magnetic field by changing the current applied to the coil
- A coil of 1600 turns and a resistance equal to 3.9 Ω, serving to the creation of a magnetic field inside the tool

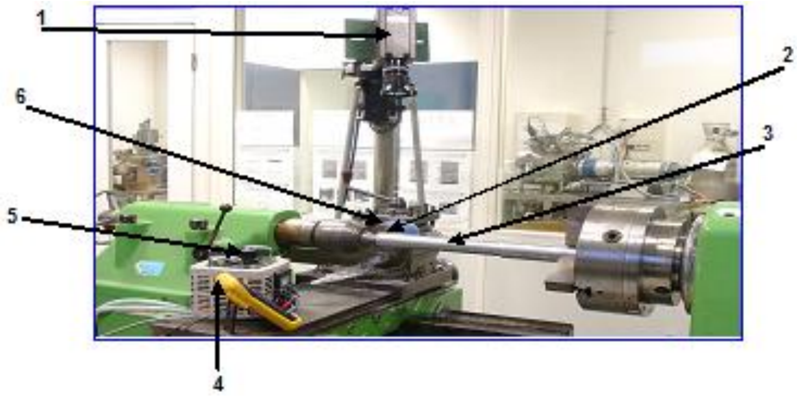

Figure 1: Experimental Apparatus

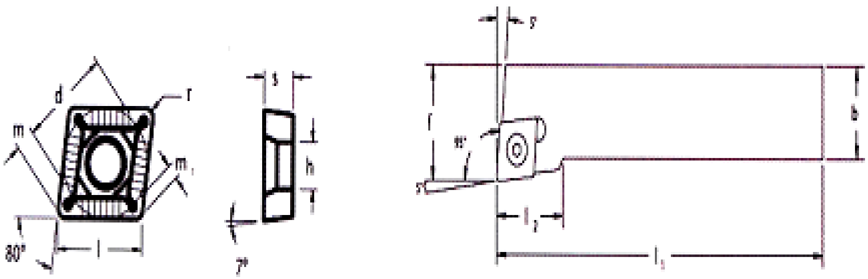

Figure 2: Forms and Dimensions of the Carbide Insert and Tool Holder

Dimensions of Inserts, Geometry of the Active Part and Body of the Cutting Tool

The insert is fixed by screws and is positioned in the direction where exercising the cutting efforts (Table 1). The cutting tests were performed without lubrication, with an advance f = 0.125 µm.tr^{-1}, a depth of cut ap = 0.5 mm, cutting speeds Vc = 6, 17, 48, 82 and 136 m.min^{-1}, intensities of magnetic field H = 5.5, 16.5 and 28.5 kA.m^{-1} and a cutting time (Tc), 14 min for each pass. Images of the scanning electron microscopy (SEM) were performed using a JEOL 5600 LV SEM operating at a voltage of 20 kV in secondary electron mode. An infrared thermography camera brand ESCIL operating during cutting operations has permitted determining the temperature between the cutting tool and work-piece (manufactured part).

Table 1: Dimensions of the Insert and Tool Holder

<table>
<tr><td rowspan="2">Dimensions of the insert [mm]</td><th>r</th><th>d</th><th>I</th><th>s</th><th>h</th><th>m</th><th>m_1</th></tr>
<tr><td>0,8</td><td>9,52</td><td>9,57</td><td>3,97</td><td>4,40</td><td>2,20</td><td>1,21</td></tr>
<tr><td rowspan="2">Dimensions of the tool holder [mm]</td><th colspan="2">b</th><th colspan="2">L_1</th><th colspan="3">L_2</th></tr>
<tr><td colspan="2">25</td><td colspan="2">150</td><td colspan="3">25</td></tr>
<tr><td>Angle of the flank face [°]</td><td colspan="7">5</td></tr>
</table>

RESULTS AND DISCUSSIONS

Influences of Magnetic Field on the Tool Wear

The cutting edge of the tool, which constitutes the active element by which the deformation work is carried out, is subjected to very severe mechanical and thermal strains, which cause its wear and degradation. This is studied as a function of cutting parameters. Figure 3 illustrates the evolution of wear as a function of the cutting speed when H is fixed (for each curve). Examination of Figure 3a reveals that the weight loss is maximal in the absence of magnetic field and corresponds to 400 µg. The wear is frontal (VB) and reached 0.3 mm. In contrast, the loss decreased down to 300 µg for H = 5.5 KA.m^{-1} (Figure 3b). When H = 16.5 KA.m^{-1} (Figure 3c), the weight loss decreased to 100 µg and is far from the value of VB = 0.3 mm (wear criterion NFE66505). Finally, when H = 28.5 KA.m^{-1} (Figure 3d), the weight loss is about 300 µg. This value is due to the cutting speed, which increases the tool wear. This wear, which is of mechanical nature, is due to permanent or cyclical stresses as well as to the action of friction. In this case, their severity is accentuated by significant thermal effects, which tend to degrade the resistance qualities of the cutting material.

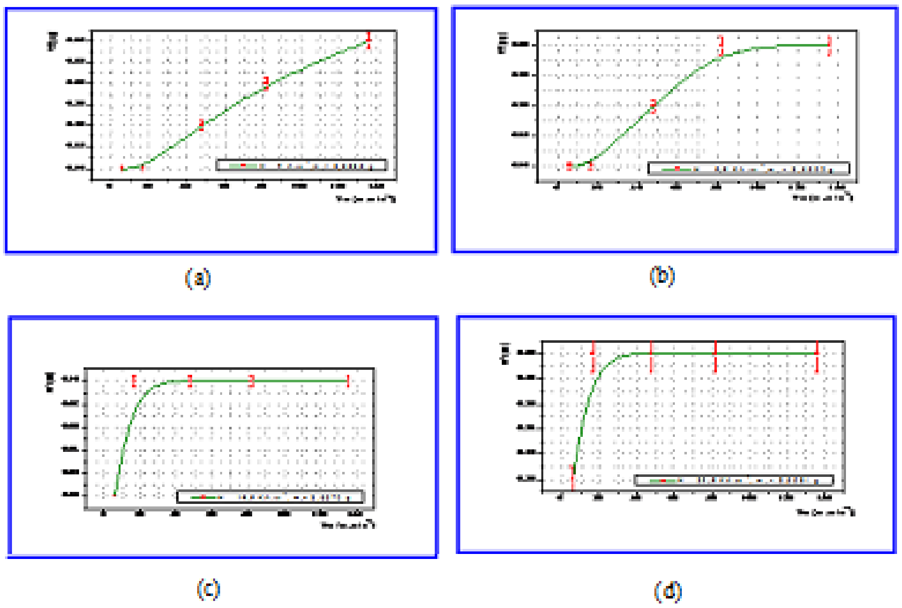

Figure 3: Evolution of Mass Loss (Wear) Depending on the Cutting Speed: ap = 0.5 mm, f = 125 µm.tr^{-1}, lc = 300 mm, (a) H = 0 A.m^{-1}, (b) H = 5.5 KA.m^{-1}, (c) H = 16.5 KA.m^{-1}, (d) H = 28.5 KA.m^{-1}

Influence of the Magnetic Field on the Roughness of the Cutting Edge of the Cutting Tool

Analysis by SEM does not enable to assess the profile of the cutting surface. It is therefore necessary to complete the observations of the attack surface of the cutting tool by analyzing the state of the surface after manufacturing with and without magnetic field. Using an interferential microscope Taly Surf ICC, we measured the morphology, roughness and cutting surface profile (contact surface). Figure 4 shows the morphology and cutting surface profile. The section of the chip removed during manufacturing without a magnetic field is much larger than that in the presence of a magnetic field (Figure 6). The shallow depth of the profile in magnetized contact confirms the small crater wear compared to that obtained without magnetic field. Examination of Figure 4a proves that the roughness of the cutting surface is maximal in the absence of a magnetic field and is equal to 1.53 µm, and the depth of the crater wear is equal to 31.1µm due to the specific pressure of chips on the attack face of the cutting edge. Contrary, in the presence of the magnetic field the state of surface decreases up to 0.305µm and the depth of the crater wear is reduced to 2.22µm. Applying the magnetic field around the contact of manufacturing slightly decreases the crater wear of the cutting tool and improves the state of the surface of the cutting edge. These effects are due to the hardening of the contact surfaces by the increase of dislocations due to the magnetic field [7] and the magnetization of the contact surfaces.

The previous Figure 4 shows the state of surface with and without the magnetic field. In the absence of the magnetic field, the delaminated particles of the cutting surface generates a very rough surface (H = 0 Am^{-1}). Application of the magnetic field demonstrates that there is no formation of the white layer (H= 5.5, 16.5 and 28.5 KA.m^{-1}) and that the cutting surface remains always smooth .The movement of dislocations toward the interface [7] generates a hardening of the contact surface (tool-piece) and the weakening of the contact junctions and increases the transfer of particles of the chip by adherence at the contact level. These effects allow having a slight softening of wear in the presence of the magnetic field, which slightly reduces the wear of the cutting tool, and modifies the mode of wear and improves the state of surface of the cutting edge in the magnetized contact.

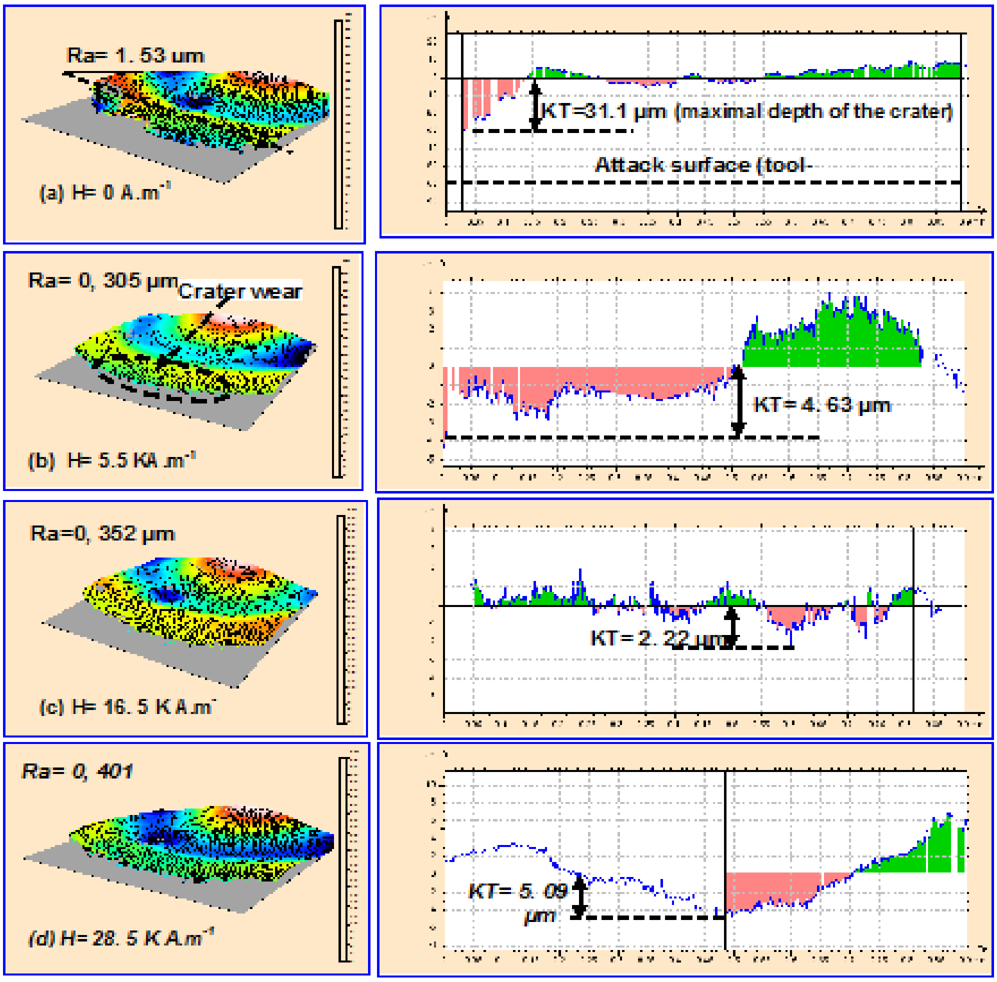

Figure 4: Morphology and Profile of the Wear of the Cutting Tool: ap = 0, 5 mm, f = 125 µm.tr^{-1}, lc = 300 mm

Influence of the Magnetic Field on the Morphology of the Surface of the Cutting Edge

Examination of figure 5 allows to identify the wear patterns developed on the tool. A first area called the running in of the cutting edge is characterized by flank wear. Then, a crater wear is recorded on the bevel of this edge, and then appears on the same edge a wear by plastic deformation. In practical terms, the frontal wear is the most important, because it conditions simultaneously the surface of the manufactured part (work piece) and the dimensional precision (Figure 5a). Figures 5a and 5b show that crater wear appears much sooner when the cutting speed increases. This phenomenon is particularly related to the cutting increased temperature which favors wear by diffusion. Figure 5d shows the presence of chips that have been adhered on the cutting surface. Indeed, when the chip slides over the clearance face (rake face) of the cutting tool, an intense friction engenders the increase of the localized temperature of mergers and micro-weldings. This may result in bonding of certain particles of the chip on the rake face of the cutting tool [13]. The damage to this later is low in the presence of a magnetic field (Figures. 5b, 5c and 5d) (noting that this later causes only a low wear of crater type). However, in the absence of magnetic field, the crater wear becomes significant, when a frontal wear and a plastic deformation wear appear on the rounding of the cutting edge.

The image of the cutting surface of the cutting tool (Figure 5d), obtained by SEM, shows that under the influence of a magnetic field, a number of fine and black particles of chips are formed on the attack surface via oxidation. Cutting surfaces manufactured without magnetic field show a very rough surface while the magnetized ones are of fine chip particles, having a relatively smooth cutting surface. These fine particles protect the surfaces of cutting in manufacturing at the interface (tool-chip-piece) in the case where this later is in decline [15, 16].

The EDS analysis of the composition of the cutting surfaces reveals the growth of the oxidation of contact surfaces by applying the magnetic field. Figure 5 (H = 0 A.m^{-1}) presents a spectroscopy that has been obtained on the surface of the cutting edge without magnetic field and Figure 5 (H = 5.5, 16.5 and 28.5 KA.m^{-1}) shows spectroscopy of the surface manufactured under different field intensities. They clearly show that the oxygen rate is much greater on the cutting edge manufactured in the presence of a magnetic field H than on those manufactured in the absence of a magnetic field (Table 2). The atomic oxygen percentage in the attack surfaces on the tools is given in table 2, as a function of the intensity of the magnetic field. The composition of oxides shows that their oxygen content increases with the increase of the magnetic field intensity.

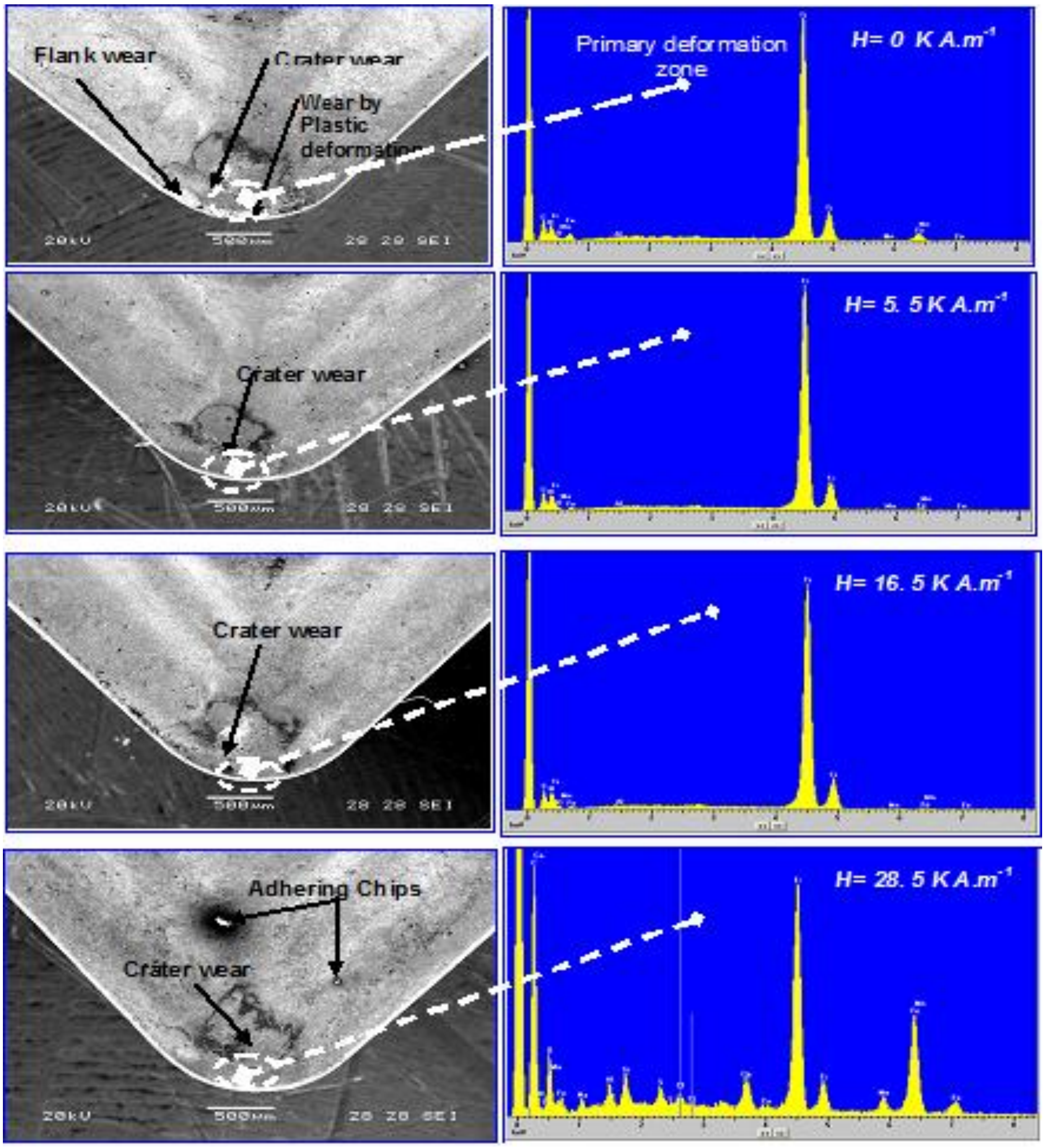

Figure 5: SEM Micrographs and EDS Analysis of the Surface of the Cutting Edge: ap = 0, 5 mm, f = 125 µm.tr^{-1}, lc = 300 mm, (a) H = 0 A.m^{-1}, (b) H = 5.5 KA.m^{-1}, (c) H = 16.5 KA.m^{-1}, (d) H = 28.5 KA.m^{-1}

Table 2: Rate of Oxygen and Iron in the Cutting Surface as a Function of the Magnetic Field Intensity

Experimental Condition	H= 0KA.m^{-1}	H= 5.5KA.m^{-1}	H= 16.5KA.m^{-1}	H= 28.5KA.m^{-1}
Oxygen(O)	4	4.5	5	17
Iron	5.65	1.29	1.05	40.83

(O et Fe atomic percentage)

Influence of Magnetic Field on the Morphology of the Chip

The different micrographic observations presented in Figure 6 reveal that the cutting speed has no significant influence on the general morphology of the chips. Indeed, these chips are always continuous and have a form of saw teeth. In contrast, the chip profile shape depends on the intensity of the applied magnetic field. Figure 6a shows the chips from the cutting, in the absence of magnetic field, with profile in large saw teeth (the distance between two teeth is about 0.5 mm). Whereas, figures 5b, 5c and 5d present chips obtained at H = 5.5 $kA.m^{-1}$, H = 16.5 $kA.m^{-1}$ and H = 28.5 $kA.m^{-1}$ respectively with teeth of smaller size (~ 10 to 50 µm). On Figure 7, we notice a change in the morphology of chips due to the magnetic attraction and the temperature rise. In addition, the application of magnetic field reduces shearing stresses at the interface tool-chip-piece, facilitating the sliding of the tool where this latter is in decline [14, 15]. During cutting, the chip saw-tooth size is proportional to shearing stresses. This shows once again that the applied magnetic field in the contact reduces the shearing stresses. This later presents a maximum for field intensities between 5.5, 16.5 and 28.5 $kA.m^{-1}$.

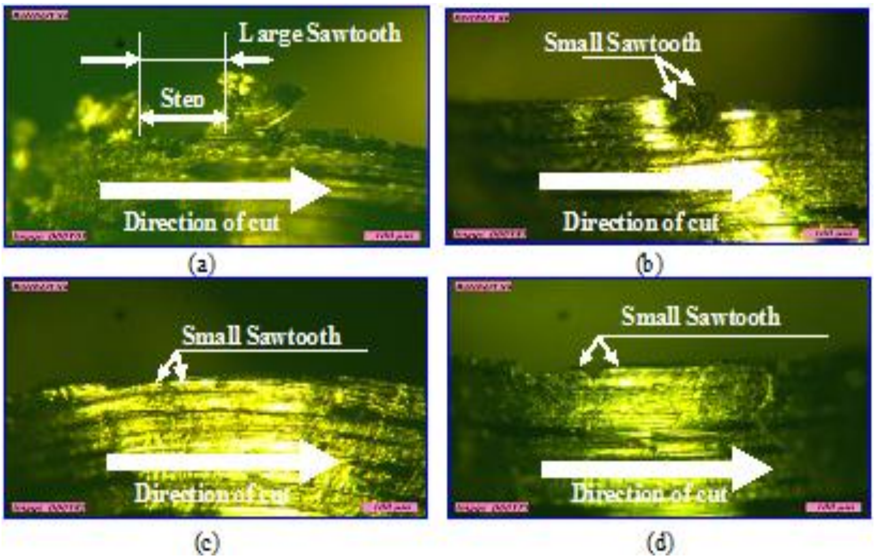

Figure 6: Changing the Form of Standard Chips Based on the Magnetic Field: Vc = 136 $m.min^{-1}$, ap = 0.5 mm, f = 125 $µm.tr^{-1}$, lc = 300 mm, (a) H = 0 $A.m^{-1}$, (b) H = 5.5 $KA.m^{-1}$, (c) H = 16.5 $KA.m^{-1}$, (d) H = 28.5 $KA.m^{-1}$

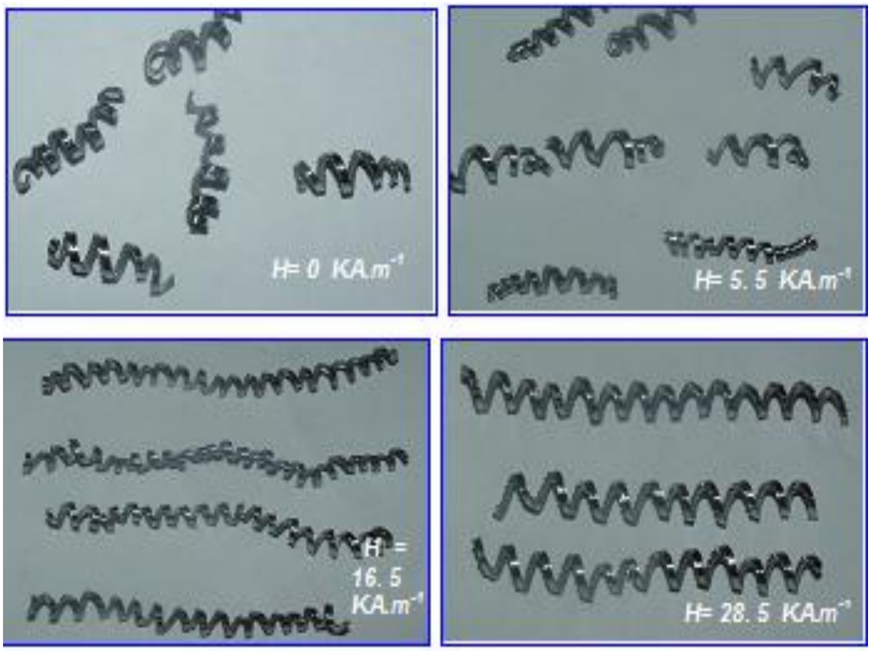

Figure 7: Influence of the Magnetic Field on the Morphology of the Chip: Vc = 6 $m.min^{-1}$, ap = 0.5 mm, f = 125 $µm.tr^{-1}$, lc = 300 mm

Influence of Magnetic Field on the Cutting Temperature

The average temperature T_m of the cutting tool obtained using an infrared thermographic camera is usually measured on the upper surface of the chip (the temperature is not that of the interface because the contact tool-piece is inaccessible). Infrared imagery of Figure 8 shows the distribution of thermal field in the cutting area around the cutting tool and chip. When we increase the applied parameters (Vc and H), the temperature at the interface increases. This elevation is not only due to the raise of cutting speed, but also to the effects of magnetization and Joule effect, created by the currents Foucault generated by the variable magnetic field in the rotating part [8,11].

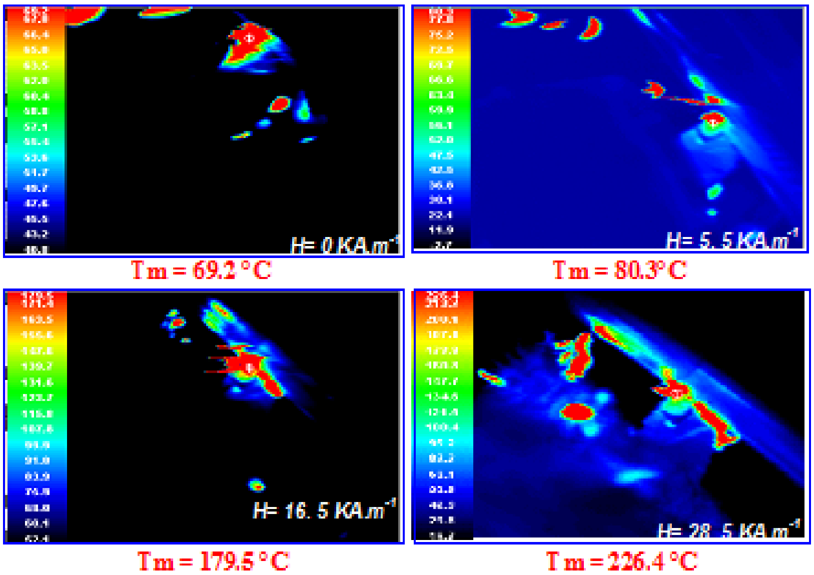

Figure 8: Distribution Temperature at the Interface along Cutting: ap = 0. 5 mm, Vc = 136 $m.min^{-1}$

CONCLUSIONS

This paper has enabled us to provide responses to certain questions related to manufacturing and the wear of a cutting tool in a magnetic field. Experimentally, after a comparison with results obtained inmanufacturing, it appears clearly that the magnetic assistance has several impacts on manufacturing and the morphology of cutting. Thus, we can notice its influence on:

- The improvement of the cutting surface roughness at the interface and the decrease of the depth of the crater wear KT
- Reducing the wear of cutting tools
- Changing patterns of the wear of cutting tools
- The increase of temperature that contributes to changing the profile type of the manufacturing chip
- Lowering shear stress at the interface tool-chip-piece

It stand out therefore that applying a magnetic field to cutting tools appears as simple, effective and inexpensive solution to increase their shelf life and thereby contribute to the optimization of the production tool.

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REFERENCES

1. Padilla, P., Anselmetti, B., Mathieu, L., Raboyeau, M., Mechanical production, Ed. Dunod, Paris, pp.136-145 (1986).
2. Al'shits, V.L., and Kristallografiya, al., Sov. Phys. Crystallogr 35, pp. 597 (1990).
3. Bagachi, P.K., Effect of magnétisation on the wear characteristics of cutting tools, Indian J. Technol, pp. 264-269 (1970).
4. Bagachi, P.K., Ghosh, A., Mechanisms of cutting tool wear in the presence of a magnetic field, Indian J. Technol, pp.165-168 (1971).
5. Muju, M.K., Ghosh, A., Effect of magnetic field on wear, ASME. 75-PT-5 (1977).
6. Muju, M.K, Ghosh, A., Effect of magnetic field on wear model of adhesive wear in the presence of a magnetic field-I, Wear 41, pp. 103-116 (1977).
7. Muju, M.K, A. Ghosh, A., Effect of a magnetic field on diffusive wear of cutting tools, Wear 58, pp. 49-58 (1980).
8. El Mansori, M., Lordache, V., Seitier, P., Paulmier, D., Improving surface wearing of tools by magnetization when cutting dry, Surface & Coatings Technology 188–189, pp. 566-571 (2004).
9. El Mansori, M., Klamecki, B., Magnetic Field Effects in machining Processes and on manufactured part mechanical characteristics, Journal of Manufacturing Science and Engineering 128, pp. 136-145 (2006).
10. El Mansori, M., Pierron, F., Paulmier, D., Reduction of tool wear in metal cutting using external electromotive, Surface and Coatings Technology 163-164, pp. 472-477 (2003) .
11. Bataineh, O., Klamecki, B., Koepke, B., Effect of pulsed magnetic treatment on drill wear, Journal of Materials Processing Technology 134, pp.190-196 (2003) .
12. International Norm ISO 9001-2000, (F), Manufacturing and distribution of precision cutting tools. Turning. pp. 35, 36 and 126 (2000).
13. Caubet, J.J., Theory and practical industrial of friction, Dunod-Technip, Paris. pp. 94-99 (1964).
14. Zaidi, H., Amirat, M., Frêne, J., Mathia, T., Paulmier, D., Magnetotribology of ferromagnetic/ferromagnetic sliding couple, Wear 263, pp.1518-1526 (2007).
15. Chin, K.J., Zaidi, H., Nguyen, M.T., Renault, P.O., Tribological behavior and surface analysis of magnetized sliding contact XC48 steel / XC48 steel, Wear 250, pp. 470-476 (2001).