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Influence of Sharpening and Coating Operations on the Wear of Sintered High Speed Steel Tools

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Abstract: In spite of the developments of new materials as cemented carbides and ceramics, which allow the use of higher cutting speeds, high speed steels are widely used as tool materials. Machining processes that need high resistance tools, as well as limiting characteristics on machine tools are the main reasons for the use of this material. The direction of sharpening, among others factors, has a crucial influence in the tool-life. The inadequate sharpening operation causes early rupture of tools. The problems arising from inadequate sharpening can be minimized with the use of coating. This work analyzes the influence of sharpening and coating by TiN and TiAlN, deposited by PVD process on the tool-life of sintered high speed steels. Square shaped tool inserts with specific chipbrakers were used on turning and evaluated by the amount of flank wear. It was found that no-coated tools, with flanks sharpened in the horizontal direction and nose radius sharpened in the vertical direction, presented an augmented wear, diminishing the tool-life. The wear is located in the transition region, between the sharpening directions, where a flux of carbides was identified.
On the other hand, the coating with TiN or TiAlN, increased the tool-life, but the wear next to the corner still appears. As a conclusion, it can be said that the adequate sharpening is imperative to the tool-life, with or without coating. Moreover, the combination of good sharpening and coating guarantees a better surface finishing, maximizing the properties of the substratum-tool interface.

Introduction

In machining processes, the parameters as chip forming and flux, cutting force, tool wear, surface finishing are deeply dependent on the tool geometry, angles and chipbraker. Besides geometry, the successful use of an specific tool is determined by: the material used for its manufacturing, the surface finishing (flanks, faces, corner and chipbreaker) and its correct use (as adequate cutting parameters, machine type, material of the component to be manufactured, coolant) [1].

There is a big influence of the sharpening process on the finish quality of the tool surface. The sharpening, by its turn, is influenced by factors as: the kind of grinding wheel, use of coolant or dry machining, and direction of sharpening.

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The subject is the study of the effects of the sharpening directions and coating with TiN an TiAlN, deposited by PVD process, in the tool-life of high speed steel inserts AISI T15 obtained by vacuum sintering. The sharpening influence on the tool-life of no-coated high speed steel tools can be found in Boehs et al [2].

The reason of using high speed steels instead of cemented carbide is its toughness characteristic. For intermittent machining operations, as milling and turning for recovering of parts or welded components, the high speed steel shows satisfactory working conditions and compatible tool-life. In addition, for machines operating at low cutting speeds, the potential of cemented carbide would not be fully explored.

Coatings

During the cutting process, the cutting tool and the workpiece, together with the involving medium and interface constitute a tribologic system [3]. The tool is under high temperatures and also submitted to mechanical stress. Solutions to deal with these two effects have been explored. The coatings TiN, TiCN and TiAlN were developed with this objective. The coating process, which interferes directly on the behavior of the tool, also has been continuously improved along the years.

Nowadays there are two kinds of deposition by vapor: CVD (Chemical Vapor Deposition) and PVD (Physical Vapor Deposition).

The methods of PVD processing are: Ion Plating, Sputtering and Evaporation. The PVD properties are listed below [4]:

- High density and good coating bonding;
- Known composition of each layer;
- Low temperature of substratum;
- Possibility of thin layer deposition;
- Application to precision tools (for both high speed steel and cemented carbide) since the sharpened edges are preserved;
- Large range of coating types and substratum materials;
- Coating uniformity for notched surfaces.

For some fields of manufacturing, the coating has been commonly used as a form of increasing the tool-life, as the processes of coating became effective in forming high quality layers. The PVD coatings are used as protection against wear for metal machining and forming as well as plastics processing [5].

Experimental Procedures

The study the sharpening direction effects and coating effects on the tool-life of high speed steel inserts, were conducted under the following test conditions:
Insert material: AISI T15 – vacuum sintered;
Coating conditions: TiN, TiAlN and no-coated;
Sharpening conditions: flanks sharpened in horizontal direction and corners sharpened in vertical direction;
Machining operations: external turning, longitudinal, long course;
Material of the workpiece: ABNT 1045 drawn steel (hardness 268 HV30).

The coatings used have the following characteristics (table 1) [6]:

Table 1: Coatings characteristics

Coating Type	TiN (single layer)	TiAlN (Futura)*
Micro-hardness (HV 0,05)	2300	3000
Friction coefficient (against steel)	0,4	0,4
Layer thickness (μm)	1-4	1-5
Max. Working Temperature (°C)	600	800
Coating Color	Gold	Violet-gray

* Balinit Futura Coating (Multilayer)

The cutting parameters used are: V_C = 40 m/min; f = 0,2 mm e a_P = 2,0 mm.

For the machining, a lathe CNC, model Cosmos 10-U, Romi-Mazak brand was used. Its power is 10 kW and equipped with tool optical reading.

The wears on the tool flank and faces (ISO 3685) [7], were analyzed by means of a Nikon optical microscope, a digital camera Pulnix TM-7CN and an Olympus DP11 camera connected to an optical Olympus microscope SZ-CTV. In this paper, the VB_{max} was represented by VB_N.

The tool-life of the inserts was determined by one or both the conditions: VB_N between 0,6 and 0,8 mm; disruption of the tool corner [8].

After assembled in a holder CSBPR 2020 K 12 [9], the inserts shown the following angles: cutting edge angle, κ_r = 75°; clearance angle, α = 7°; rake angle, γ = 15° (neglecting the chipbraker); included angle, ε_r = 90° and nose radius, r_e = 0,8 mm.

Results and Discussion

The inserts used for the experiments were TSV68 (no-coated), TSV07 (TiN coated) and TSV73 (TiAlN coated). These notations identify them among a batch produced for different experiments. The notation TSV means high speed steel with tungsten, obtained by vacuum sintering.

The image of the tool flanks prior to the tests can be seen in Fig. 1. It can be noticed a clear difference between the directions of sharpening for the corner and the flank. That difference is the cause for an atypical flank wear, which weakens the corner and diminishes the tool-life [2].

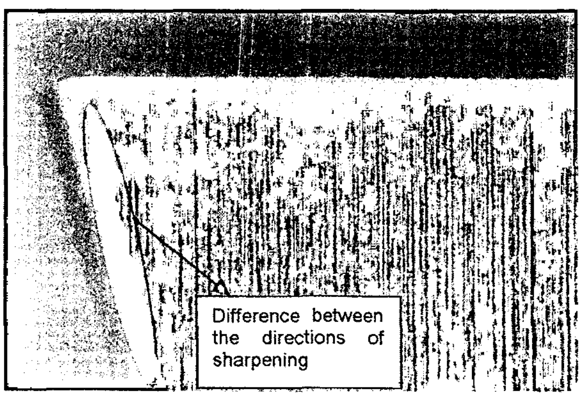

Fig. 1 – Edge and corner with inappropriate sharpening, 35x magnification.

The wear behavior of the tools (TSV68, TSV07 and TSV73) can be seen in Fig. 2. For each of the tested tools a replica was manufactured. So the curves were obtained by the mean value between the tool and its replica. The TSV68 (no-coated) had a 40 min tool-life, which occurred at a flank wear V_B = 0,35 mm, with the early disruption of the corner. The corner disruption was a result of its weakening, caused by an atypical wear provoked by abrasion. The abrasion is a consequence of a carbide flux in the tool substratum. The two coated tools had very close behavior until 90 min of machining. At that time the TSV07 insert collapsed, by disruption of the corner. The TSV73 insert, however, reached 150 minutes, still showing good cutting conditions.

An important aspect of the test is that both the coated inserts revealed build up edges. The optical microscopy is depicted in Fig. 3 and 4. This phenomenon can also be detected during the machining, by the occurrence of a strong noise together with a power demand increase up to 65% of the nominal power. At normal cutting conditions, the power stays between 35% and 50% for the smallest and biggest diameters (25 mm and 45 mm) respectively. After the occurrence of this phenomenon, however, the machined surface didn't show any significant finishing damage.

Fig. 3 – insert TSV07 coated with TiN – shows the bonding of material to the edge as well as the disruption of the corner. It can be seen the difference between flank and corner sharpening. The wear is much bigger for the corner than for the flank. In spite the improvement of the tool performance, the coating was unable to compensate the inadequate sharpening.

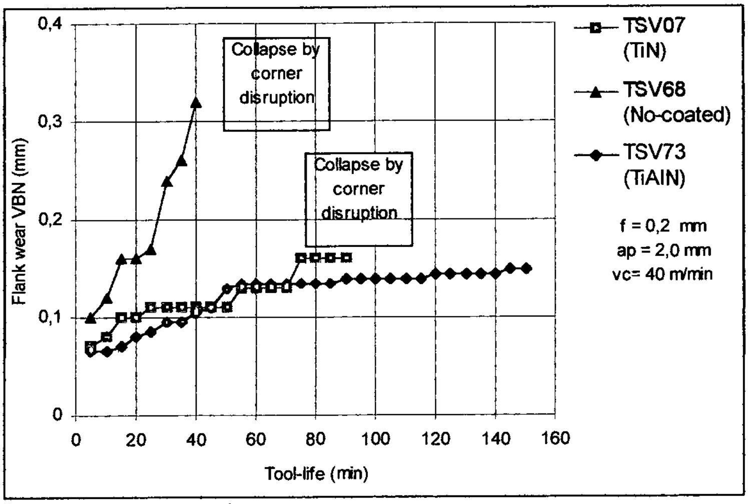

Fig. 2 – Wear curves for TSV68, TSV07 and TSV73.

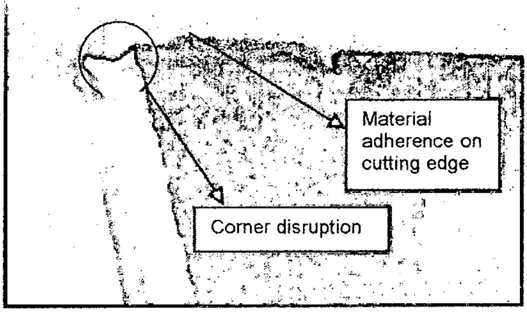

Fig. 3 – Atypical wear, damaged corner and build up edge – TSV07, 50x magnification.

As shown in Fig. 4, the insert TSV73 coated with TiAlN presented also an atypical wear, besides the build up edge. However this tool is better for wear resistance. As the substratum is the same for both coated inserts, one can conclude that the extra resistance is due to the TiAlN coating.

Another observed fact for the coated tools is that the secondary edge was well preserved, resulting in a better surface finishing for the workpiece.

Fig. 5 shows the typical wear that occurs in high speed steel tools working on continuous turning process. It can be seen that the corner integrity is preserved, but a notch (VB_N) appears on the end of the active cutting edge. This was the expected wear of the no-coated tool and coated tools used for this research, but according to Figs. 3 and 4, it didn't occur.

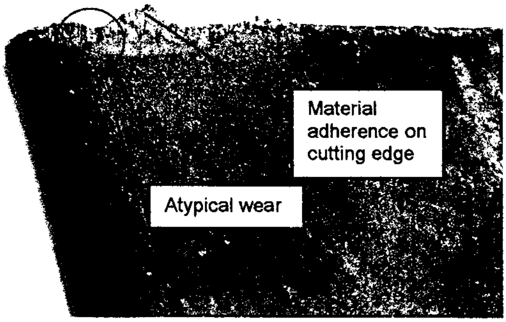

Fig. 4 – Wear and material adherence on cutting edge – TSV73, 50x magnification.

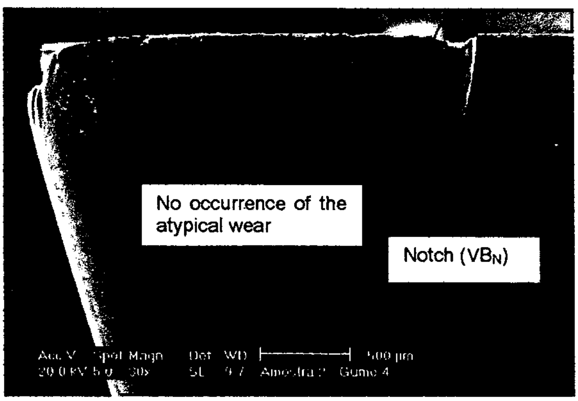

Fig. 5 – Typical wear of sintered high speed steel tools, 30x magnification.

Conclusions

The use of tool coating, under the chosen test conditions, resulted in increasing wear resistance and tool-life of inserts. The TiN coated tool had a tool-life increase up to 125% compared to the same no-coated tool.

For the TiAlN coated tool the proportion is 275% compared to the no-coated tool. Another conclusion is that the thickness of the coating layer was unable to eliminate the influences of an inadequate sharpening. These are preliminary results. Further tests must be conducted for conclusive indications of best performance parameters.

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