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EVALUATING CBN TOOL LIFE IN HARDENED BORING OPERATIONS IN LONG OVERHANGS

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Abstract: This work aims to monitor the tool wear process using optical microscopy, so that the lifespan of the tool could be verified. The tool overhang was varied until it reached a limit (the deepest hole it could machine). The results show that, when the tool overhang is within its stability range, the flank wear of the tool is accentuated when the tool overhang outreaches its stability limit.

Keywords: *tool wear, lifespan, tool overhang*

1. Review of Literature

Under ideal conditions, the surface roughness profile is formed by the replication of the tool tip profile at regular intervals of feed per revolution. However, many other factors like the dynamics of the metal cutting operation, elastic recovery of the cut region of the work material, ploughing, spindle rotational error and tool vibration, leading to the relative displacement of the tool and work material contribute to the modification of surface profile. In hard turning, theoretically tool vibration is likely to play a significant role in surface generation. Also, tool vibration is significantly influenced by tool wear [1].

It is convenient to calculate the material removal of the machining process, its important parameter that determinates the productivity of the process and quite fundamental for the calculation of the machine power. Therefore, the method of obtaining the volume values should be well calculated such as feed, cut depth, cutting speed and part diameter. The latter should be resized when the diameters of the part are very close to the depth of cut (small diameters), to avoid very large errors on the material removal rate with a variation of 4 to 25% [2].

One of the initial assumptions of machining is that the insert must have a higher hardness than the material that is machined. However, in general, the greater its hardness, the more brittle the material turns to [3].

In the turning of hardened materials operation, due to the high hardness of the cBN, the monitoring of the wear is a fundamental procedure to avoid chipping and breaking of the inserts [3].

Previous work has already indicated the possibility of the use of cBN inserts in the machining of hardened materials and in facing operation, even during the occurrence of interrupted cutting. In the work of Oliveira et al., (2009) [4] the interruptions generated by the geometry of the test specimens promoted excitations in the cut around 184 Hz and more recently, Godoy and Diniz (2011) [5], again turning hardened steels with interruptions promoted excitations at the tip of the tool. The results of this work prove that the cBN insert also resists to higher frequency excitations, as is the case of boring bar operations [3].

2. Materials and methods

All the internal turning experiments of this work were performed using a CNC lathe with 20 CV of power in the main motor and maximum spindle rotation of 4,500 rpm. One 16 mm diameter boring bar of high hardenability ANSI 4140 steel (ISO code A16R SCLCR 09-R) were chosen.

As for the tool insert, an adequate insert for finishing operations on smooth surfaces of hardened steels was chosen. It was composed of CBN (50% wt) and a ceramic phase of TiCN and Al_2O_3; it is ISO code is CCGW09T308S01020F 7015 (class ISO H10). The advantage of the chosen tool insert, when compared to others with a greater CBN content, is its chemical stability in relation to iron. Besides, its toughness is enough to preserve its cutting edge, even though it is reduced when compared to other inserts with a greater CBN content.

The 4340 steel used in the fabrication of the test specimens is a widely employed material in the metal mechanical industry. It presents high hardenability, bad weldability and reasonable machinability, as well as a good resistance to torsion and fatigue – its hardness after quenching varies from 54 to 59 HRc.

The cutting conditions and the machine setup (tool overhang) were tested in two distinct machining tests. The first measured the tool lifespan, where a maximum flank wear (VB_{max}) of 0.2 mm according to ISO 3685 [6] for operations without coolant was considered as the end of tool life criterion. The second measured the radial and tangential components of tool acceleration during the cutting process, in the beginning and in the end of tool life.

For the tool life tests, we defined a complete experimental factorial matrix, composed of 2 factors in 2 levels of variation, resulting in 4 conditions. Each condition was replicated once and led to 8 tests. Thus, the 4 conditions were set below on *Table 1*.

Table 1

Cutting conditions for tool life test with an overhang of 70 mm

Condition	Feed rate [mm/rev]	Cutting speed [m/min]
C1	0.08	360
C2	0.08	300
C3	0.06	300
C4	0.06	360

3. RESULTS

The *Table 2* reports the cutting conditions tested until the end of life, evidencing the results of metal removal rate, surface finish (R_a and R_z) and flank wear (VB_{max}). The results show that the tool at the end of life does not generate significant changes in the roughness of the part, but it generates transformations in the geometric profile of the tool, mainly in the rake plane of the insert, after the removal of a large volume of chips, limited by the flank wear values of the tool.

It is known that the end of tool life was reached when tool flank wear reached 0.2 mm (ISO 3685). The parameter of material removal rate allows a better comparison of the tool life than the time of cutting, especially in cases where there are variations of the cutting speed. it is possible to observe that the increase of the cutting speed causes a decrease in the tool life due to the higher cutting temperatures. The increase in feed rate permits an increase in life. This results carried out to check the significant contribution of each input factor (cutting speed and feed rate) showing the results for surface roughness. It can be observed that the feed rate has significant contribution whereas the cutting speed has less contribution and thus is of less importance.

Table 2

Machining parameters employed in the lifespan test of the CBN insert with constant depth of cut equal to a_p = 0.1 mm

Condition	v_c [m/min]	f [mm/rev]	End of tool life			
			Material removal rate Q [10^4 mm³/min]	R_a [µm]	R_z [µm]	$VB_{máx}$ [µm]
C1	360	0.08	6.05	0.58	2.9	201.6
C2	300	0.08	7.2	0.83	3.4	234.6
C3	300	0.06	7.56	0.5	2.72	220.8
C4	360	0.06	6.48	0.78	3.12	212.5

This experimental study is also to analyse the impact of tool wear on the quality of surface generated in hard turning. *Table 2* shows the roughness parameters Ra, as a function of the flank wear land. The bar graph indicates a gradual increase in the surface roughness as the flank wear land of the tool increases. It can also be observed that, even at the point when the flank wear land was about 0.2 mm, the Ra the value of the surface roughness is less than 0.8 µm for almost conditions. It is an example showing that the uniform flank wear up to 0.2 does not matter from the standpoint of surface finish. This shows that as a manufacturing process, hard turning can be employed for finish machining as an alternative to grinding. The deterioration in the surface roughness becomes very steep as the wear land crosses the critical value of 0.2 mm.

Figure 1 shows the evolution of tool flank wear during the lifespan test for the 4 tested conditions and an of L/D = 4.4. The gradual evolution of the maximum flank wear (VB_{max}) indicates the absence of malfunctions leading to an abrupt change in the slope of the curve and to the sudden end of the life of the insert.

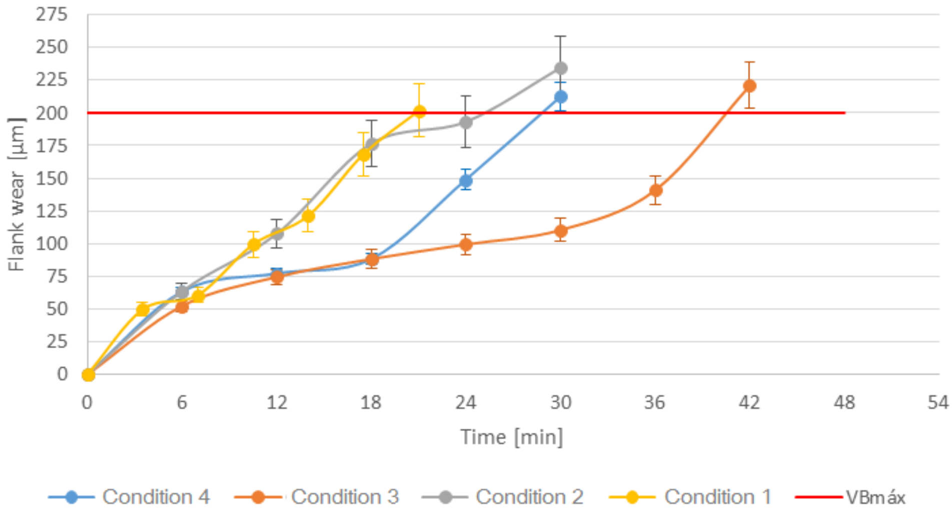

Figure 1

Evolution of tool wear in the 4 machining conditions (Table 1) for an end of tool life criterion of VB_{max} = 200 µm

4. Conclusion

It can be concluded for internal turning operations of hardened steels, in conditions similar to those used here, that:

- In boring bar operation in hardened materials with continuous cutting, the flank wear of the tool insert is mainly caused by the abrasion of cBN particles originated from it.
- Even at the point when the flank wear land was about 0.2 mm, the Ra the value of the surface roughness is less than 0.8 µm due to the stability of the cutting condition.

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References

[1] Bhaskaran, J. (2011). *Process monitoring of hard turning using acoustic emission technique*. Doctoral Thesis, Faculty of Mechanical Engineering, Anna Uniersity, Chennai – 600 025.

[2] Isakov, Edmund (2009). *Cutting Data for Turning of Steel*. New York, NY, 10018, Industrial Press, Inc., p.179, Table 4.2.

[3] Suyama, Daniel Iwao. (2014). *Uma contribuição ao estudo do torneamento interno em aços endurecidos*. Doctoral Thesis, UNICAMP, Campinas, São Paulo, Brazil.

[4] De Oliveira, Adilson José, Anselmo Eduardo Diniz, Ursolino, Davi Janini (2009). Hard turning in continuous and interrupted cut with PCBN and whisker-reinforced cutting tools. *Journal of Materials Processing Technology*, 209, 12, pp. 5262–5270.

[5] De Godoy, Vitor Augusto A., Diniz, Anselmo Eduardo (2011). Turning of interrupted and continuous hardened steel surfaces using ceramic and CBN cutting tools. *Journal of Materials processing technology,* 211, 6, pp. 1014–1025.

[6] ISO 3685. *Tool-life testing with single-point turning tools*.