24th ABCM International Congress of Mechanical Engineering
December 3-8, 2017, Curitiba, PR, Brazil

COBEM-2017-2679
TURNING OF HARDENED AISI 4340 STEEL USING COATED CARBIDE TOOL

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Abstract. *The elimination of the grinding process is the main objective of the machining of hardened steels, guaranteeing even greater productivity; Possibility of performing multiple operations in a single duty cycle; Low tooling cost; More affordable investments in CNC machine tools; Increased life to the fatigue of the part and small changes in its microstructure related to the hardness. However, the rapid reduction of the life of the tool impairs the machining of hardened steels. With the technological advances in carbide tools and in coatings these tools begin to become an option for the machining of hardened steels. A comparative study of the turning of hardened AISI 4340 steel (56HRc) was performed using Ti (C, N) +* Al_2O_3 *coated carbide metal tools by chemical vapor deposition (CVD) and CBN tools. Machining parameters were varied (cutting speed 150 and 200 m / min and feed rate 0.1 and 0.2 mm / rev), with a machining depth of 0.5 mm. The average roughness (Ra) and total roughness (Rt), tool flank wear (VB) and cutting power were analyzed. The results were promising, with roughness results for Ti (C, N) +* Al_2O_3 *coated carbide tools, similar to roughness obtained in grinding processes (0.258um), with slightly greater flank wear than CBN tools.*

Keywords: *Cutting power, roughness, tool wear, Ti (C, N),* Al_2O_3

1. INTRODUCTION

There are many applications and machining characteristics of hardened steels between 45 and 65 HRC. These steels have good dimensional stability combined with high mechanical strength. However, they are difficult to machine (CHINCHANIKAR & CHOUDHURY, 2015).

The turning of hardened steels, with hardness above 45HRC, appeared with the arrival of the ceramic tools for continuous roughing (MATSUMOTO ET AL, 1987) and with cubic boron nitride (CBN) for continuous finishing (LIU and MITTAL, 1996).

The cutting of hardened material can be seriously considered as an alternative to grinding operations under certain circumstances. (TONSHOFF and MOR, 2000).

The turning of hardened materials is still carried out mainly with CBN and ceramics tools. The benefits of hard turning are: reduction of cost per product, good surface finish closer to grinding, high productivity, reduction of set-up times, less expensive equipment and dry cutting with a more friendly environment (SAHOO ET AL, 2012).

More et al. (2006) notes that machining finish of hardened steels has been a beneficial practice for machining industries because of their high productivity, an option for dry machining, improved surface integrity and improved mechanical properties of machined components.

According to Ezugwu et al. (2005), polycrystalline cubic boron nitride (PCBN) tools offer excellent performance in the machining of hardened steels. However, their costs are still relatively high. Therefore, studies on the machining of hardened steels using coated carbide tools become interesting.

The development of carbide tools with different coating technologies has attracted many researchers as an alternative to the machining of hardened steels in replacement of PCBN and ceramic tools. However, in these cases the high flank wear is what makes these tools difficult to implement. (CHINCHANIKAR AND CHOUDHURY, 2014).

There has been a constant attempt to improve and develop new tooling materials and coatings for cutting tools in order to contribute to the machining of hardened steels. Huge advances have occurred in the field of ceramic tools with different dopants and in the field of carbide tools with different coatings. Making machining of hardened steels with carbide tools can economically impact machining processes when compared to higher-cost polycrystalline boron nitride (PCBN) tools. PCBN, known as the tool material suitable for the machining of hardened steels, can cost about 80 times a hard metal insert and about 15 to 20 times the price of ceramics, for example (MACHADO et al., 2011).

2. EXPERIMENTAL PROCEDURE

The tests were in a turning center CNC brand Romi model GL 240M with main motor of 15 KW (Figure 1). The hardened AISI 4340 steel was used, with a hardness of 56 HRC, whose dimensions were 100mm in diameter and 300mm in length.

Figure 1: Turning center CNC brand Romi model GL 240M used.

The tool support used was Capto (C3-MCLNL-27 040-12) brand Seco Tools. The tools used (CNMG120412 type inserts) were CBN (CBN010), without break-chip and CVD coated carbide coated with Ti (C, N) + Al_2O_3 coating (TH1500), with MF5 break-chip geometry (Seco Tools) (Figure 2) according table.

The carbide tool coated with Ti (C, N) + Al2O3 used in this work (TH1500) has a micro-grain grade of extreme hardness, indicated to machining of partially hardened steel components (SECO, 2014). The CBN tool used (CBN010) is a universally without coating class recommended for the turning of hardened steels. (SECO, 2014).

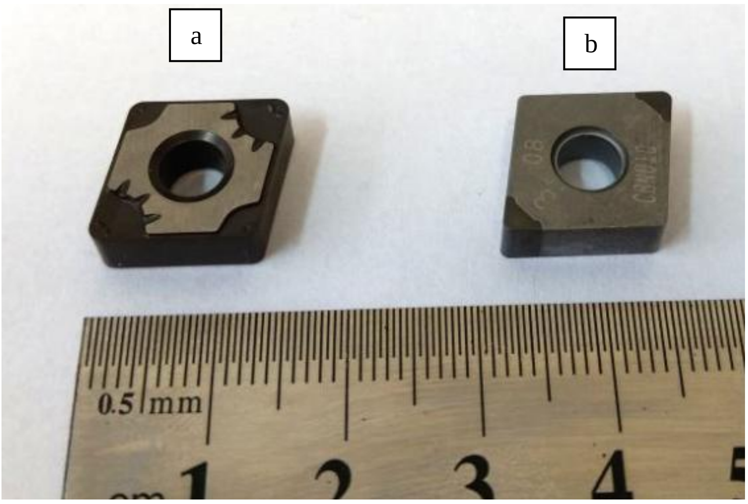

Figure 2:Tools used in experiments of type CNMG120412; (a) CVD coated carbide coated with Ti (C, N) + Al_2O_3;(b) CBN (CBN010),

Four different machining conditions were performed, machining parameters being varied as cutting speed (Vc=150 and Vc=200 m. min^{-1}) and feed rate (f=0.1 and f=0.2 mm. rev^{-1}). A machining depth of 0.5mm was used (Figure 1). Three replicates were performed for each condition (Table 1). Each test condition was performed at a cut length of 150m in dry condition.

Table 1 – Test conditions.

Conditions	*Vc(m.min^{-1})*	*f(mm.rev^{-1})*	*Tool*
CBN-Vc150f0,1	150	0,1	CBN
CBN-Vc200f0,2	200	0,2	CBN
CVD-Vc150f0,1	150	0,1	CVD
CVD-Vc200f0,2	200	0,2	CVD

In Figure 3 is possible to observe the test bench used in the experiments, with emphasis on the piece of AISI 4340 steel fixed in a plate with castles and counter-tip, in addition to the Capto type tool holder.

The roughness was obtained with a Mahr model of the Marsurf M300, with a probe tip in the shape of a spherical cone made of diamond with a radius of 2µm, and the average roughness (Ra) and the total roughness (Rt) were raised. The cut-off was adjusted according to AISI NBR4287: 2002 and in accordance with AISI NBR ISO 4288: 2008.

For the acquisition of the consumed power were used power sensors brand LEM model AT 100 B. The flank wear was measured by a measuring microscope of the Mahr Brand, model MarVision MM200.

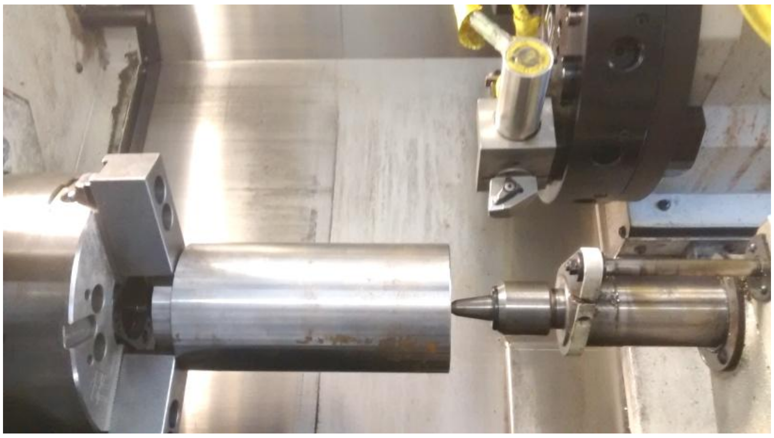

Figure 3: Test bench.

3. RESULTS AND DISCUSSION

Figure 4 to 7 shows the results obtained in the turning of hardened AISI 4340 steel according to the conditions presented in Table 1.

Results of average roughness (R_a) are in Figure 4. It is observed that using a carbide tool with Ti (C, N) + Al_2O_3 coating, with a cutting speed of 200m.m^{-1} and an feed rate of 0.1mm.rev^{-1}, the average roughness (Ra) obtained (0,24um) was lower with all tested conditions, with roughness values similar to those obtained with grinding, even using a tool with tip radius of 1.2mm and a feed rate of 0.1 mm.rev^{-1}, showing promise for obtaining good finishes.

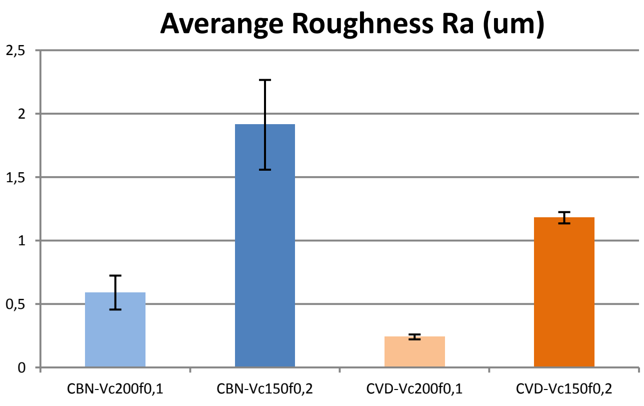

Figure 4: Results of average roughness (R_a).

The total roughness (R_t) is shown in Figure 1c. Observa-se que os resultados da rugosidade total apresentou as mesmas características obtidas para a rugosidade média (Ra), destacando o ótimo resultado obtido com a ferramenta de metal duro revestida na condição de 200m.min^{-1} e avanço de 0.1mm.rev^{-1}.

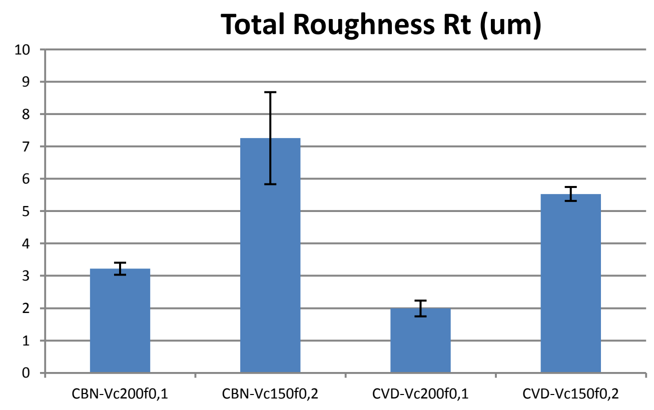

Figure 5: Results of total roughness (R_t).

The cutting power results are shown in Figure 6. Observing the results, it was verified that the highest cutting power was obtained using cutting speed of 150m.min^{-1} and feed rate of 0.2mm.rev^{-1}e for CBN and coated carbide tools. Further advances represent a larger area of the cutting section producing higher power as expected. Although the coated carbide tools produced higher power than CBN, the increase in power was relatively low, with a 13% increase for Vc = 200m.min^{-1} and f = 0.1mm / rev^{-1} and 8.5% for Vc = 150m.min^{-1} and ef = 0.2mm / rev^{-1}.

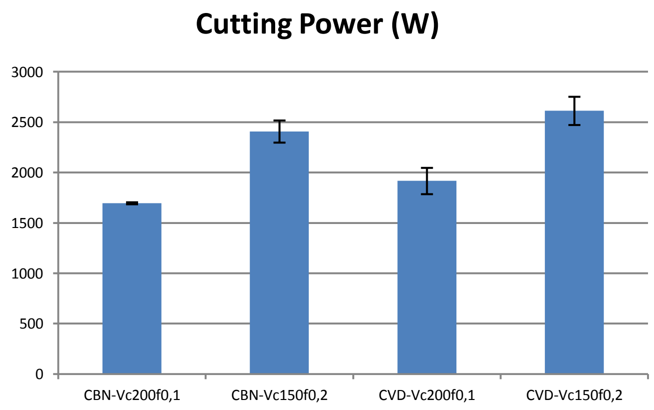

Figure 6: The cutting power results.

The flank wear (V_B) of the tools is in Figure 7. It can be seen that in comparison to the CBN tools, the coated carbide tool, in the condition of Vc = 200m.min^{-1} and f = 0.1mm / rev^{-1}, showed less flank wear and less variation, but without statistics difference representative.

In the condition of Vc = 150m.min^{-1} and f = 0.2mm/rev^{-1} the coated carbide tool showed flank wear 70.5% higher than the CBN tool.

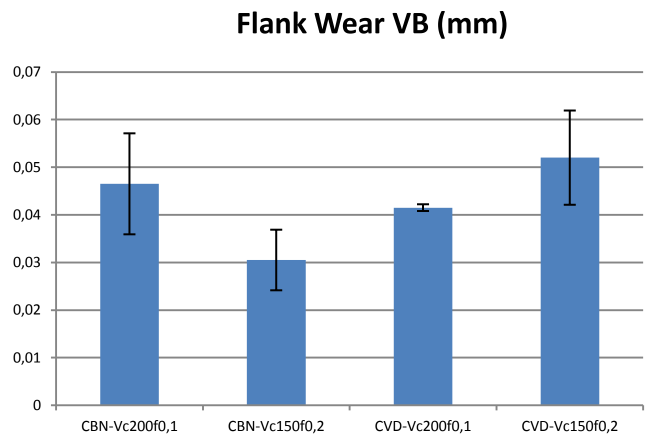

Figure 7: Test flank wear results.

The carbide tool with Ti (C, N) + Al_2O_3 coating gave excellent results, especially in the condition using a cutting speed of 200m.min^{-1} and a feed rate of 0.1mm.rev^{-1}. The high hardness of the micro grain of Ti (C, N), which reaches 3,000 HV, ensured high resistance to wear, consequently a low flank wear, besides providing the rapid conduction of heat away from the cutting region. The Al_2O_3, due to its high hot hardness that can reach 2100 HV (Mitsubishi, 2006), resistance to oxidation and chemical actions, did not allow the formation of crater wear. The low heat conduction of Al_2O_3 ensured that the substrate was protected from high temperatures during machining and was very important for the finishing process with high speeds and interrupted cutting.

4. CONCLUSIONS

Through this work, it is concluded that for machining steel AISI 4340 hardened (56HRc), the carbide tool coated by CVD with Ti(C,N) + Al_2O_3 proved to be a promising option as a replacement to the CBN tools, In the condition using a cutting speed of 200m.min^{-1} and an advance of 0.1mm.rev^{-1}, the roughness results R_a and R_t were lower than those obtained with CBN tools, with values compatible with the found in grinding processes. In the condition using a cutting speed of 200m.min^{-1} and an advance of 0.1mm.rev^{-1}, the roughness results Ra and Rt for coated carbide tools were lower than those obtained with CBN tools, with values compatible with those found in grinding processes. In this same condition, flank wear was lower than that obtained with CBN.

As a negative point of the use of CVD coated carbide tools of Ti (C,N) + Al_2O_3 is the increase in power consumed between 8.5 and 13%. In the experiments performed the CBN tool (CBN010) presents a 10 times higher cost to the CVD coated carbide tool, and that with the results obtained, it is clear the economics that can be obtained using CVD coated carbide tool of Ti (C, N) + Al_2O_3, in the condition of cutting speed of 200m.min^{-1} and advance of 0.1mm.rev^{-1}.

Another great result is that the coating used for the carbide tools has resisted the machining of hardened AISI 4340 steel (54 HRc) without the use of cooling (dry), without damages and wear, proving the maintenance of hot hardness of this coating.

5. ACKNOWLEDGEMENTS

Special thanks to Seco Tools for the support given to this research.

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7. RESPONSIBILITY NOTICE

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