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WEAR ANALYSIS TOOLS AFTER USE OF HOT AIR IN THE TURNING PROCESS WITH INTERRUPTED CUT

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Abstract. *Turning processes, often in the interrupted cutting conditions are present in several operations on mechanical components industry is when a specific geometry is required or when the resulting product is machined from a previous step of a process, for example, in forgings. This condition can lead to variations of mechanical and thermal loads, resulting in increased wear on tools, as a result, there are stops in the process that can lead to financial losses for a company because of the drop in productivity. In order to check the wear and damage incurred in cutting tools due to thermal variations in this process, taking into account that such an event is considered a major contributor to the formation of thermal origin cracks, that motivate the weakened edge sharp, leading the cutting edge of micro-spalling, especially in cemented carbide tools. This study proposes an analysis of wear carbide inserts for turning process with interrupted cutting on an ABNT 1020 steel.*

Keywords: *Turning, Interrupted cut, Wear, Cutting tool, Heating, Thermal variation*

1. INTRODUCTION

Machining is the term used to describe processes in which a layer of material, the chip is removed from the surface of a part by a wedge-shaped tool in (Almeida, 2010). With great importance in industry, this process is characterized by transformation of raw materials into a product having shape, dimensions and finishing.

In its various operations used in industry, the wear of a cutting tool is subject to constant analysis and studies in order to get more and more improvements in the process, thus increasing productivity and reducing costs. Despite the cost of cutting tools will not be as high when compared to the total cost of machining, there are situations where failures occur in the high frequency tool, is required to stop the process or return edging, leading to a fall in productivity (Segundo, 2011).

Two well-known machining processes suffer from variations in mechanical and thermal loads, which result in increased wear on these tools: milling and turning with interrupted cuts. In these types of operations the development of uniform wear on or off output surface will dominate only the cutting tool have sufficient toughness to resist the thermo-mechanical shock inherent in such processes (Santos and Sales, 2005a).

The turning is a machining process in which a tool removes unwanted material producing a surface of revolution (Shaw, 2005a). Thus, the workpiece rotates around the main axis of rotation and the machine tool moves simultaneously along a path coplanar with said shaft (Ferraresi, 1977a). Thus, the cut can be considered continuous when interruptions are assumed to be of little importance. However, during the machining of the interrupted cut forged material is generating thermomechanical cycles due to tool entry and exit in the material, which considerably reduces the life of tool (Pekelharing, 1980a). Previous work analyzed the tool wear behavior when turning was given the interrupted form. The results showed that the interrupted cut is always more severe than the solid (Sanches, 2011a).

In interrupted cutting occur fluctuations of these loads on the cutting edge of the tool throughout the machining time. A cutting edge can be damaged at the entrance, in the middle or at the court of output during a cycle or revolution of the tool. With the frequency of turning on the shaft of the machines occur dynamic variations of the mechanical and thermal loads, which have been identified as major causes of material fatigue of the tools, this factor causes the development of parallel cracks of mechanical origin and perpendicular cracks of thermal origin to cutting edge, motivating wear by weakening and could lead to micro-spalling, especially in cemented carbide tools (Lima, 2011a).

It was proposed in this paper, the court stopped the turning process, as an object of study for wear analysis of cutting tools. In previous studies where the proposed similar tests were conducted, it was satisfactory results in face milling processes with hot air application, turning with interrupted heat application by burning torch and the other with pre-heating electric resistance, resulting drop the amount of thermal cracks. It was suggested then the objective of this work, the study of turning process with cutting interrupt applying the tool heating with the aid of a heat gun, where the

main objective is to minimize the " ΔT factor," decreasing the thermal load variations in cutting edge and thereby reduce the wear on the cemented carbide tool caused by these loads, enabling the onset of thermal origin cracks.
For performance analysis, we used microscopic observation in the evaluation of flank wear of the tools used in the trials and subsequent verification of possible wear mechanisms present. Thus, the main results for the wear and the malfunctions observed in this assay are in this article.

The influence of temperature on shear failure of a tool during a machining process is well known. Due to the thermal source, some bibliographies cite a relevant factor to the acceleration of crack nucleation process, this is due to the difference between the maximum and minimum temperatures suffered during the milling process and turning with cutting interruption.

Temperatures in court interrupted fluctuate cyclically, increasing during active time, decreasing during the downtime. These thermal conditions occurred in the tools used in interrupted cuts they have been investigated by several researchers (Palmai, 1987; Lima, 2011b).

In the case of milling, these tensions occur cyclically and alternates between tensile and compressive stresses, which triggers a process of fatigue that may result in crack nucleation.

One of the first papers on thermal origin of cracks in the interrupted cut that could be found in the literature (Shinozaki, 1962a). He says that even then, the researcher reported in some previous research, which had been observed that the life of carbide tools used in face milling was smaller than the tool of this same material used in turning. In this case, such behavior used to be attributed partly to the damage developed at the cutting edge motivated by interrupted cut, characteristic of milling. This idea began to consolidate from the work of researchers (Optiz and Frolich, 1954; Roubik, 1952), as previously it was believed that due to the inactive phase, the cutting tool would be cooled more effectively than in the continuous cutting, which retard wear. Already in these first publications, are wont to point to as a major cause of the formation of heat checking the cyclical temperature fluctuations experienced by the cutting tool, a feature of the milling process. This seems very reasonable, since the thermal stress developed in the cutting tool are directly proportional to the temperature difference experienced by that during machining (Shinozaki, 1962b; Cep et al., 2009a).

According to the author (Ferraresi, 1977b), during machining develops a large amount of heat, which is dissipated in part by the tool. The tool of the region in which the temperature is higher is that which is in contact with the chips (chip-tool interface). In the most remote areas of this, the temperature is lower. As a result, the tool suffers uneven deformations, which generates voltages.

Recently, researchers (Cep et al., 2009b) examined the influence of the cyclic thermal loading in the life of tools used in interrupted cutting mentions that the thermal fatigue process developed in the tools used in interrupted cutting as a function of temperature differences and some physical and mechanical properties cutting the workpiece material and tool, ie, this investigation shows that the temperature distribution dependent on the cutting conditions (mainly cutting speed, feed and the ratio between the active and inactive time of one cycle and the use of cutting fluid). Thus the greater thermal expansion coefficient and the modulus of elasticity of the tool material, the higher the thermal stresses and hence the greater the probability of occurrence of thermal cracks (Lima, 2011c). In (Wang et al., 1994a) carried out a research on thermal cracks, where the temperature distribution in the carbide tool was analyzed. In this case the heating was simulated experimentally using pulsed laser. The calculations and measurements performed indicated that thermal cracks have not developed the tool's output, after the end of the active phase and during the inactive phase. The author proposed that temperature gradients resulting from heating the exit surface and increase very abruptly at the beginning and during the active phase, and that, due to volumetric expansion of these parts of the tool are, therefore, more prone to develop of tensile stresses, promoting the formation of cracks. Thus, the thermal crack would arise during the active phase and the air current caused by the speed of the tool during the inactive phase, would have little influence on the distribution of temperature at the tool edge, independent of the cutting parameters and the properties of this material. However, it seems unlikely, as proposed by the author (Wang et al., 1994b), the inactive phase has no influence in the formation of thermal cracks, as evidence of the effect of this phase in the phenomenon in question have already been discussed and defended by several researchers. This effect is related to temperature variations experienced by the cutting tool calculated by the difference between the temperatures at the end of the active and inactive phases, called " ΔT factor" as (Melo, 2001).
In order to check the influence of this temperature difference in the formation of thermal cracks in carbide inserts, turning tests, simulating the cutting stopped, were carried out in (Lehewald, 1963a). To do this, the researcher constructed a tool holder with an electric heater attached to your rod. With this device it was possible to preheat the tool at temperatures of 300° to 400°C. Thus it was possible to observe the influence of temperature prior tool in the amount of thermal cracks generated where it decreases with increasing heating temperature, indicating that the smaller the " ΔT factor", the smaller the amount of generated cracks. Experiment similar to that described above was performed by (Vasilko, 2007), with positive results in terms of fall in the amount of thermal cracks with increased tool temperature and, therefore, reduced wear rate of the cutting tool. In this case, the main difference compared to the experimental work (Lehewald, 1963b), was the fact that the cutting tool has been heated by fire torch. For this article the proposal is to verify and confirm these results through a very similar method in (Lehewald, 1963c), which will use a heat gun with an average temperature of 80°C in interrupted turning process, which is expected to decrease in the " ΔT factor" beyond

a removal of chips produced in the cutting operation the cutting up edge (APC), this as a factor that enables increased wear of a cutting tool.

2. EXPERIMETAL PROCEDURE

The performed tests consisted in the analysis wear of the cutting tool material when turning process with interrupted cut without heating and heating of the cutting tool. For this we used a heat gun 1800 W of power at an average temperature of 80 ° C. The material used in this test was the carbon AISI 1020, which is a high forgeability and weldability steel, but low mechanical strength and low machinability, whose chemical composition and mechanical properties are shown in "Table. 1 . The steel described was used in a test body in a cylindrical shape of 160 mm in length and 22.4 mm in diameter, about 90º mm being machined containing nine (9) interrupts with longitudinal grooves (keyway) 2 mm thickness and 3 mm deep, to simulate the interrupted cut.

Table 1 - Chemical composition as standard sae - j404

3. **Elemento**	4. **Métrico**
5. Carbono (C)	6. 0,17-0,230%
7. Manganês (Mn)	8. 0,30-0,60%
9. Ferro (Fe)	10. 99,08-9,53%
11. Fósforo (P)	12. <=0,040%
13. Enxofre (S)	14. <=0,050%

The equipment used was a bench around Manrod MR - 334, 850 W, with motor Manrod MS 8024 insulation class F and IP54 protection degree of 220V and frequency of 60Hz as shown in Fig.1.

Figure 1: Lathe Manrod MR 334; own.

Rotation values, advance, cutting depth and length in the part machining, were defined by measurements with calipers and tests performed on the lathe, to avoid too dispersed results and possible equipment damage.

With the cutting speed varying from 150 RPM to 600 RPM, as the assembly of pulleys indicated for use lathe where each pulley receives an identification letter and its settings provide different rotations. For this test setup was used at BC1, BC2, BC3 respectively providing the rotational speeds of 150, 300 and 600 rpm, as shown in the table of the machine

To advance the assembly provides two combinations of gears, which are generated two columns with different feed variations. For this study we used the following advance variations: 0.07; 0.14 and 0.28 mm / revolution, according to the table contained in the vice shown in

For the machining of the material was used six carbide inserts coated (TiCN and Al_2O_3 + TiN) cabonitreto titanium, aluminum oxide and titanium nitride fixed in a tool holder as shown in Fig. 14 and Fig. 15, respectively.

Eighteen tests Were Performed in full for this turning process, the first nine tests Were Conducted at room temperature with the case without heating the cutting tool from the tenth test was applied to the preheating of the tool, to check the wear occurred in inserts. For BOTH procedures, with or without heating, to vary the feedrate (F) 0:07; 00:14 and 12:28 mm / revolution to present each cutting edge on the insert, so each insert having three edges, each of Which was used in the test tool in a rotation range of 150, 300 and 600 rpm, the mentioned. Due to the repetitions the body-specimens with braces (tears) Were Performed in consecutive passes, the cutting depth is varied, (ap) at 0:03 mm diameter every pass, so que the opening diameters every pass Were different, Resulting the end of the test the body-of-test with end diameter of 17.0 mm.

The Measures and analysis of wear and breakdowns in the cutting edges of the inserts Were held in a scanning electron microscope (SEM), through its aid, checking the wear was possible, considering only Those present in the insert substrate and visible with a magnification of 100 times. In checking the wear of flanks was measured (VB) of the tested inserts Which enabled the analysis of cutting edges, as seen in Fig. 2.

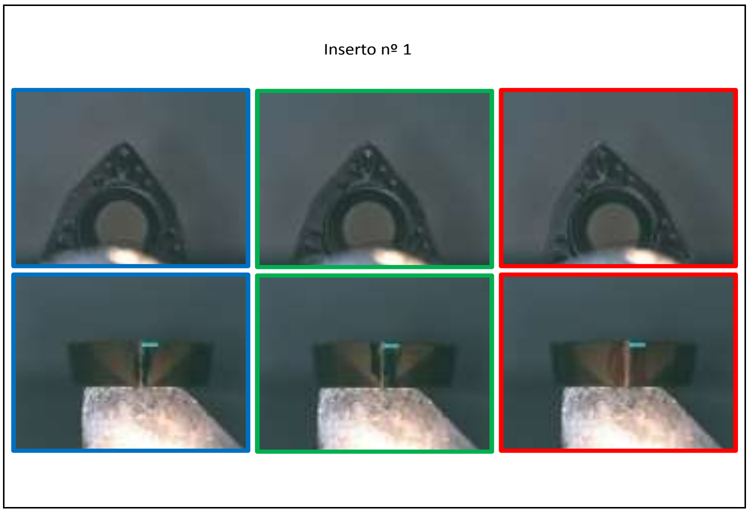


Figure 2: Example of inserts of photos taken by the SEM for analysis of wear (V_B) on the edges; own.

3 RESULTS AND DISCUSSION

After checking the edges of the insert, through the optical microscope, the results obtained were the average wear of flanks (V_B) in the tool. To calculate the cutting speed (V_c), required the analysis of the results, the values of the variations obtained in the diameters of the body of the test piece and the rotation of the equipment during the tests were used. Comparisons of results obtained in calculations with the numbers seen in laboratory analysis, generated the expected values or this work.

In Table 3, one can see these recited values as well as advance values (f) used in the assay and feedrate (vf) calculated to facilitate the analysis of these results have been generated using this two (2) Graphic wear comparison (VB) in relation to cutting speed (vc), in the processes carried out without heating and with heating in turning with interrupted cuts.

Chart 4 represents the average values of wear (VB) found in both cases, with or without heating. Where it had other two (2) graphs, as further analysis for this research.

Table 2 - comparison of results Results of unheated turning tests

Test	Feed (f) [mm]	v_f [mm/min]	V_B [mm]	v_c [mm/min]
1	0,07	10,5	0,031	10,55
2	O,14	21,0	0,062	10,41
3	0,28	42,0	0,046	10,27
4	0,07	21,0	0,031	20,26
5	0,14	42,0	0,039	19,98
6	0,28	84,0	0,039	19,70
7	0,07	42,0	0,055	38,83
8	0,14	84,0	0,031	38,26
9	0,28	168,0	0,039	37,70

Table 3 - comparison of results Result of the turning tests with heating

Test	Feed (*f*) [mm]	v_f [mm/min]	V_B [mm]	v_c [mm/min]
10	0,07	10,5	0,046	9,28
11	O,14	21,0	0,023	9,14
12	0,28	42,0	0,039	9,00
13	0,07	21,0	0,031	17,72
14	0,14	42,0	0,039	17,44
15	0,28	84,0	0,031	17,15
16	0,07	42,0	0,039	33,74
17	0,14	84,0	0,046	33,17
18	0,28	168,0	0,031	32,61

Table 5 - wear average (V_B)

V_B – No Heat [mm]	V_B – As Heat [mm]	Total average Wear [mm]
0,041	0,036	0,039

It is observed that by increasing the feed tends to increase wear, due to increased vibration of the apparatus during the procedure, but with the increase of shear rate occurs at an equilibrium process that allows for less wear. Comparing the first two graphs, it can be seen better performance in machining carried out with preheating, thus enabling a lower tool wear track. Also it can be seen in absolute terms, increased wear in the process without heating in the machine settings to forward (f) of 0.14 and 0.28 mm / rev at low cutting speed (in a range of 10.27 to 10.41 mm / min) and feed (f) 0.07 mm / revolution at a surface speed (u) of 38.83 mm / min with wear values checked at 0.062 mm..; 0.046 mm and 0.055 mm; respectively. While in the process with heating verified these absolute valuesin less occasions, and at a time with equipment configured to a breakthrough (f) of 0.07 mm / rev and cutting speed (vc) low to 9.28 mm / min . and a surface speed (u) greater than 33.17 mm / min. with feed 0.14 mm / rev, with wear values (V_B) of 0.046 mm in both cases. Have valuesless wear, checked in the process with heating stand out, where the lowest value observed was 0.023 mm in the setting of 0.14 mm / forward rotation (f) and cutting speed (vc) 9.14 mm / min. As can be seen in Tab. 3 and in Figures 1 and 2.

Figure 3: Wear Assessment x Cutting speed (in unheated process)

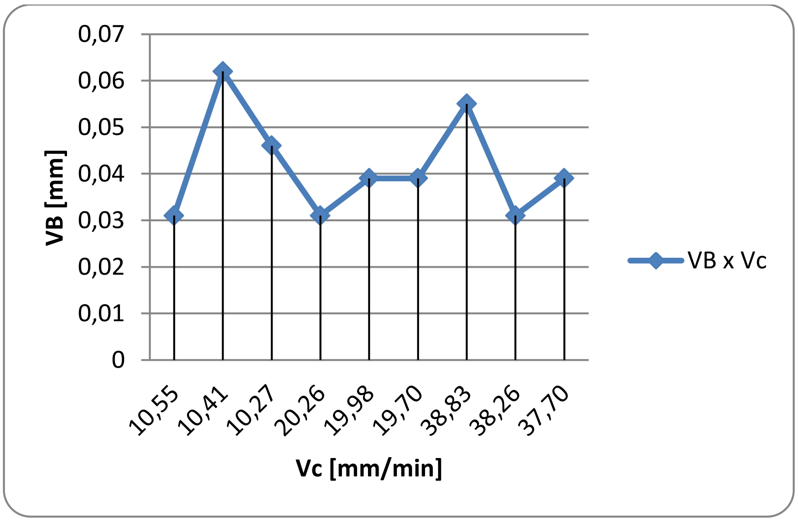
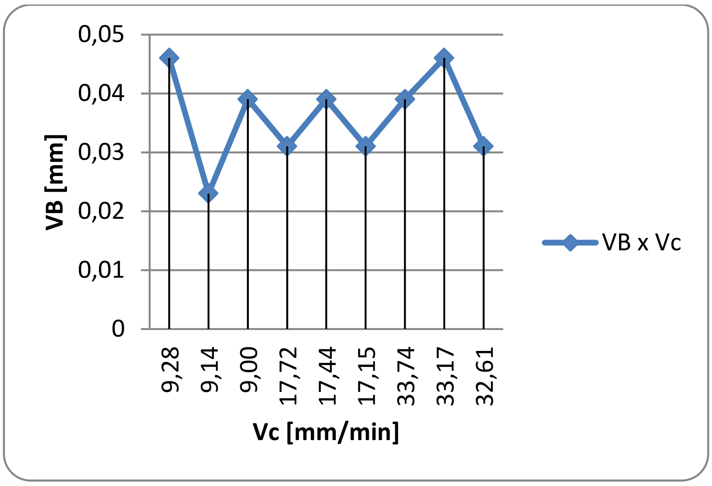


Figure 4: Wear Assessment x Cutting speed (in heating process)



As confirmation of this analysis it was found that less wear of the cutting tool in the process, through the medium of graphics wear and comparison between the tests that used the pre-heating process and at room temperature. Where an average wear used in each procedure and an average total wear occurred in the two procedures, as shown in Tab. 4 and in Figures 3 and 4. Then observe a lower average in wear (VB) tool used in machining with preheating, both in relation to the average wear unheated tool used, as compared to the average total wear observed in the trials.

Chart 1: Wear Assessment for trial

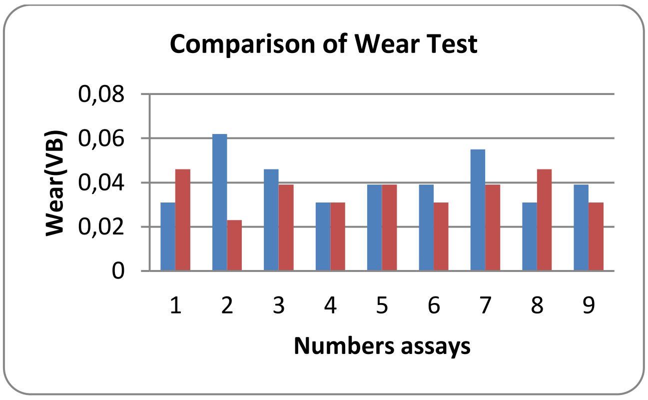
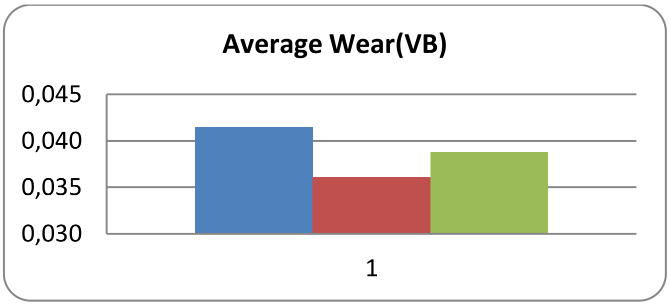


Chart 1: Wear Medium



4 CONCLUSIONS

As a conclusion of this study, it can be stated that the results were expected, as it is confirmed in less wear of the cutting tool for turning with interrupted cutting process using the preheating cutting tool, according to results obtained in studies above. Although it was not possible to check thermal origin of cracks in this test, the tests were decisive for verification lower flanks wear on the cutting edges of the inserts used in laboratory, possibly caused due to lower temperature variation "factor DT "in and out of the cutting tool during the process with interrupted cutting.

An important factor is the use of thermal blower and contribute to reducing the process "DT factor," also contributed by replacing the use of fluid towards the outlet tablet surface lubrication during the active phase in cutting through the flow of the heated air, the clearance of chips on the cutting edge of the material is possible, thus avoiding the formation of (PCA).

Although no studies about the roughness on surfaces have been addressed in the article, during rehearsals also observed a better visual finish on the surface of the workpiece, indicating a lower surface roughness in the process using heating. Thus, it is suggested as future work for the subject machining with interrupted cut, the further study of this matter, the surface roughness comparing the use of a preheating of the tool, with the use of a cutting fluid process.

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