EVALUATE OF PERFORMANCE OF COATING ON THE DRILLING AND THE EXPANDING OF AL-SI ALLOY USING ONE TOOL AND YOUR INFLUENCE IN THE VIBRATIONS SIGNALS

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Abstract: *In present work, the relation of tool vibration to hole quality and surface roughness was assessed for coated and uncoated tools applied to the drilling of a hypoeutectic Al-Si alloy. Drilling operations were performed at a ROMI Discovery 560 machining center with one ISO 40 mandrel of hydraulic fixation and Al-Si alloy blocks. The cutting parameters used were: rotation of 1000rpm, feed rate in 3240mm/min and cutting speed of 376m/min. The operation was realized in dry condition and with emulsionable cutting fluid. The cutting fluid used was the BLASOCUT with the concentration of 8% and 15bar of pressure. Upon completion of the tests workpieces were cooled to room temperature and submitted to metrology analysis. Vibrations signals were compared to diameter, circularity and roundness of the holes. Assessment of the surface roughness in terms of the Ra, Rz e Rt was also performed..*

Keywords*: Machining, Aluminum-Silicon Alloy, Quality, Vibrations.*

1. INTRODUCTION

Drilling is the machining process used for obtaining cylindrical and circular internal surfaces which are coaxial to the rotation axes of the cutting movement. The difficulty of drilling Al-Si alloys lies on the adhesion of the Al on the drill. Quality of the drills is determined by a synthesis of dynamic process parameters and also by the thermal distribution in the workpiece/drill interface. Among the mechanisms may induce errors leading to loss of drill quality one can include abnormal deviation or rotation of the drill at entry, deflections of the drill due to the unbalanced forces, errors due to cutting in the edge of the drill; errors due thermal expansion of cutting tool and workpiece. The stiffness of the cutting tool is related to the induced errors due to the dynamic mechanisms, but isn't affected by the presence/absence of the drill coatings (KALLIDAS et al.; 2001).

In spite of their superior fluidity and the lower contraction in comparison to hypoeutectic alloys, eutectic Al-Si alloys observed limited application due to reduced ductility and resistance. Suarez et al (2006) studied the modification of the eutectical alloy structure with the introduction of modifier agents such as Sr and Ti, which were able to improve ductility of the alloys. The Al-Si alloys most applied are the hypo, hyper or eutectical with the Si content between 10 and 18% in weight (Fig. 1).

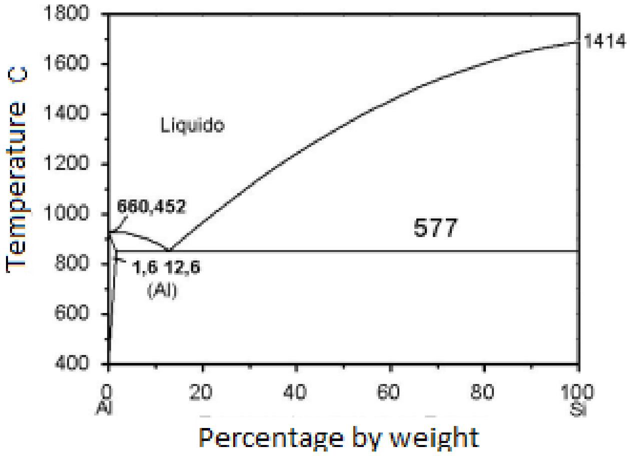

Figure 1: Equilibrium diagram of the Al-Si Alloy (Suarez, 2006).

Al alloys have observed large industrial use due to mechanical resistance, low density and the superior machinability when compared to other metals. The Si addition to Al decreases its melting point and increases the wear resistance of the alloy. The Al-Si alloys are used in the manufacture of engine components which demand high fluidity and low tendency of contraction in casting.

The existence of tool vibration associated with machining operations is well established. According to Polli (2005), processes may exhibit different levels of tolerable vibration frequency or amplitude. For processes focused on the removal of material from bulk workpieces, for example, concerns are directed towards determining the vibration amplitude level which will produce higher tool life, whereas in finishing processes, amplitude is controlled in order to assure surface quality and dimensional accuracy in the machined workpiece.

Vibration in machines and tools are a worrying variable that impact on the productivity of the machining industries. Excessive vibration compromises the machined surface quality, decreases tool life, increases the catastrophic failure of tools and damages bearings of the machine axis, increasing the machine energy consume (KING, 1985).

One of the causes of these vibrations can be attributed to the eccentricity generated by fixation insert failure leading to irregular drill radii. The existence of eccentricity produces changes in the cutting forces and also in the instantaneous force maximums depending on the cutting conditions, on the geometry of the cut and the nature of the eccentricity (SCHOROETER et al., 2001). Tool deflection acts towards decreasing the effects of the eccentricity. In this case, according to Deonisio (2004), if chip thickness is larger than that theoretically determined, cutting forces will be higer (and the inverse occurs if chip is smaller than estimated).

In machining, vibrations are consequences of the cyclical variations of the dynamic components of the cutting forces (DIMLA e LISTER, 2000). Normally, these vibrations begin with little chatter which generates a wavy texture on the machined surface and varying chip thickness, leading to larger vibrations as the process progresses (SOUTO, 2007). A relationship can be established between process vibrations and finishing quality of the machined surface. For small vibration levels, the relative movement between tool and workpiece is a combination of the feed rate and the cutting speed.

Many are the origins of vibrations in the machining process. The principal vibrations in machining are: vibrations from the environment, vibrations generated by the workpiece and by discontinuities therein and vibrations generated by the machine-tool interface. Many of the free, forced and auto-excited vibrations are normally present on the machine-tools. Vibrations in the machine-tool interface are based on the external energy and may be classified as free, forced and auto-excited vibrations.

According to Altintas (2000), the vibrations generated by the tool chatter result from an auto-excited mechanism in which accompanies chip thickening during the machining operation. Depending on the phase change between the two successive chips, maximum chip thickness may observe an exponential increase while chatter frequency is close to the dominant structural mode in the system. The increase in the vibration level increases the cutting forces and may cause breaking of the cutting tool or, in less severe cases produce a poor surface finishing. Auto-excited chatter vibrations can be caused by coupling or by regeneration of the thickness of the chip (TOBIAS and FISHWICK, 1958). The coupling chatter mode occurs when vibrations exist on two directions of the cutting plane. The regeneration phenomenon results from the phase difference between the vibration waves on both chip sides and occurs before of the coupling mode in many machining operations.

2. EXPERIMENTAL PROCEDURE

In this work, we used blocks of fused Al-Si for study the effects of the drills. The chemical composition of alloy is shown in tab. 1.

Table 1: Average chemical composition of the Al-Si alloy in weight percent.

Element (%)	Al	Si	Cu	MG	Mn	Ti	Fe	Zn	Ni	Pb	Sn
Workpiece	86,8	7,76	3,11	0,36	0,40	0,02	0,74	0,56	0,03	0,05	0,02

For each block 100 drills were produced, of which 11 were submitted to further investigations. These samples were analyzed by applying optical microscopy with a 200x magnification. For microstructure analyses, the samples were attacked with distilled water 95% in volume, fluoride acid HF-1 ml, nitric acid - HNO_3-2,5 ml, chloride acid HCl-1,5 ml, for 5 hours. Samples were also submitted to Vickers micro hardness test with 100gf charge.

The microstructure of the alloys is shown in Figure 2, where the typical hypoeutectic microstructure constituted of both α-phase (rich in Al) and eutectic phase can be seen.

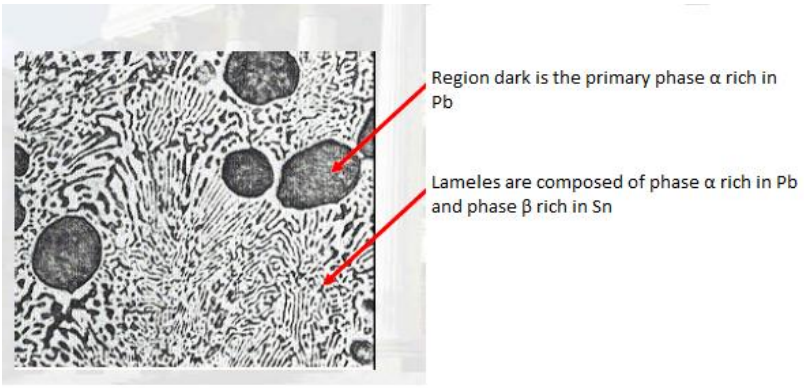

Figure 2 – Microstructure of the Al-Si Alloy evidencing both α and the eutectic phase.

An accelerometer was placed in the workpiece perpendicular to the feed direction for monitoring of process vibration during execution of the drills. The drilling was made using cermet carbide tool (WC + Co) with polished channel of diameter $11,00^{+0,003}_{-0,003}\,mm$ without coating and with monolayer TiCN coating deposited by PVD, with a nib angle of 145º and break angle of 10º (Fig. 3).

Figure 3 – Cermet carbide drills without and with TiCN coating.

The operation consisted on manufacturing the holes and simultaneously expanding them in a single operation. The machining was made using emulsionable fluid applied by the channel of the tool with 30 bar of pressure. The vibration signals were collected for every 10 drills. In order to assess the impact of tool wear on the quality of the drilled holes, cutting tools at the end of tool life were chosen for the experiments.

The drill fixation was performed by hydraulic system with interchangeable gland. Cutting parameters were: feed rate (v_f) of 3240 mm/min, rotation of 10000 rpm, feed (f) of 0,324 mm/rot, depth of cut (a_p) of 0,05 mm and cutting speed (v_c) on 376 m/min.

3. RESULTS AND DISCUSSIONS

All vibration data were assessed in terms of the Root Mean Square (RMS) value of the collected signals, which is a good indicator of vibration on the machining at large (MAIA, 2009). Analyzing Fig. 4, which presents the RMS value of the vibration signal (in V) as a function of the roughness parameter Ra, it can be seen that vibration levels are lower for the tool coated with TiCN, followed by the new uncoated cutting tool and, at last, with the highest level of vibration with respect to surface roughness, the uncoated cutting tool near the end of tool life. The increase in tool vibration appears, therefore, to be correlated with tool wear. With respect to the surface roughness, it could be noted that the largest changes took place on the workpieces machined with coated drills TiCN. It is known that the Ti has a strong affinity with non-ferrous elements as in the present case of Al-Si alloy, which could be a contribution to the large variation on the average roughness levels. On the uncoated tools, the roughness variation observed for the new drill occurs mainly by settling of the tool.

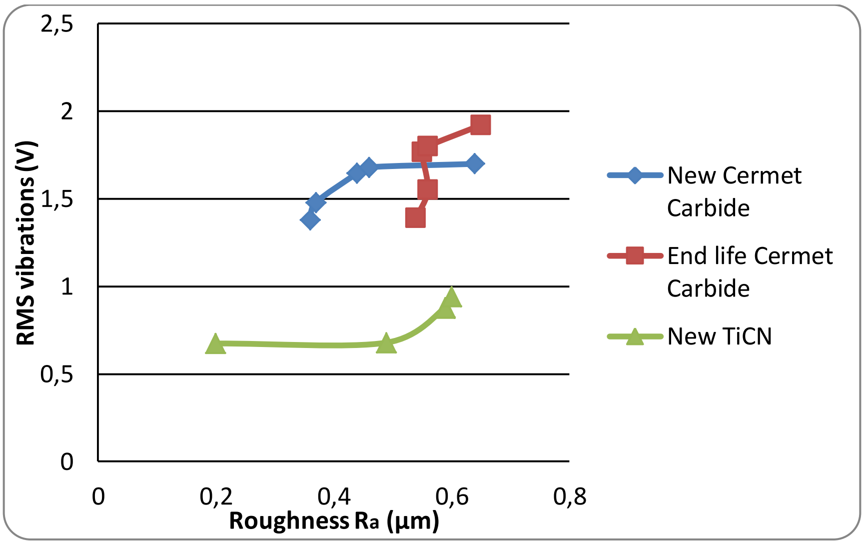

Figure 4. Surface roughness (R_a) in function of the RMS of the vibrations signals on the drilling of the Al-Si alloy.

Fig. 5 shows the relation between the R_z roughness parameter and the vibration level. It can be observed that the lowest roughness values occurred for holes drilled with the new uncoated tool. The holes manufactured with coated tool presented a great range of amplitude, which again can be explained by the fact of the chemical affinity between Ti and Al. At first moment the values are low, but with increasing temperature and acceleration of diffusion processes, incorporation of Al in the cutting tool becomes greater leading to the rise in surface roughness. For the worn cutting tool, values are already high due to the degradation of the cutting edge.

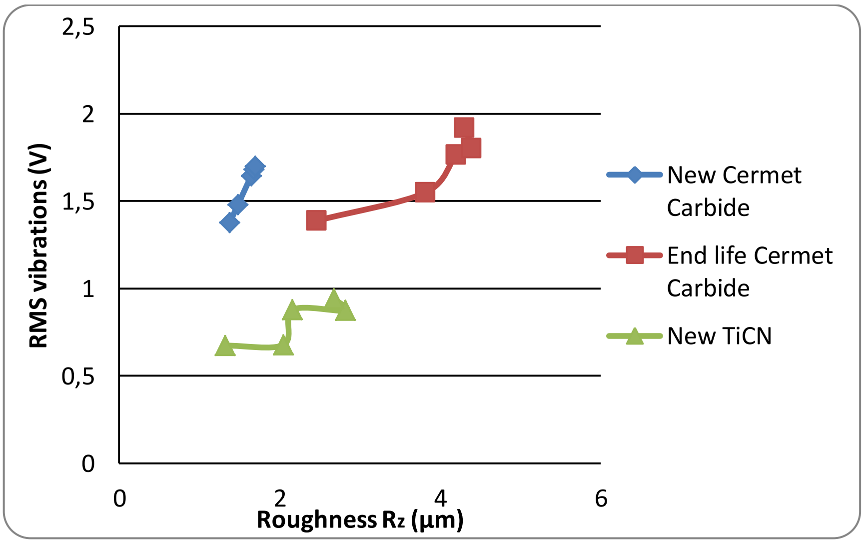

Figure 5. Roughness (R_z) in function of the RMS of the vibrations signals on the drilling of the Al-Si alloy.

Evaluating Fig. 6, which presents the behavior of the R_t roughness parameter as a function of the vibration levels, it could be noted that the smaller roughness amplitude were observed for the TiCN coated tool, followed by holes machined with the uncoated worn tool, whereas the largest values correspond to the holes machined with new uncoated tool. If R_z roughness is analyzed in terms of the maximum and minimum values, the hole machined with the new uncoated tool present smaller values compared to the worn uncoated tool.

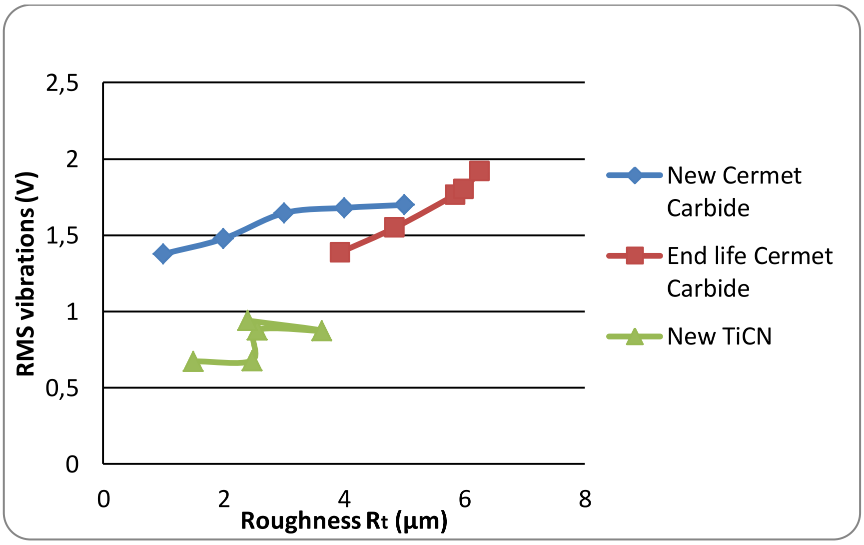

Figure 6. Roughness (R_t) in function of the RMS of the vibrations signals on the drilling of the Al-Si alloy.

Fig. 7 shows the diameter of the drilled holes as a function of the workpiece vibration signals. It can be noted that the diameters of the holes made with TiCN coated drills showed the lower range of amplitude, as well as the RMS values of vibrational signals, indicating that the vibration is closely related to the diameter formed by the hole. A decrease in process vibrations directly affects the characteristic of the machined piece.

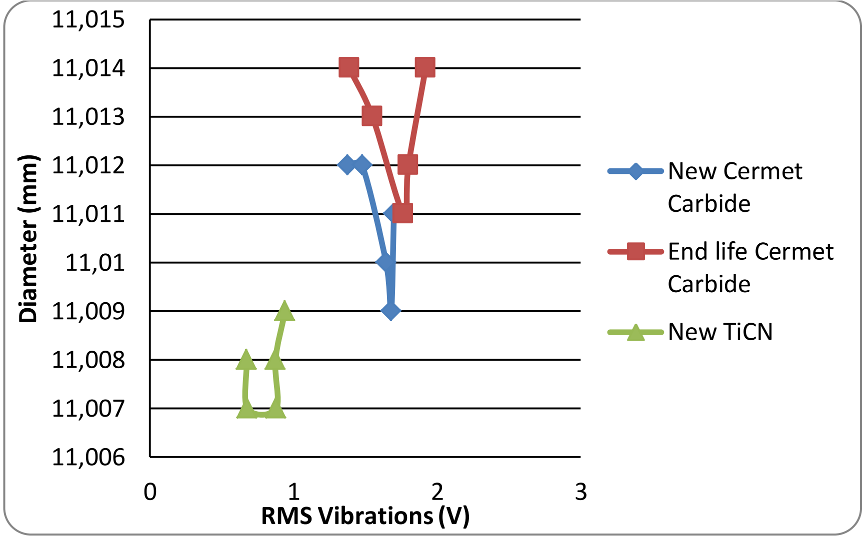

Figure 7. RMS of the vibrations signals in function of the mean diameter of the drill.

Fig. 8 shows the roundness values of the holes as a function of the RMS values of vibration signals. It can be noted that the lower values of roundness were obtained, on average, in machining using TiCN coated drills. The lowest average vibration levels were also observed for the coated tool, indicating that the coating has good stability. In addition, it could be noted that the largest roundness values were observed for the holes executed with the uncoated worn tool. Fact that also occurred with the RMS of vibrational signals, as expected, corroborating that the advanced wear on the cutting edge generates instability in the cutting.

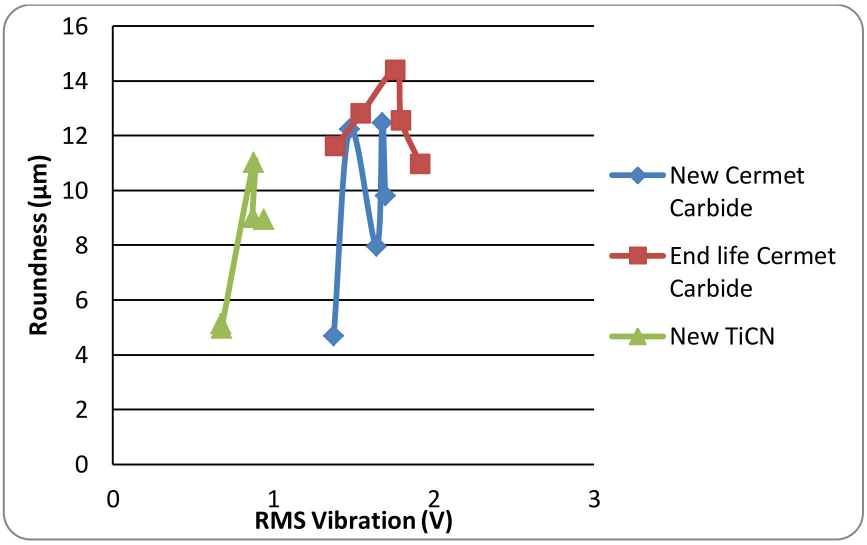

Figure 8. RMS of the vibration signals in function of the roundness of the drill.

Evaluating Fig. 9, which shows the RMS values of vibration signals as a function of the circularity of the holes, it could be once more noted that, on average, superior performance was observed for the coated tool which also produced the smallest levels of vibration.

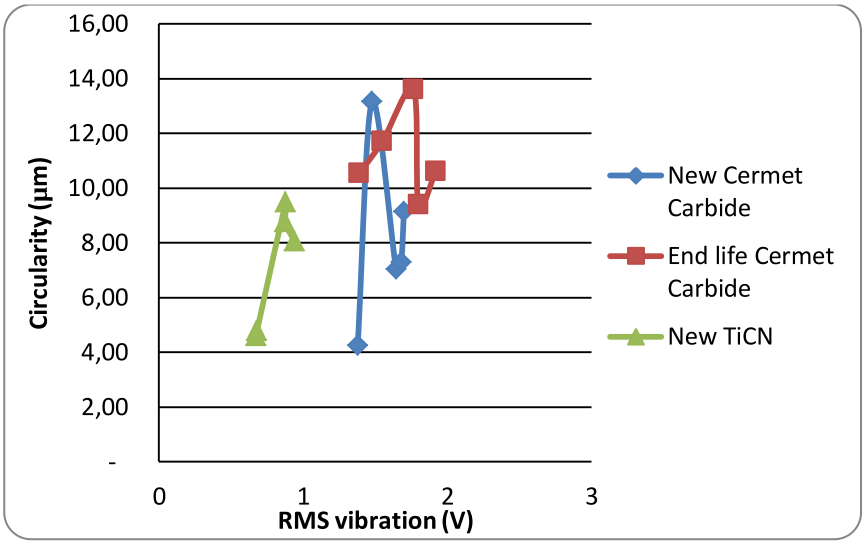

Figure 9. RMS of the vibration signals in function of the circularity of the drill.

4. CONCLUSIONS

With respect to the surface roughness results, it could be noted that the holes drilled with coated tools presented the largest amplitudes of results. This is probably due to the strong affinity between the Ti and Al, which may have led to the creation of an adhesion layer changing the contact surface of the tool. Another possible cause is the irregular coating deposition on the tool, which is most remote due to the vibration signals and the quality of the hole showed the lowest values in the holes with a drill coated.

Regarding tool vibration, it could be noted that the lower signals were produced by the coated drills, which suggests that there was a decrease in the coefficient of friction between the surfaces. The largest signals were precisely performd with the uncoated worn tool, which already presented deteriorated cutting edges..

With respect to drill quality parameters, superior results obtained for the drills produced with the TiCN coated tool, a further indication that the coating reduces the friction coefficient between tool and workpiece. With regards to the coated drills, results were superior for the holes produced by the new cutting tool in comparison to the worn drill, which could also be detected from the RMS vibration signals.

5. ACKNOWLEDGEMENTS

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