EVALUATION OF HIDRAULIC AND THERMAL FIXATION SYSTEMS USING HARD METAL DRILLS IN A FIRE MOTOR HEAD

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Abstract. *Companies concerned with cost reduction seek alternatives to be more competitive. Cutting tool fixation systems, as well as machine-tool dynamic stability and tool-holder stiffness constitute a group of great importance, which directly influences the quality of the machined piece, and also the associated costs. Currently, companies use the hydraulic fixation system for its better handling during pre-mounting, tool change and tool assembly repeatability to the hydraulic. This adjustment after pre-mounting allows a 0.003 mm runout tolerance, however with high cost, both in serial or non-serial machining processes. New technologies, such as thermal fixation, are used in order to obtain lower costs and achieve tolerances closer to those of the hydraulic fixation system. This work compares the hydraulic and thermal fixation systems, using hard metal drills in a motor head made of high pressure Al-Si alloy, evaluating product tolerances and tool wear. In this study, optical and scanning electron microscopy and with EDS analyzer were used to monitor tool wear, geometric deviation and surface texture parameters. Flank wear evolution was proven in stages I and II; additionally, the thermal system performs more effectively in comparison to the hydraulic system.*

Keywords: *hydraulic fixation, thermal fixation, drilling, drill fixation systems.*

1. INTRODUCTION

The aluminum alloys are used because of its mechanical resistance, low density and an easier machining between materials. The addition of silicon to aluminum decreases its fusion point and improves the abrasion resistance of the component. The Al-Si alloys are used on the production of combustion engine components, which require fluidity and low contraction tendency in pressure casting. The cutting force and the tool abrasion rate are low due to the good heat conduit of Al-Si alloy (Cotterell and Kelly, 2002).

Machining is a process used on the fabrication of components on most different areas of industry. Drilling is a kind of machining process used to obtain internal cylindrical surfaces, this cylindrical surface is coaxial to the rotation axle on cutting movement, and the cutting movement can be considered as drafting, semi-finishing or finishing. The drilling of Al-Si alloys shows difficulty due to the adherence of aluminum on the drill. The quality of a hole from this process is determined by an error synthesis due to the dynamic of process and, also, to the thermal condition on the interface part/drill. Some of the mechanisms which induce the process to errors are, deviation or abnormal drill rotation on entrance; drill deflections due to the unbalanced strength; errors due to process failure; errors due to cuttings on drill edges; errors due to thermal expansions of parts and drill. The drill stiffness determines, largely, the induced errors due to the dynamic mechanisms, but it is not affected by the presence or absence of drill covering (Kalidas *et al*, 2001).

Several fixation systems are, nowadays developed to guarantee a bigger stiffness to the drilling system in which the thermal fixation, replace the hydraulic fixation. The fixation system determines the dimensional allowance and roughness, and also errors of the machined holes shape. The purpose of this work is to verify the thermal and hydraulic fixation systems at two machining process finished bores of an Al-Si alloy motor head, executed by hard metal drills of two different diameters, using the hydraulic chuck HSK63 and thermal shrink chuck HSK63, at Huller machining center.

The hydraulic fixation system presents a cylindrical dilating bushing that provokes a centralized expansion due to an oil injection on its interface. The fixation systems by thermal contraction use the expansion principle when heated. For the fixation, the chuck is heated and it expands mounted with an interference of 0.0025 mm to 0.050 mm in the cylinder. The necessary heat can be obtained by hot air, electrical induction or open flame (Fiedler and Würz, 2001).

The temperature on the tool-shaving interface has an important influence at the tool wear and on the strain region microstructure (King *et al*, 2005; Ozcelik and Bagci, 2006; Nouari *et al*, 2003). Abu-Mahfouz (2003), introduced five artificial wear types at the transversal drill tip, crater, flank, fracture or breakage and wear on the cutting angle.

The map of the mechanisms wear is a powerful tool on the choosing and selection of tribology parameters. Zhang *et al* (2001) defined four separate regions by outlines of 0.3 (log VB / cutting distance) intervals in dry drilling of Al-Si alloy pressure casting with high-speed steel. On this map, Fig. 1, there is a lesser wear cutting zone for the high-speed steel drill on Al-Si alloy drilling.

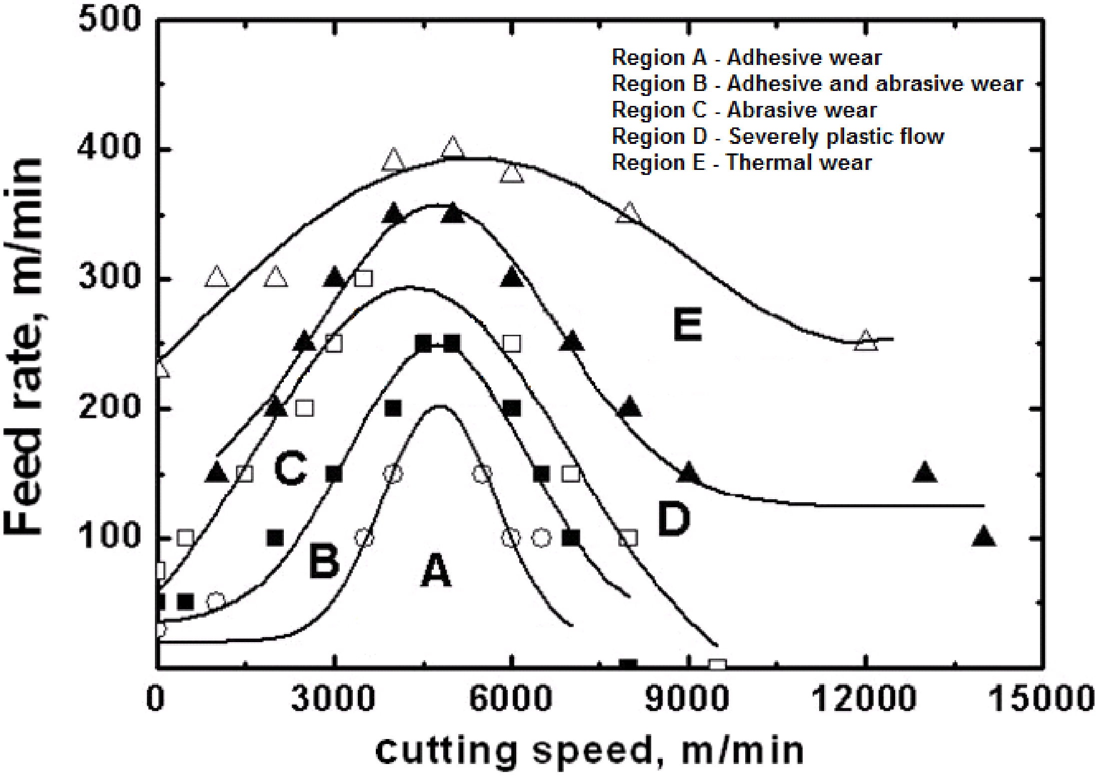


Figure 1. Al-Si alloys wear map for dry drilling process (Zhang *et al*, 2001).

Teer *et al* (2005) showed that the wear evaluation through the cutting edge was prevented by the adhered material and, in this case, the wear evaluation was made after etching with a 10% NaOH solution at scanning electron microscope, while Bhowmick and Alpas (2008) measured the false edge height through the perpendicular line to the drill cutting edge. Sundarajan *et al* (2008) divided the flank length in regions to each cutting edge. The flank wear was obtained by measuring four points realized on the cutting edge length and making the arithmetic average.

2. METHODOLOGY

The raw material used on this work is an Al-Si alloy with motor head shape obtained by pressure casting for posterior machining. A representative test specimen run was casted, milled and cut. The samples taken were 30 x 30 mm^2. Chemical and metallographic analyses were made. These samples were analyzed in optical microscope, Leitz, with 200X increase. For microstructure analyses, the samples were etched with 95% distilled water in volume, fluoridric acid HF – 1 mL, nitric acid-HNO3 – 2.5 mL, hydrochloric acid – HCl - 1.5 mL, for five hours. Vickers micro-hardness tests were made in a micro-durometer, Leitz, with 100 gf loading.

Many motor heads were used on the tests on pre-machined condition with 10.50 mm pre-hole. The first contact of the tool with the pre-hole must be equal between all cutting edges. Nevertheless, the cutting may become irregular due to the disalignment of the pre-drilling tool axle, shape deviation, drill beating error and drill fixation problems at the machine-tool spindle (Weinert *et al*, 1998). The machining process is made in machining centers with numerical command Simens 840D Huller and transfer Comau. The machine has 28 kW installed power, axle tree with a maximum rotation of 16000 rpm. The drills used are made of hard metal (WC + Co) with parallel rod, H7 allowance, no covering, with the tip angle diameter of 145º, 10º clearance angle, second diameter with tip angle of 90º and 8º clearance angle, the drill diameter is 12.150 (+0.025 +0.007) mm. To house the drill to the fixation system, thermal and hydraulic, a semi-automatic equipment, Speroni, was used, with a 20X increase camera.

After that, the radial beating was measured on the drill rod at the hydraulic and thermal fixation systems on correspond distance of 127 mm from the HSK cone face to the drill tip. The measurement was made through a Mitutoyo comparator clock with 1 μm resolution, coupled to a magnetic base.

The cutting fluid used was the HOCUT® B 205D with 6% to 8% concentration and 30 bar pressure. The holes were 8 mm profound. After completing the drilling tests, the parts were chilled to the room temperature, and measured at the metrology lab. The parts 1, 50, 100, 150, 200, 250, 300, 350, 400, 500, 1000, 1500, 2000, 3500, 5000, 6500, 8000, 11500 were taken, so the geometric parameters as cilindricity, circularity and diameter of the hole could be measured.

The measuring at the geometric parameters was made respectively, at the Talyrond 4 Coord A and Hera 3 coord equipments. The beating error was also measured for the hydraulic and thermal systems at the same sequence.

The surface parameters, R_a, R_z and R_t were evaluate on the parts 1, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 1500, 3000, 4500, 6000, 7500, 8500, 10500 and 11.500, using the equipment Taylor Hobason Form-Talysurf series and Gaussian coarseness filter, with 0.8 mm cut-off and 4.8 mm length. The R_a allowance, 1.6 μm from the hole surface, was controlled through the software developed specifically for this analyses. The wear analyses, of the tool used on the tests, were made in an optical microscope OMIS MIMI. It has been observed that, the wear dimension occurred between the cutting edge and the maximum color contrast width, verified at the microscope. The observed wear is the average of the thickness values measured on both faces.

For this analysis a Phillips scanning electron microscope, model XL30, equipped with X-ray energy dispersive system (EDS) was used. The drills, after a definite number of pre-specified holes, were put in watery solution with 10% NaOH for 24 hours. After, these drills were analyzed in optical microscope and scanning microscope, to measure the wear and make an analysis of the deposited material.

3. RESULTS AND DISCUSSION

The tests were realized on pressure casting motor head in Al-Si alloy, with chemical composition in percentage of weight, as shown in Table 1.

Table 1: Chemical composition of the Al-Si alloy, in weight percentage

Element	Al	Si	Cu	Mg	Mn	Ti	Fe	Zn	Ni	Pb	Sn
Composition (%)	86.8	7.76	3.11	0.36	0.40	0.02	0.74	0.56	0.03	0.05	0.02

The microstructure has consisted in a rich Alfa phase in aluminum and eutectic, as shown in Fig.2. The intermediate eutectic phase is $Al_5Cu_2Mg_2Si_6$ or $Al_{15}(FeMn)_3Si_2$ (Teer, D.G, 2005). The silicon content in the alloy means that, the alloy has primary particles which promote the tool wear due to abrasion, when compared to others aluminum alloys.

Figure 2. Microstructure of the Al-Si alloy, evidencing the light phase rich in aluminum and eutectic.

The Figure 3 shows the evolution of the tools beating error fixed on the thermal systems and hydraulic after the drilling of the parts 1, 50, 100, 150, 200, 250, 300, 350, 400, 500, 1000, 1500, 2000, 3500, 5000, 6500, 8000, 11500.

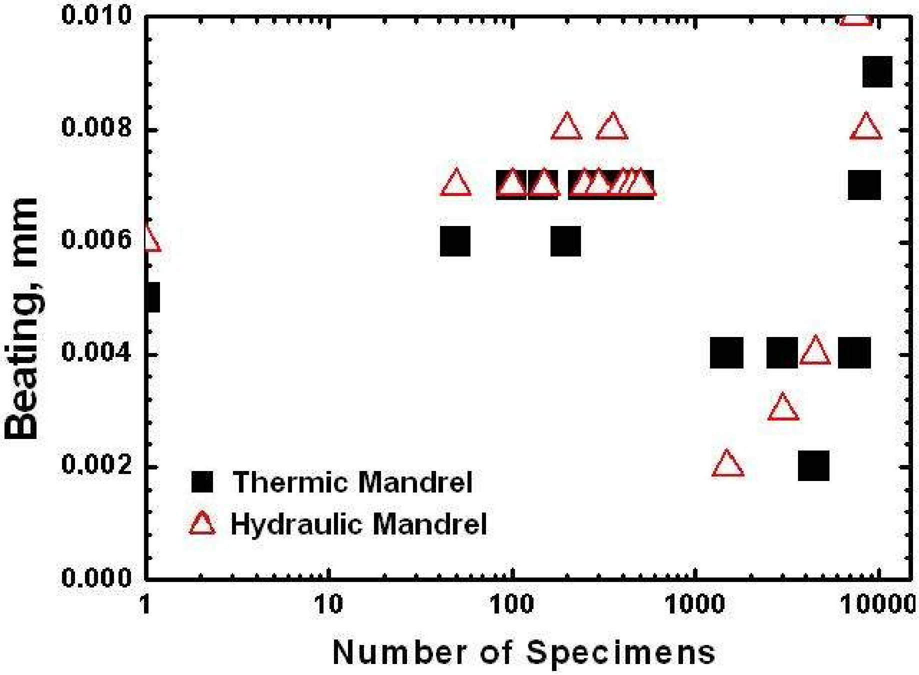
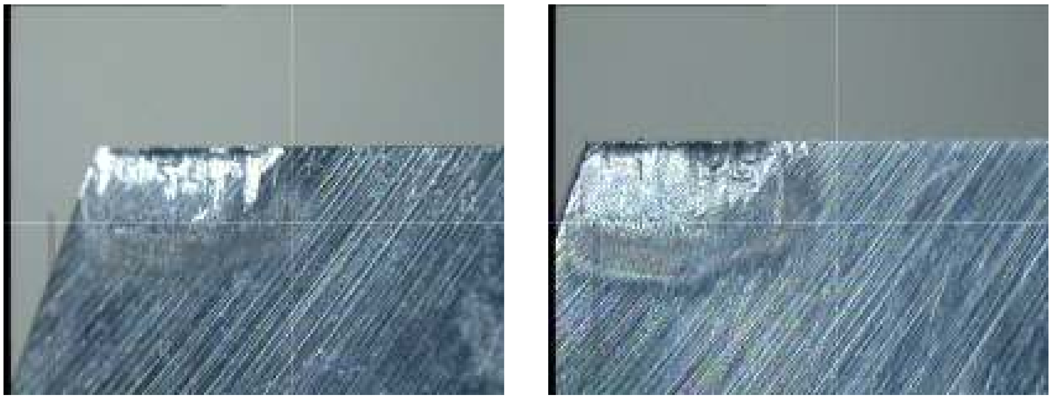


Figure 3. Evolution of the tool beating related to the number of machined parts until 11500.

It is verified that, the maximum beating of the thermal system was lesser then the hydraulic beating until the part 300 and after, hitched the value of 0.007 mm at the part 500. The error rising possibly occurred due to the tool replacement at the chuck seat, in reason of the group vibration. It could be observed that, the error evolution didn't experiment consistent growth with the number of machined parts, with the exception of the parts 3500 to 11500. The Fig. 4 shows the wear aspect verified on the drill flank in optical microscope for thermal and hydraulic systems on faces 1 and 2.



(a) (b)

Figure 4. Wear analyses VB_{max} of the faces 1 and 2 of the fixed drill on the hydraulic chuck

On Figure 5, the wear evolution is shown measured by the VB_{max} in function of the number of machined parts until 11500.

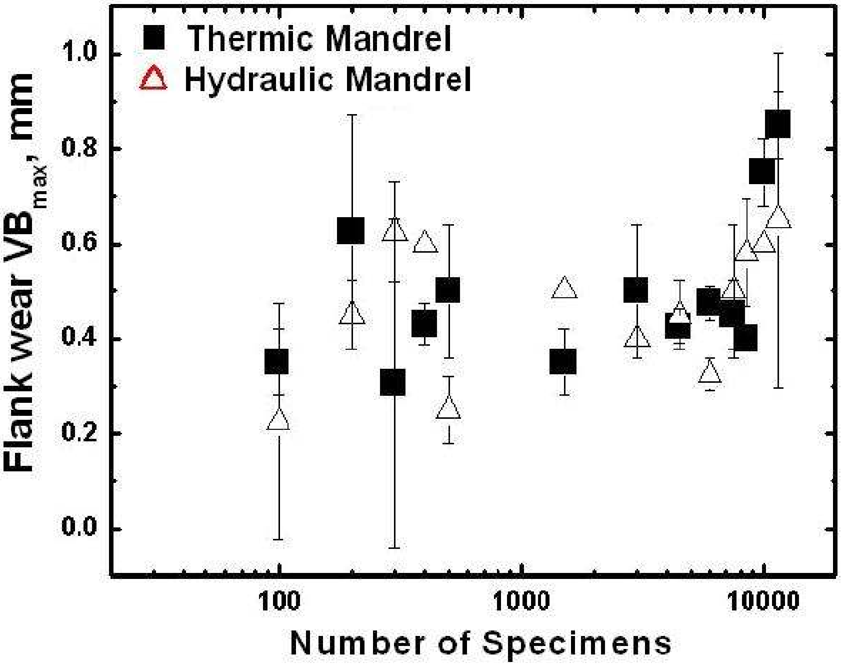
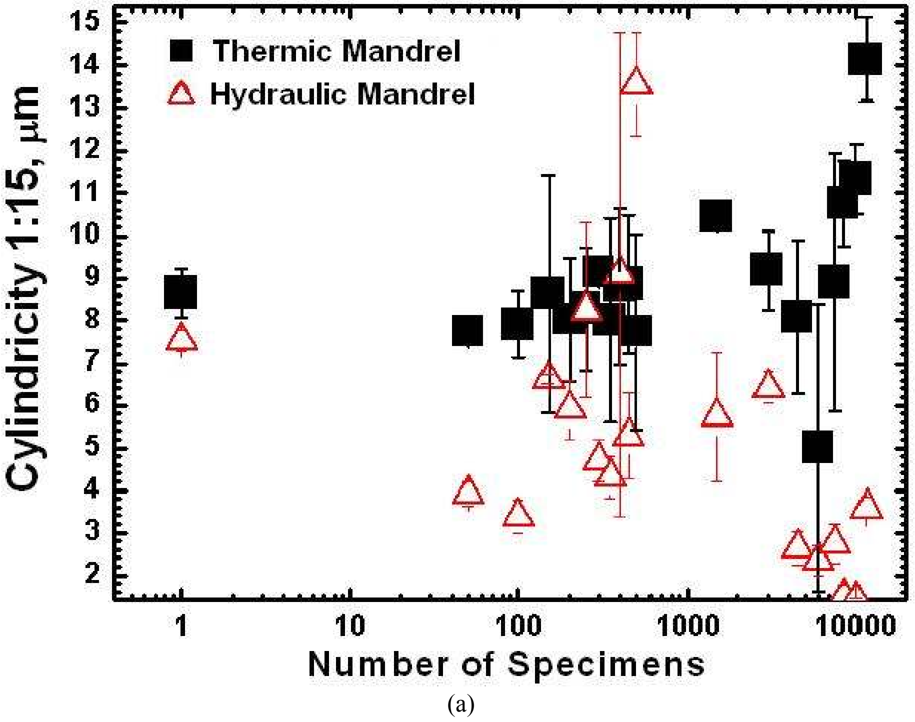


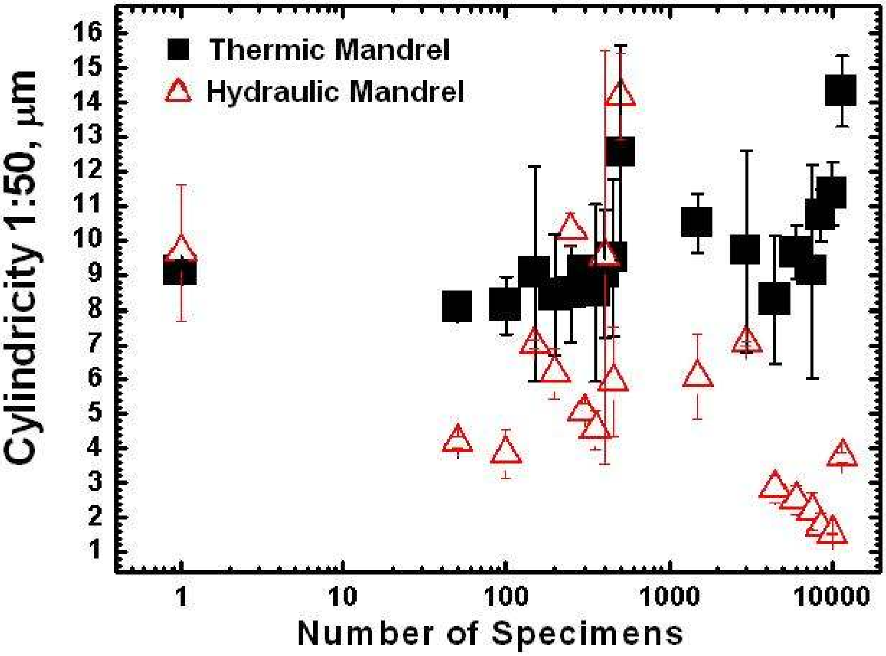
Figure 5. Analyses of the VB_{max} wear at the fixed drill of the cutting edge on hydraulic and thermal systems.

The wear value, for both systems, is practically constant between the parts 500 to 8500. From the part 8500 on, the rise of VB_{max} was verified for the hydraulic system. The aspect of VB_{max} curve in function of the number of parts shows similarity with Quick *et al* (2003) purpose, where three stages of the helical drill wear process exists, which are progressive lost, constant wear rate and catastrophic failure.

On Fig. 6 the cilindricity evolution is shown with two Gaussian filters, respectively 1:15 and 1:50 in function of the number of machined parts. The Gaussian filter 1:15 emphasizes the results dispersion in a bigger intensity when compared with the filter 1:50, though was verified that the filter 1:50 has presented itself in conditions of revealing the difference in cilindricity between both fixation systems, thermal and hydraulic.



(a)



(b)

Figure 6. Analyses of the holes cilindricity generated by the fixed drill on the thermal and hydraulic systems evaluated in the Gaussian filter 1:15(a) 1:50(b).

It also has been observed that, the thermal chuck presented medium values and standard deviation lower than hydraulic values. After the thousandth machined part, this discrepancy became more marked, what it hasn't been justified by the beating.

The Fig. 7 shows the circularity evolution with a Gaussian filter 1:50 in function of the number of machined parts. It also has been checked that, the best performance is of thermal system comparing with the hydraulic system.

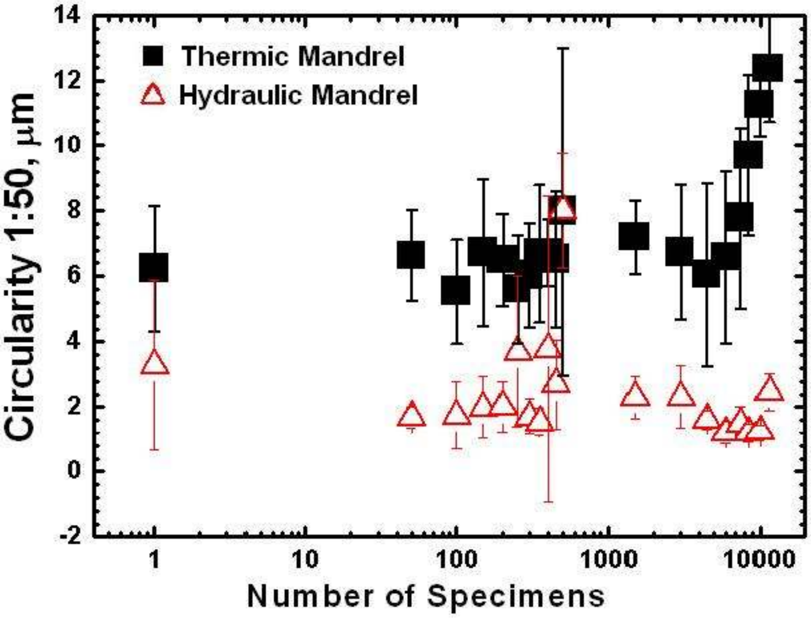


Figure 7. Analyses of the holes circularity generated by the fixed drill on the thermal and hydraulic systems evaluated in the Gaussian filter 1:50.

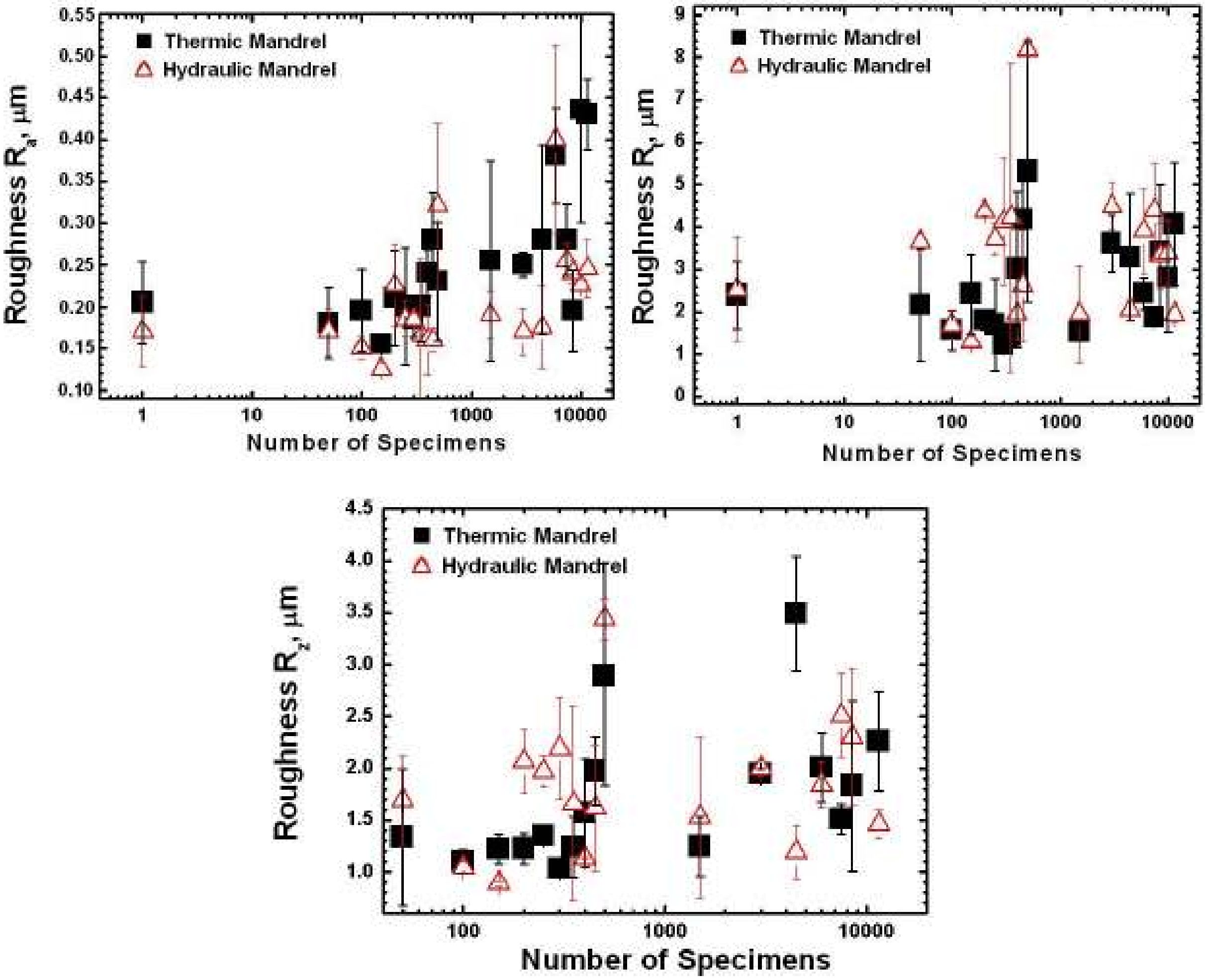


Figure 8. Surface analyses R_a, R_t, R_z of the generated holes by the fixed drill on thermal and hydraulic systems.

The average and dispersion of the analyzed surfaces through the parameters R_a, R_t and R_z for the thermal and hydraulic systems, didn't show marked variations until the part 250 with the average, respectively, of 0.3, 4 and 2 µm. The surface parameter R_a, evidenced that, during the process, the averages and standard deviations of the thermal system became emphatic for machined parts superior then 1500. The performance of these systems was compared through a result distribution to a 95% confidence level. Although the average test has confirmed that the thermal system is more efficient, a conclusion of the material influence adhered on surface parameters, wasn't possible.

It is possible that, the deposit of material on the drill have any interference on the quality of the surface parameters, once that, as observed on SEM, this deposit has irregular texture throughout the thickness and it changes during the drilling process.

The Fig. 9 shows the aspect of the surface of drill faces 1 and 2 on the scanning electronic microscope on different observation angles and increases of 160 and 250X for hydraulic system.

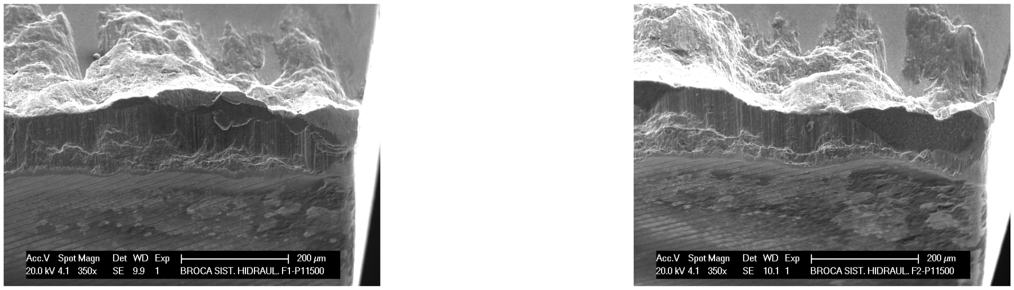


Figure 9. Presence of material parts on drill faces 1 and 2 of the hydraulic system part 11500

It is observed the presence of peaks and valleys throughout the thickness of wear region and the difference of this thickness value throughout the depth. The chemical analyses made on scanning electron microscope of the material present on the drill faces 1 and 2 of the fixation system after the part 500 showed the presence of Al and Si, as shown in Fig. 10.

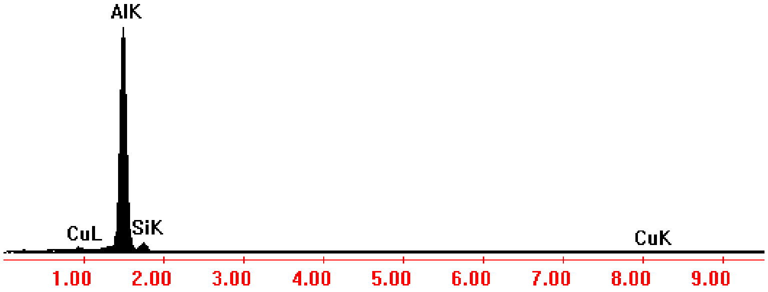


Figure 10. Chemical Analyses obtained by EDS on scanning electron microscope of the adhered material on the hydraulic chuck

The chemical analyses made on a distant region of the cutting edge on EDS showed the presence, as shown in Fig.11, of W, Si and Co (Figure 10).

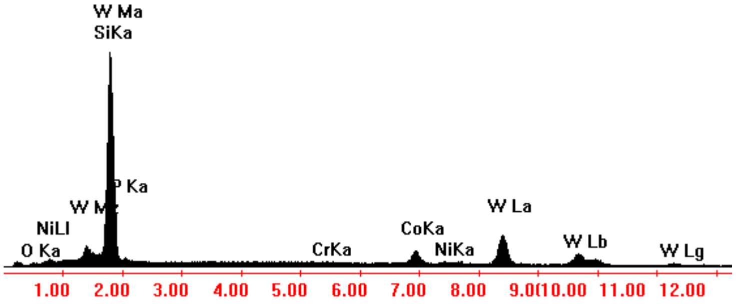


Figure 11. Chemical analyses of the hydraulic fixation system drill

The aspect on scanning microscope after etching the material with NaOH solution is shown on Fig. 12.

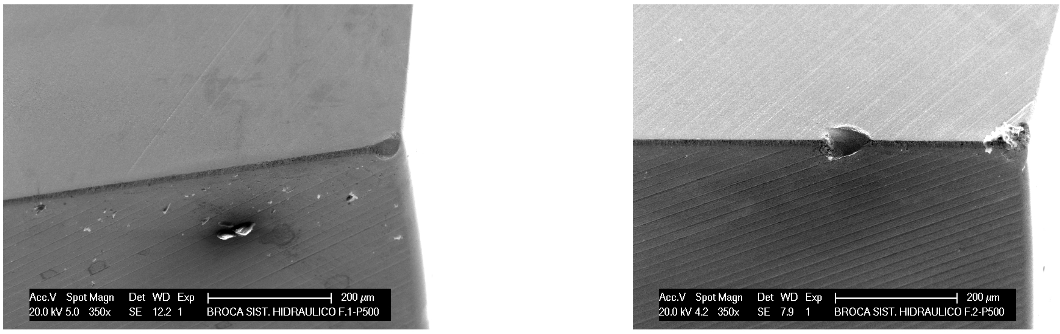


Figure 12. Wear of the drill cutting edge of hydraulic system after pickling with NaOH solution on faces 1 and 2 on the drilled part 500.

It is observed after the pickling, that a spalling happened on the cutting edge and no adhered material was present on the drill surface either on face 1 or 2. This spalling on the cutting edge didn't change the geometric parameters and the surface parameters when compared with thermal system. Figure 12 shows the chemical analyses by EDS on faces 1 and 2 of the fixed drill on hydraulic system after the pickling, using 10% of NaOH solution on distilled water during 24 hours.

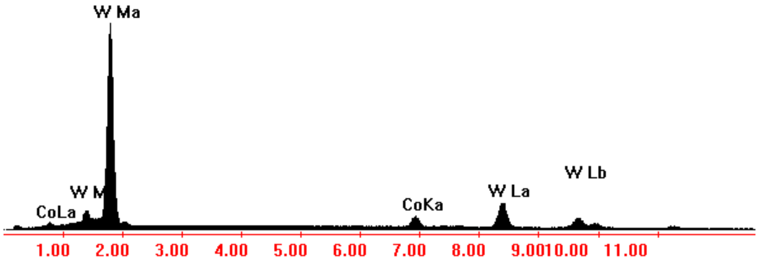


Figure 13. Chemical analyses after pickling on NaOH solution on the face of the machined part 500, with hydraulic fixation system.

It could be confirmed that the chemical analysis is representative of the drill material, it means, Co-WC. On Fig. 14 is shown the variation of the averages and standard deviation of the diameter generated by the fixed drills on hydraulic and thermal systems. It is observed that, the holes average is in agreement with the project specification 12.20 (+0.0 -0.1) mm. So, it could be possible to verify that, the beating error hasn't interfered on the dimensions of the hole. The heating signs with grooves on the cutting edge increased with spalling and craterization on the cutting edge, changing the diameter of the hole near to the specified superior limit (12.20 mm), what has contributed to delimit the drill life.

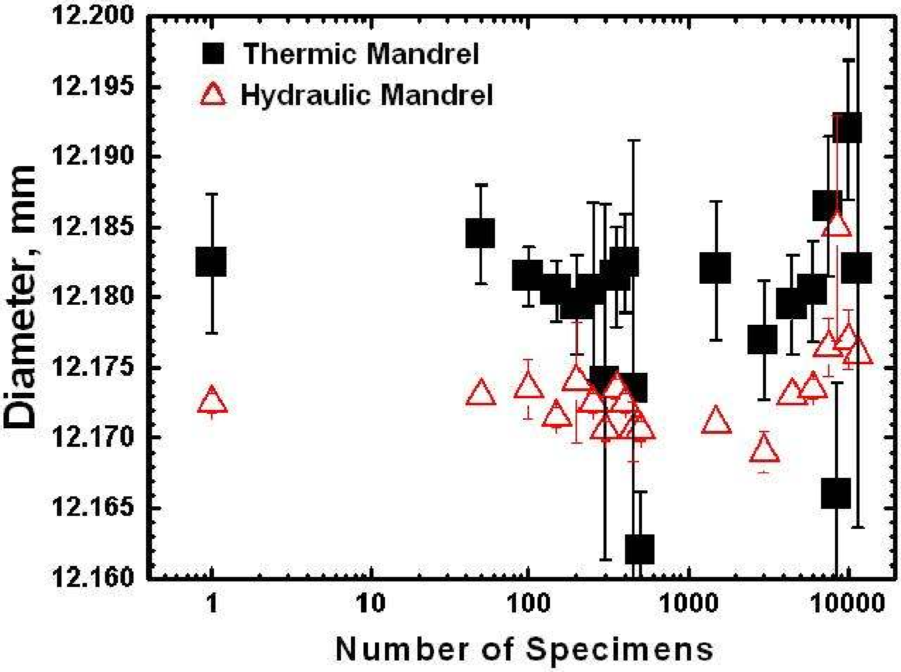


Figure 14. Reference bushing fixation hole diameter in function of number of parts.

4. CONCLUSION

The beating error didn't show evolution with the number of machined parts either for the hydraulic fixation system or for the thermal fixation system and also, didn't interfere on dimensions and texture of the obtained holes.

The cilindricity and circularity average and dispersion obtained by the hydraulic systems were bigger than the values obtained by the thermal system, which could evidence a bigger mounting stiffness by interference of thermal system.

The thermal fixation system produced surfaces with R_a average and standard deviation inferiors then those obtained through hydraulic system. It could be noticed that the variables R_t and R_z had a different behavior when compared with the roughness parameter R_a and the beating error didn't contribute for this abnormal result.

The wear evaluated by the thickness average on the flank didn't reveal the consistent growth with the number of parts either for the thermal system or for the hydraulic. This measurement had revealed as a non drill wear, but as an adhered material on the flank.

The machined parts elevation from 8000 to 11500 was found in reason of the non obtaining of the hole diameter above the project specification.

The wear thickness average observed on the part 11500 was 40.25 µm with 10.20 µm standard deviation

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