# STUDY OF DRILLING IN HIGH-SPEED CUT IN ALLOY Al-Si USING STEEL DRILLS FAST AND HARD METAL

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***Abstract**. New cutting tool technologies, geometries, materials and coatings applied on different substrates demonstrate an increased mechanical strength, also an improvement on over the fluidity on tool chip interface, and an increasement in cutting speed during the machining. Advanced characterization techniques are used to analyze tool substrate. In the automotive industry, steels and cast iron have been gradually replaced by materials of lower density, better machinability and better cost-effectiveness. Al-Si alloys have gained space and are used in heads, gearboxes and engine block. Holes are present in almost all automotive mechanical parts with different diameters and depths, making them necessary to be machined in the shortest possible time within narrow tolerance ranges, shape and roughness. This work evaluated the drilling of a die-cast Al-Si alloy using high-speed steel and carbide drill as tool. The cutting speeds were of 340, 360, 380, 430 m/min and feed rate was of 0.36 mm/rev. It was used pre-drilled parts removing 0.7 mm of overmold in diameter. The geometric evolution of the hole surface was evaluated measuring roughness parameters $R_a$, $R_z$ and $R_t$ for the cutting speeds of 340, 360, 380 and 430 m/min. Behavior of the fast steel drills presented good results in the machining process, at a speed of 430 m/min. Hard carbide drills showed good results at all speeds tested.*

***Keywords**: turning operation, machining, cutting fluid, glycerin, 1020 steel*

## 1. INTRODUCTION

The drilling process in the machining is used to obtain internal cylindrical surface, which is coaxial to the axis of rotation of the cutting movement, that can be considered as thinning, semi-finishing or finishing. Al-Si alloy drilling presents difficulties due to the adhesion of aluminum to the drill bit. The quality of a hole in the is determined by a synthesis of errors due to process dynamics and also to the thermal regime at the workpiece/drill interface, which also includes shape deviations such as circularity, cylindricity and surface roughness (Rosa, 2012).

According to Diniz et al. (2010), during the cutting a drill is subjected to torsional stress due to the rotation of the drill and the compression due to the advancement of the tool. Regarding the velocities used in the process, these will depend on the type of material machined and the type of operation performed (Schulz apud Christoffel, 2001). Helleno and Schützer (2003) emphasize that machining under high cutting speeds appears as a solution for the production of several types of parts, since the manufacturing time, cost and quality of the product are improved. According to some researchers, studies on the influence of shear velocity on surface roughness are beneficial for machined surfaces. Surface finishing is considered as one advantage attributed to machining with high shear rates, but it does not always occur completely according to Yousefi and Ichida (2000).

The cutting speed, the shear depth and the feed rate respectively indexed by $v_c$, $a_p$ and $f_n$ are the most important variables in this process. The cutting speed ($v_c$), is the instantaneous speed of the reference point of the cutting edge of the tool, according to the direction and the sense of cutting. For processes with rotational motion, the cutting speed is calculated by Equation I.

$$(I) \qquad v_c = \frac{N x \pi x \emptyset}{1000} \left[\frac{m}{min}\right]$$

Where $\emptyset$ is the diameter of the part (mm) or the tool, (N) corresponds to the number of revolutions per minute. The feed rate $f_n$ is the feed path at each revolution (mm/rev) or at each stroke of the tool. The cutting depth $a_p$ is the penetration depth or width of the tool in the part, measured in a direction perpendicular to the working plane (NBR6162

/ 1989). In drilling with helical drills, the stresses are related to drill geometry and process cutting conditions such as feed rate, cutting speed and rigidity of the part/machine tool set (ARENAS, 2003).

Aluminum alloys are used in various industry sectors because of their mechanical strength and low density. Another factor that favors the use of aluminum is its greater machineability. The addition of silicon to aluminum decreases its melting point and improves the wear resistance of the alloy. Al-Si alloys are used in the manufacture of components of combustion engines that require fluidity and a low contraction tendency in die casting. In the production of a engine head, for example, various machining operations are performed. During these processes the wear rate of the cutting tool is low because of the good heat conduction of the Al-Si alloy (Martins et al., 2015).

The machining process is nonlinear and involves some phenomena such as plastic deformation, fracture, impact, intermittent and continuous wear points and wear. It is characterized by heat generation and high cutting temperature. At high temperature, the cutting tool can quickly lose its shape or be wearied resulting in an increased shear strength, product dimensional inaccuracy, reduced life, mechanical and chemical damage to the finished surface (Martins et al., 2015).

The measurement is used to monitor, control or investigate a process and its result is a range of values associated with a unit of measure where the true value is within this range. The quality, safety and control of a process are ensured through this measurement. The imperfections contained in a surface can be measured with appropriate equipment and the importance of the surface finish increases, when the precision of adjustment between the parts increases. It should be noted that the actual engineering surfaces are composed of shape, curl and roughness and can be filtered in five stages. Actual surfaces with respect to macro and micrometric parameters are respectively, for example, circularity, cylindricity and roughness. The average roughness (Ra) can be expressed as the average deviation of a profile of its line or the average distance of a profile from its midline, over a mean length (Oliveira, 2004 and Martins, 2008).

The objective of this work was to study the behavior of the machining at high cutting speeds using fast steel drill and carbide in the drilling process, varying the cutting speed and analyzing the influences on the roughness parameters $R_a$, $R_q$ and $R_z$ and dimensional in an Al-Si alloy.

## 2. EXPERIMENTAL PROCEDURES

The raw material used in this work was an Al-Si alloy obtained in die casting in the form of an engine head for further machining. In the casting process, a specimen of the race was cast, which was later milled and cut for sample removal (30x30 mm) for chemical analysis after cleaning with compressed air.

Afterwards, the finishing was done in felt impregnated with diamond paste with dimensions of 7, 3 and 1 μm. The samples were analyzed by optical microscopy, Leitz brand, with an increase of 200X. For analysis of the microstructure, the samples were attacked with distilled water 95% by volume, hydrofluoric acid (HF) -1 ml, nitric acid- (HNO3) -2 , 5 ml, hydrochloric acid (HCl) -1.5 ml, for 5 hours. A Vickers microhardness test was performed in a microdurometer, Leitz brand, 100 gf load. Figure 1 shows the microstructure of Al-Si alloy:
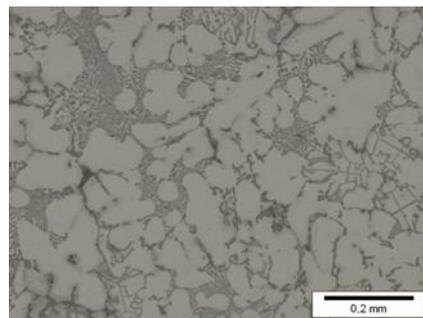


**Figure 1 - Al-Si alloy microstructure, evidencing the aluminum-rich clear phase and the eutectic**

**Table 1 - Mean chemical composition of Al-Si alloy, by weight percent**

| 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 |

Figure 2 (a) and (b) show the microstructure of the fast steel and hard metal in MEV that shows inter and intragranular precipitates in a martensite matrix.



**a) Analysis of the general structure of the fast steel**



**b) Analysis of the general structure of Hard Metal**
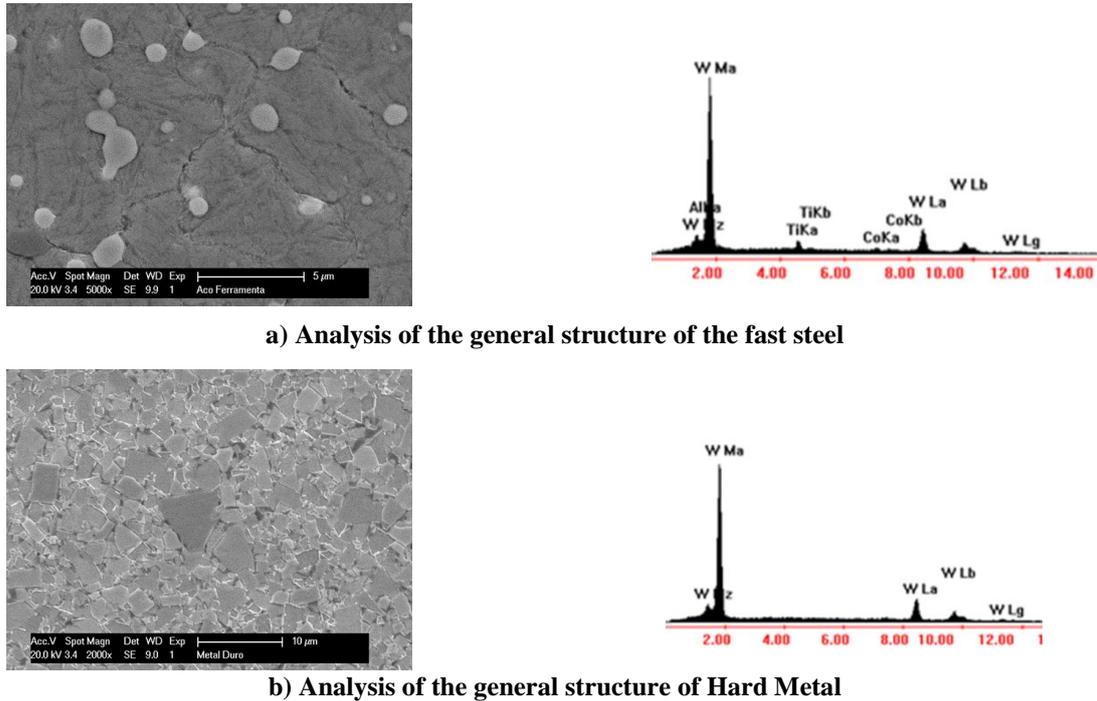
**Figure 2 - Microstructure and EDS of the fast and hard steel in MEV evidencing the presence of intra and intergranular precipitates in martensite matrix**

Figure 3 shows the hard metal drills (WC + Co) and fast steel with parallel rod, tolerance H7 and without cover, with two diameters tip angle 145º, clearance angle 10º, second diameter with tip angle 90º and angle (± 0.1) ^ (+ 0,0) mm and the hydraulic system used in the drilling tests of the Al-Si heads.
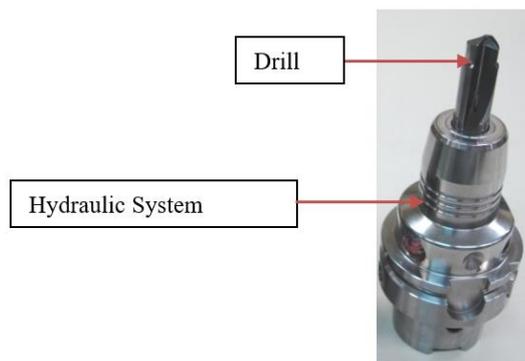


**Figure 3 - Hydraulic system with carbide drill and fast steel used in the machining of the holes**

The cutting fluid used was HOCUT® B 205D with a concentration varying from 6% to 8% by volume of water and a pressure of 30 bar. The holes had a depth of 8mm. After completing the drilling tests, the parts were cooled to room temperature and measured in the metrology laboratory.

It was taken the pieces of numbers 1, 150, 300, 450, 600, 750, 900, 1050 to 3100 for measuring the geometric parameters of cylindricity, circularity and hole diameter, respectively, were taken from the Talyrond 4 Coord Her A and Hera 3 coord.

The surface parameters $R_a$, $R_z$, and $R_t$ were evaluated for parts 1, 150, 300, 450, 600, 750, 900, 1050 through 3100 using Taylor Hobson Form-Talysurf series equipment and Gaussian roughness, cut-off of 0.8 mm, and length 4.8 mm. The tolerance of $R_a$ 3.2 µm from the hole surface was controlled through software specifically developed for this analysis.

## 3. RESULTS AND DISCUSSIONS

In Figure 4 (a), (b) and (c) show the behavior of the surface texture evaluated by $R_a$, $R_t$ and $R_z$ with the number of pieces and the cutting speed variations (340 m/min, 380 m/min and 430 m/min). It was verified that, as the cutting speed increased, the behavior of the parameters $R_a$, $R_t$ and $R_z$, obtained lower values at the beginning of the machining of the first pieces.

For the cutting speeds (380 m/min and 430 m/min), the behavior was similar with smaller values of $R_a$, $R_t$ and $R_z$ when compared to a speed of 340 m/min. This phenomenon occurs due to the reduction of the contact of the cutting edge of the tool on the machined surface of the part.
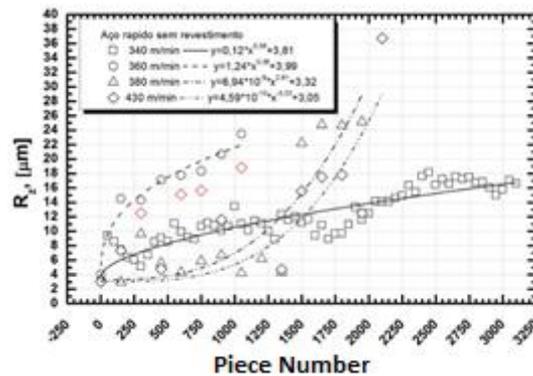
However, the increase in speed raises the temperatures at the interface, tool part, thereby accelerating the wear level of the tool which reduces the values and parts produced. For Diniz, Marcondes and Coppini (2013) the main factors influencing surface roughness are: tool tip radius, feed rate and cutting speed.
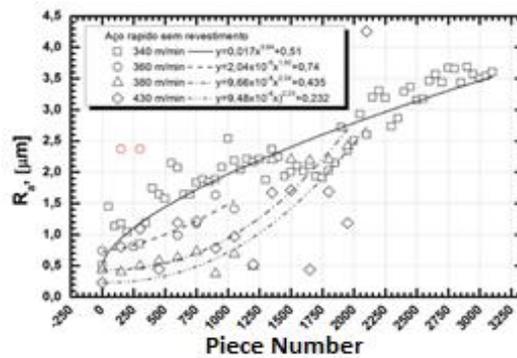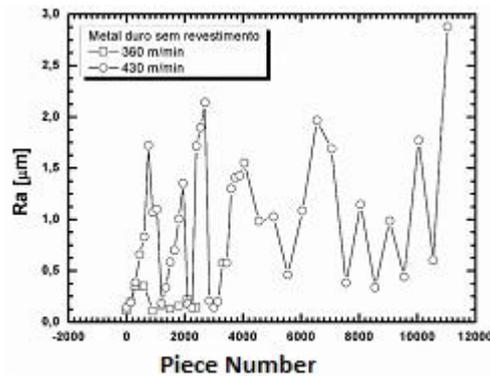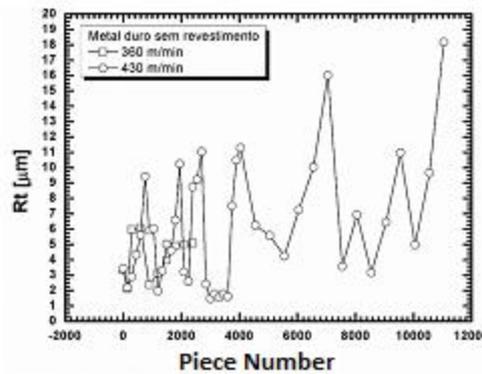


a)
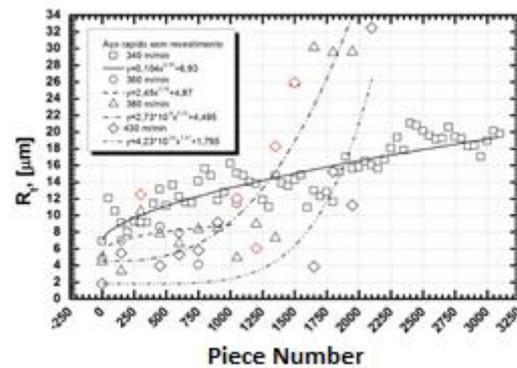


b)



c)

**Figure 4 - (a, b and c) Analysis of the surfaces $R_a$, $R_t$ and $R_z$ of the holes generated by the fast steel bit at the cutting speeds (340, 380 and 430 m/min)**

In the Figure 5 (a), (b) and (c) is shown the evolution of the surface parameters $R_a$, $R_t$ and $R_z$ in the machining of holes using carbide drills. The surface parameter Ra shows that, throughout the process, they are dispersive with higher frequency in the cutting speed of 430 m/min. The difference between the two speeds is by the number conditions of produced parts, that is, at the cutting speed of 360 m/min the number was lower due to machine availability to be realized.



(a)



(b)
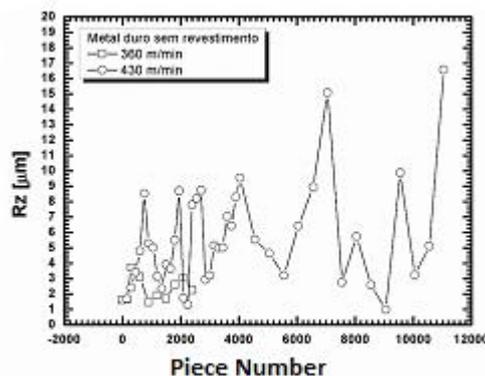


(c)

**Figure 5 - Analysis of the surfaces $R_a$, $R_t$ and $R_z$ of the holes generated by the carbide drill without DLC film at the cutting speeds of (360 and 430 m/min)**

## 4. CONCLUSIONS

It was analyzed the behavior of the surface texture evaluated by $R_a$, $R_t$ and $R_z$ with the number of pieces and with the cutting speed variations (340 m/min, 380 m/min and 430 m/min). It was verified that, as the cutting speed increased, the behavior of the parameters $R_a$, $R_t$ and $R_z$, obtained lower values at the beginning of the machining of the first pieces.

For the cutting speeds (380 m/min and 430 m/min), the behavior was similar with smaller values of $R_a$, $R_t$ and $R_z$ when compared to a speed of 340 m/min. This phenomenon occurs due to the reduction of the contact of the cutting edge of the tool on the machined surface of the part.

Surface parameters $R_a$, $R_t$ and $R_z$ in the machining of the holes using carbide drills. The surface parameter Ra shows that, throughout the process, they are dispersive with higher frequency in the cutting speed of 430 m/min. The difference between the two speeds is due to the conditions of the number of parts produced, that is, at the cutting speed of 360 m/min.

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