STUDY OF ALUMINUM USINABILITY THROUGH THE METHOD OF CONSTANT PRESSURE IN DRILLING, BY USING VEGETABLE LUBRICANT FLUID

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Abstract. The drilling process is a quick, low cost and simple machining process that is widely used in industry. Improper use of drilling tools can lead to collapse during machining. In this way, it is important to carry out studies to analyze how changes in input parameters can reflect drill performance and machinability. The productivity in the drilling process is significantly dependent on the geometry of the tool, as well as the cutting fluid used. For this process to be carried out, it is also important to know the material to be machined. In this sense, this work aims to show the machinability of aluminum, submitted to a drilling process using the constant pressure method under dry and vegetable fluid conditions. The tests were carried out obeying a factorial planning 2^4, which means to use four variables and two levels of variation for each of them. It was also used HSS drills with 10 mm diameter, 110° and 125° tip angles, and two constant pressure values, 10 and 14 kgf under two rotational speeds, 270 and 580 RPM. In addition, it was used dry and vegetable fluid (soy oil) conditions. Through the tests, it is noticeable that independent of adding fluid or the drill bit angle there is a tendency to increase the penetration in the hole with the increase in rotation velocity. Besides that, increasing the force used provokes an increase in penetration. Understanding how changes in parameters affect the machinability of aluminum in drilling results in the possibility of generating a more efficient drilling process.

Keywords: Aluminum, Drilling, Machining process, Vegetable Fluid.

1. INTRODUCTION

The industries are always trying to improve their processes, final products, and also to reduce costs. In the machining field, there are several industries that invest in research, seeking to make their process more efficient. The drilling process is one of them due to its widespread use in industry.

According to Ferraresi (1970) drilling is a cutting process that permits to obtain holes in a workpiece through a multi cutting tool. In this process, the tool or part moves along a rectilinear path coinciding or parallel to the main axis of the machine.

To study the drilling process, one of the types of tests that can be used is the constant pressure. Mills and Redford (1983) state that the constant pressure test consists of maintaining a constant advance force and to take measurements of the time necessary to machine a predetermined distance, then to obtain the range with which will be used as the machining parameter of the material. This is a short test.

It is always important to select the right type of drilling tool for the material to be drilled because it avoids low efficient process or even potential tool failure. Beltran (2011) consider that HSS polished tip drills are excellent for non-ferrous metals and can be used in aluminum, copper, brass, zinc and unalloyed steel. As the material in the study of this work is aluminum, the drill bit chosen is the HSS type. Besides that, according to Amorim (2007) the angle of the drilling tool is also important in the drilling operation, because it helps in the detachment of the chip. The harder the material, the smaller the propeller angle should be. Larger propeller angles are recommended to facilitate chip removal. In this work, the use of two propeller angles (110° and 125°) of a HSS drill bit during the drilling process of aluminum will be analyzed.

Amorim (2002) also claims that several factors may influence machining of the tool, the most important is the chemical composition (alloying elements) and the properties of the material to be machined.

According to Ferraresi (1970), when comparing the ferrous metals, aluminum and its alloys are easier to machine materials. They have lower specific cutting pressures and high cutting speeds, feed rates, and large chip production. Due to its high thermal expansion rate, machined aluminum must always be kept cold if its dimensions are to be controlled correctly.

Zeilmann (2002) believe that worldwide trend is cutting-free (dry) machining, because it aims to significantly reduce costs with the purchase of cutting fluids and their final destination. Besides that, this would reduce the

occupational problems such as skin diseases and respiratory issues, and environment-related problems, where the cutting fluids become severe pollutants of water, soil and air.

CIMM (2009) affirm that cutting fluids are indispensable for machining: improving finishing, reducing friction, cooling tool and part, reducing mist and others. When fluids are not used, issues usually happen such as temperature, yield, and process accuracy can be compromised. When cutting hard materials, cutting fluids are usually developed with strong elements - such as chlorine, phenols, metals, etc. One of the major industrial challenges is to use a cutting fluid that is both productive, safe and environmentally friendly.

Davin (2008) states that the cost of machining amounts to more than 15% of all manufacturing processes. Because of this, the machining process, as an element of manufacturing science and technology, is very important to modern manufacturing industries.

2. MATERIALS

The materials used in the test were the following:

1) The drilling tests were performed on a drilling machine (model: GHD-35B, serial no. 3512012006, motor (Kw): 1.8 and 2.64 (60Hz), rotation (RPM): 86.4 a 3120, in which it was fitted with a 14 kg weight system and a 10 kg weight system, attached to the base of the lever forming a pulley to characterize a constant pressure drilling test, as shown in the figure below.

Figure 1 - Column Drill with constant pressure system adapted

Source: Authors

2) The specimen used was an aluminum sample, with a cubic and massive shape;

Figure 2. Aluminum workpiece

Source: Authors.

3) Also used were HSS (High Speed Steel) propeller drill bits without coating. The diameter of the bits were 10 mm and propeller angles of 110º and 125º;
4) To measure the tip angle of the drills, a Profile Projector was used;
5) A measurement level was used to correctly align the drill bit in the workpiece;
6) A caliper of 0.05 mm precision was used to measure the penetration of the drill in the steel sample;
7) To produce the constant pressure, two different loads were used, one with 14 kg and one with 10kg;
8) Vegetable oil;
9) Drill sharpening machine.

3. METHODS

The first step was the selection of the aluminum test specimen, for a maximum use of the sample was chosen a format that had a flat surface. Then, the type of drill bits that were proper for the testing were chosen, which was a 10mm diameter High Speed Steel. Subsequently, the Profile Projector was used to measure the tip angle of the drill bits. Once this was done, the drill bit was positioned on the drill, the workpiece on the walrus and the table on right position for the drilling process. Two cutting speeds (270 and 580 RPM) were used. In order to promote the constant pressure force, a load of 10 kg and a load of 14 kg were attached by a steel cable and positioned on the feed lever, forming a pulley separately for the tests.

Tests and retests were done for each condition, each of them with a time interval of 10 seconds. After that, an average for the penetration values was taken for each condition.

For the test, four cut-off parameters were defined as input variables: Cutting speed (RPM), two drill angles, mass variation, and addition of vegetable fluid. It was considered a 2^4 factorial planning that were two levels of variation of the four variables relative to the cut conditions, which results in 16 experiments. When considering one test and one replicate, it will be 32 tests in total. Figure 3 illustrates the experiment.

Figure 3. Machined workpiece

Source: Authors

4. RESULTS AND DISCUSSIONS

The penetration average values and their conditions and parameter were arranged in following table 1:

Table 1. Experiment testing data

Testing Table								
Experiment	Angle (Drill bit)	Rotation (RPM)	Mass (Kg)	Test time interval (s)	Cutting Fluid	Penetration		
						Test	Retest	Average
1	110	270	10	10	Dry	5,1	5	5,05
2	110	580	10	10	Dry	6,1	6	6,05
3	110	270	14	10	Dry	5,3	6	5,65
4	110	580	14	10	Dry	12,8	12	12,4
5	125	270	10	10	Dry	3	2,7	2,85
6	125	580	10	10	Dry	4,2	4,5	4,35
7	125	270	14	10	Dry	3,7	3,8	3,75
8	125	580	14	10	Dry	7,6	7,8	7,7
9	125	270	10	10	Soy	2,4	2,4	2,4
10	125	580	10	10	Soy	3,7	3,5	3,6
11	125	270	14	10	Soy	3,5	3,2	3,35
12	125	580	14	10	Soy	6,2	6,3	6,25
13	110	270	10	10	Soy	2,3	2,2	2,25
14	110	580	10	10	Soy	3,3	3,5	3,4
15	110	270	14	10	Soy	4,6	4,4	4,5
16	110	580	14	10	Soy	6,4	6,7	6,55

Source: Authors

Through this table data, it permitted to generate some graphics that were used to analyze the relation between the input parameter and conditions with the results.

Graphic 1 shows the penetration in mm as a function of the rotational speed (RPM), with 110° tip angle drill and constant pressure system with 10 kgf. In this graph, it reveals the increasing penetration with the increasing rotation speed from 270 to 580 RPM. The tests performed with vegetable cutting fluid had lower penetration values compared to the dry process due to the cutting fluid creating a liquid "puddle" between the drill and the workpiece, so the drill skids at the beginning of the operation in an attempt to cross the fluid layer. In the 10 second interval, the drilling is delayed because of the fluid layer. It is observed that for a longer period of time the performance of the tool improves.
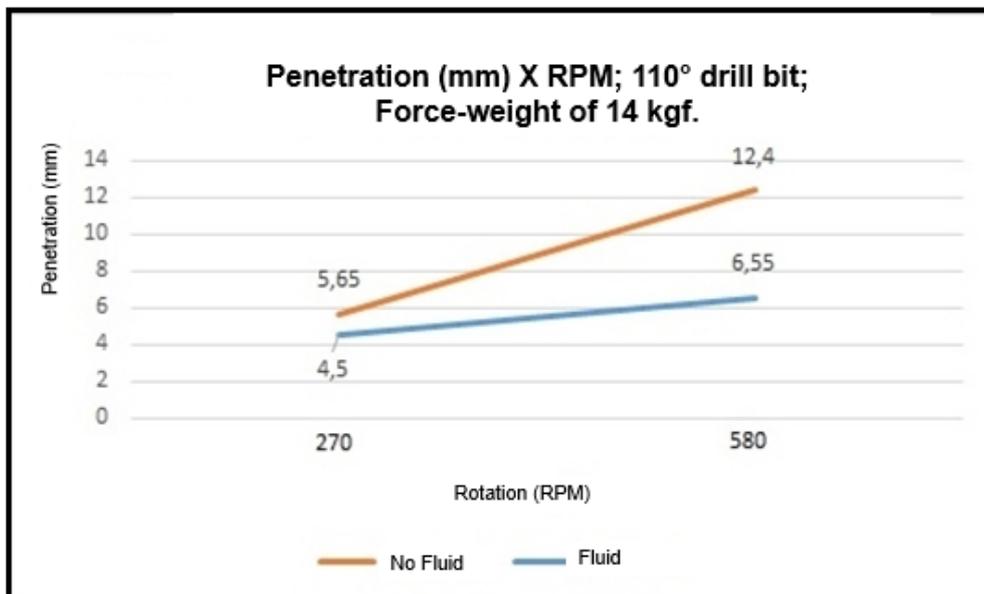
Graphic 1. Penetration (mm) X RPM; 110° drill bit; Force-weight of 10 kgf.
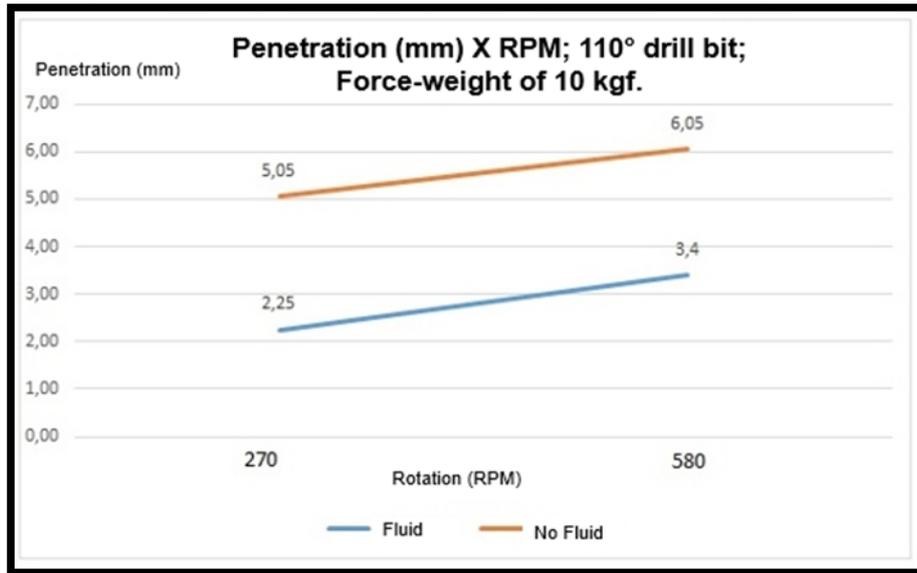
Source: Authors

The graphic 2 shows a penetration (mm) as a function of the speed of rotation (RPM), with 110 ° tip angle drill and constant pressure system with 14 kgf. It reveals that an increase in penetration with the increase of rotation speed from 270 to 580 RPM as expected. It happens inversely with dry cutting and with vegetable fluid, the dry cut is more superior to the other one. With the increase of the force-weight used (from 10 kgf to 14 kgf), there is an increase in penetration because the pressure on the area is greater. In both cases a combination of the 110 ° angle effect with the dry cut gave better performance than in the vegetable fluid cutting condition.
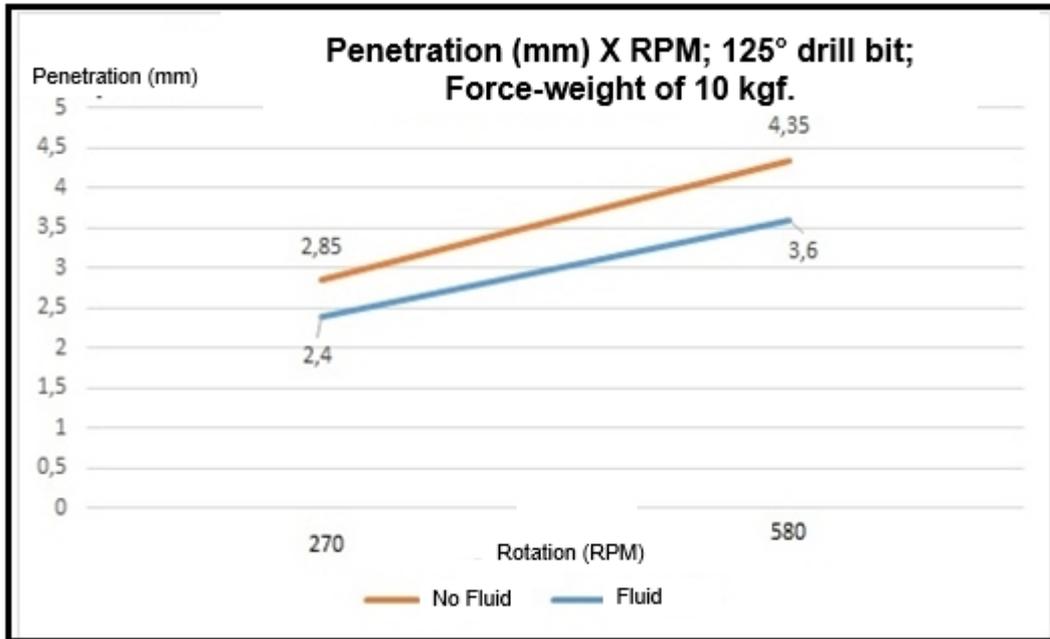
Graphic 2. Penetration (mm) X RPM; 110° drill bit; Force-weight of 14 kgf.

Source: Authors

The Graphic 3 is the penetration as a function of rotation (RPM), with tip angle drill 125º and constant pressure system with 10 kgf. This graphic reveals that the penetration increases with increasing RPM. It is also observed that the addition of vegetable cutting fluid resulted in lower penetration values than when dry drilling was done. This fact happened because the tip geometry of the 125 bit combined with the effect of the fluid hinders the cutting in the beginning of the penetration.

Graphic 3. Penetration (mm) X RPM; 125° drill bit; Force-weight of 10 kgf.

Source: Authors

The graphic 4 shows the penetration in mm as a function of the rotational speed (RPM), with tip angle drill 125º and constant pressure system with 14 kgf. Even with the change of the 125º angle drill, it is evident that penetration increases with increasing RPM. The addition of vegetable fluid results in lower values compared to dry drilling. The addition of vegetable cutting fluid combined with the tip geometry of the drill made the initial penetration of the drill bit difficult, thus obtaining smaller results compared to dry conditions.
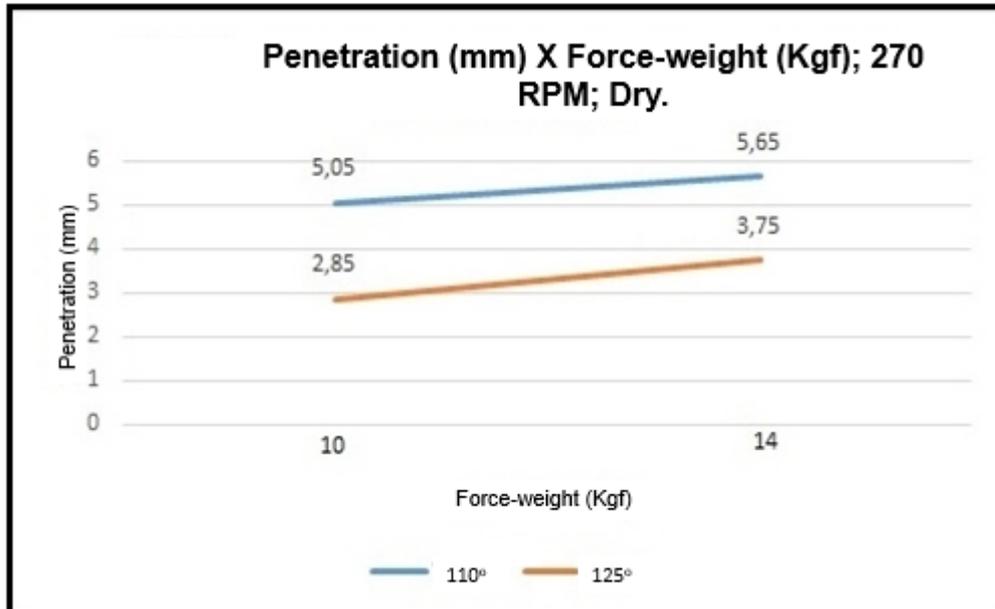
Graphic 4. Penetration (mm) X RPM; 125° drill bit; Force-weight of 14 kgf.
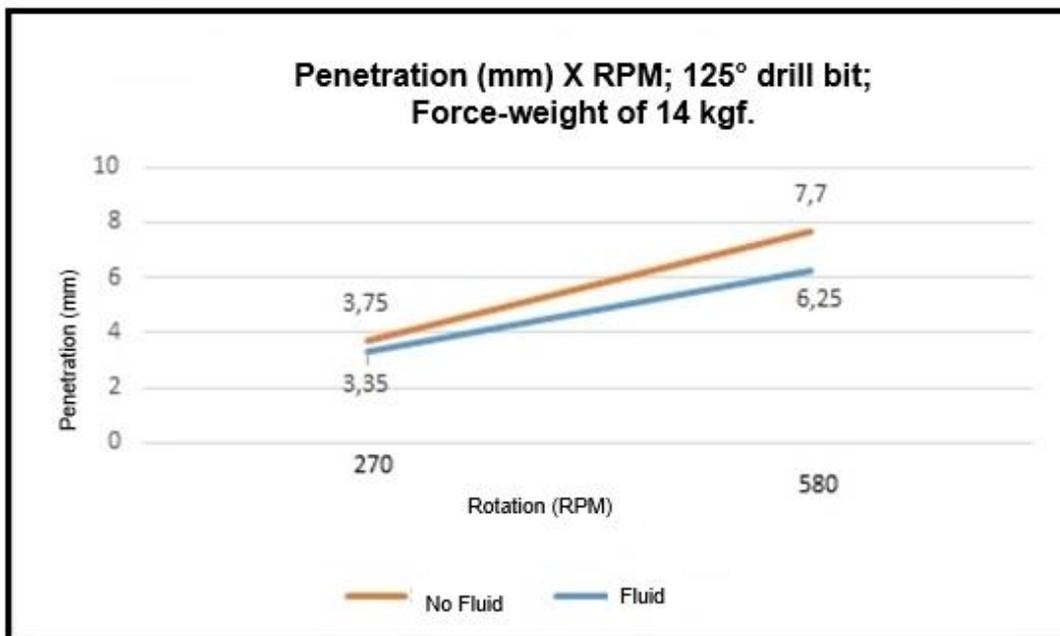
Source: Authors

Figure 4 shows the penetration in mm as a function of the force-weight (kgf) of the constant pressure system made in dry condition at 270 RPM. The contrast obtained from the different drills 110 ° and 125 ° was analyzed in this graph. It is observed that there was an increase in penetration with the increase of force-weight from 10 kgf to 14 kgf. We can also observe that the drill of 110º obtained a better performance than that of 125º, but it varied little from one force-weight to another, this is due to the low rotation imposed in this comparison.

Graphic 5. Penetration (mm) X Force-weight (Kgf); 270 RPM; Dry.
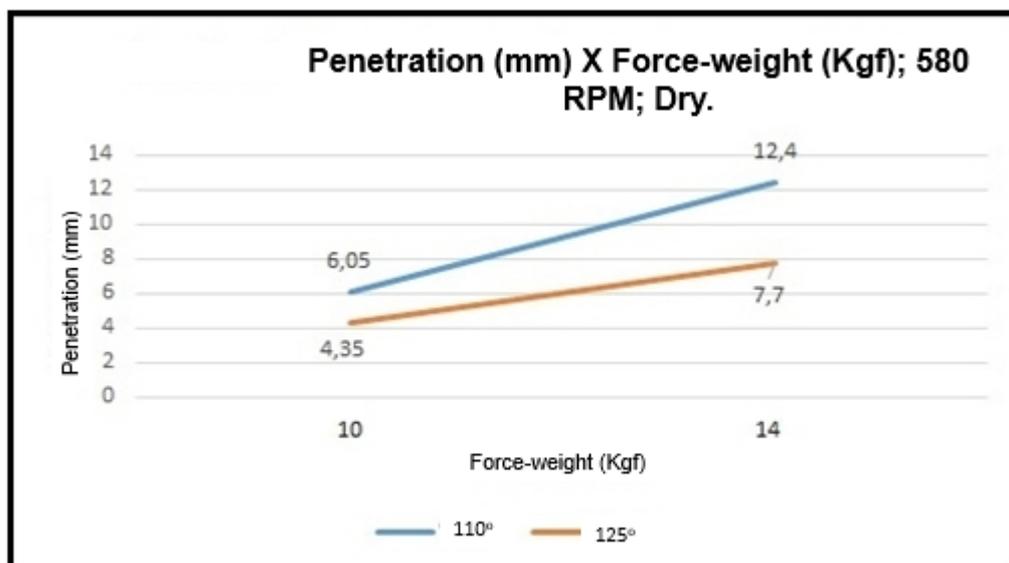

Source: Authors

The following graphic 6 shows the penetration in mm as a function of the force-weight (kgf) of the constant pressure system made in the dry condition at 580 RPM. The contrast obtained from the different drills 110 ° and 125 ° was analyzed in this graph. It is observed that there is a similarity with the tendency of graphic 5, since there was an increase of the penetration with the increase of force-weight of 10 kgf to 14 kgf, as well as there was greater drilling using the drill of 110 ° in both weights.

There was a significant variation with the increase of force-weight, reaching values of penetration almost twice as much as the previous situation (Graphic 5). This is certainly due to the increase in rotation.
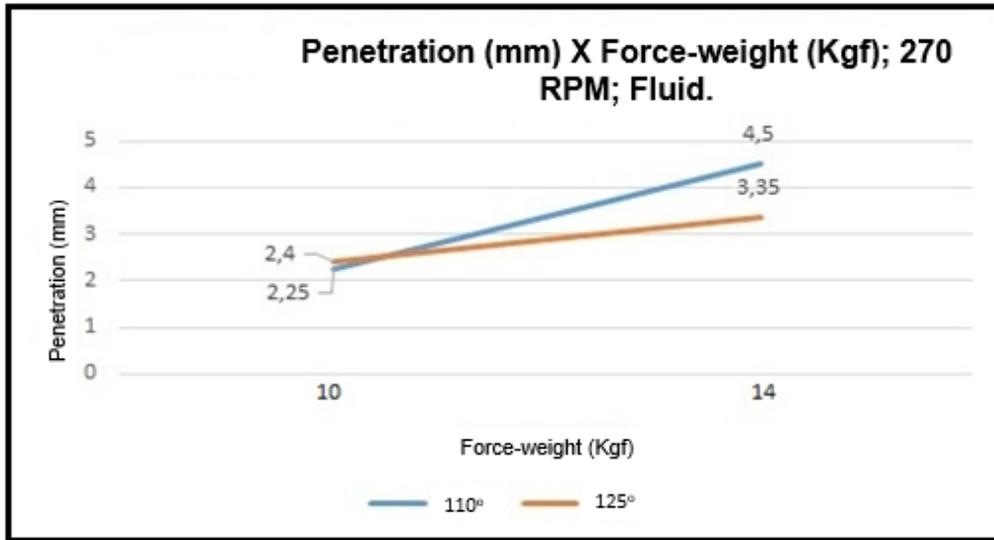
Graphic 6. Penetration (mm) X Force-weight (Kgf); 580 RPM; Dry

Source: Authors

Graphic 7 shows the penetration in mm as a function of the force-weight (kgf) of the constant pressure system made with vegetable cutting fluid at 270 RPM. The contrast obtained from the different drills 110 ° and 125 ° was analyzed in this graph. It is observed that there was an increase in penetration with the increase of force-weight from 10 kgf to 14 kgf, but we can observe that in this specific case the drill of 125° was a little better than the 110° when the force-weight was at 10kfg, but then it suffers low variation with the increase of force-weight, which makes the 110º drill performs better in the 14kgf condition, in this particular cutting condition.
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Graphic 7. Penetration (mm) X Force-weight (Kgf); 270 RPM; Fluid
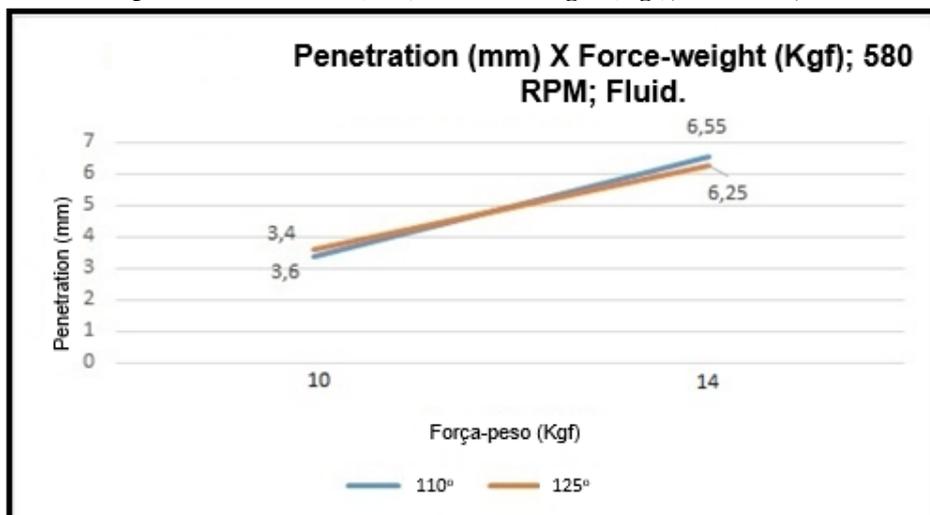

Source: Authors

The 110 ° drill bit, because of the nature of its geometry, has an initial penetration potential greater than 125 °, but as explained above, the vegetable fluid created a layer between the drill and the sample, causing a slight delay in drilling and compromising the performance of the two drills.

Graphic 8 shows the penetration in mm as a function of the force-weight (kgf) of the constant pressure system with fluid and 580 RPM. The contrast obtained from the different drills 110 ° and 125 ° was analyzed in this graph. It is observed that this graph has similarities with graphic 7, since there was an increase of the penetration with the increase of force-weight of 10 kgf to 14 kgf, as well as there was the variation between the two drills in the force-weight situation 10kgf where the 125 ° drill bit has a better performance compared to a 110 ° drill bit. In this case of addition of vegetable fluid, the results were lower than the figure 6 which we have the same parameters, but without the addition of fluid. It is also possible to observe a small advantage of the drill of 110º in relation to the drill of 125º with the increase of force-weight, this is due to the geometry of the drill of 110º to present larger surface of gap and edge, being able to reach a greater depth than that of 125 °. Therefore, with the most incisive angle drill, better results were obtained.

Graphic 8. Penetration (mm) X Force-weight (Kgf); 580 RPM; Fluid

Source: Authors

5. CONCLUSIONS

Through the sequence of tests performed with all combinations of predetermined parameters it can be concluded that regardless of the addition of fluid or the tip angle of the bit, there is a tendency of increasing penetration with increasing rotation speed. It is also worth mentioning that with the increase of the forces used, there is an increase in penetration.

The addition of the vegetable cutting fluid during machining with the 110° bit showed lower penetration values compared to the dry process, due to the cutting fluid creating a puddle between the bit and the surface, causing a certain delay in the machining and impairing tool performance. It can also be observed that the machining with the 125 ° dry drill obtained higher values of penetration compared to the cutting fluid, because tip geometry of the 125 ° drill combined with the effect of the fluid makes difficult the beginning of the penetration, that with the use of the fluid, tends to decrease the penetration with respect to the dry condition.

In relation to the tip angle of the drill, it was observed that using the 110 ° drill bit in the dry condition showed higher penetration values compared with the use of the 125 ° drill. This may be due to the drill of 110 ° being more incisive, having an edge and a clearance surface greater than 125 °, and is closer than is recommended for drilling aluminum, which rotates around 100°. This allows for a greater penetration into the dry condition. While observing the tip angle of the drill with the addition of cutting fluid, the 110 ° drill bit outperformed the 125 ° since the drill of 110 °, by the nature of its geometry, has an initial penetration potential greater than that of 125 °. This makes it easier to penetrate when the cutting fluid is added.

It can be concluded that according to the results obtained, to achieve higher penetration values in both dry and fluid addition, the use of the drill with a 110 ° tip angle is indicated. This matches with the information found in several catalogs of recommendation. The best combination of parameters for aluminum cutting was dry machining with a rotation of 580 RPM, using the 110º drill bit with the constant force of 14kgf.

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