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STUDY BETWEEN DOWN-MILLING AND UP-MILLING IN ABNT 1020 STEEL SURFACE FINISH

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Abstract. Two test specimens of ABNT 1020 steel were machined in order to evaluate the results of the arithmetic mean deviation and temperature output parameters, varying the cut-off direction between up-milling and down-milling frontal. Realization of 10 passes in each body of evidence corresponding to each movement. The test was performed without cutting fluid and new cutting edges were used for each test specimen. The following cutting parameters were used: depth of cut (ap) of 1mm, feed per tooth (fz) 0.12 mm / edge, cutting speed (vc) 160 m / min, penetration of work (ae) 30 mm and diameter of the cutter (Dc) of Ø 63 mm. The tool applied to the tests was a Ø 63 mm milling cutter with 5 uncoated cermeted carbide tool of class P 25-40. At each pass for both movements the mean arithmetic deviation was recorded and the temperature was monitored during milling. For arithmetic mean deviation the up-milling movement had lower values in relation to the down-milling, in the temperature parameter the down-milling movement presented lower values when compared with the up-milling.

Keyword: Milling, up-milling, down-milling, temperature and roughness.

1. INTRODUCTION

The milling process is widely used in the metalworking industry because of its versatility and excellent performance in the machining of parts of the most different profiles and guaranteeing excellent rates in the removal of material. The machining operation involves many more variables when compared to other machining processes, such as turning for example. For this reason a thorough study on this subject is necessary. For "Ferrarezi (2000)" milling is a mechanical machining process to obtain any surface with the help of a tool that is usually multi-cut. The milling operation occurs in two different cutting directions, in the up-milling and down-milling movement, the difference between these two influences several factors in the machining, such as tool wear, material roughness, temperature, shearing force and presents a direct relationship with the machine gaps "Dib et al., (2015)". In the corresponding movement, the cutting speed and the feed speed occur in the same direction of advance, the cutting edge when penetrating the part causes the cutting thickness to be maximum and continues cutting until reaching a value equal to zero "Chigbogu, (2013)", for this movement the temperature generated are smaller due to the way in which the tool penetrates the material which is beneficial to the tool. Experimental results from "Toh, (2005)" showed that the surface temperature of the chip produced in the down-milling movement was generally lower compared to milling up-milling. Bad for the finish of the piece becomes detrimental, this is because when it comes to machine with slack this movement tends to increase it causing vibrations and damaging the finish. For the up-milling, the cutting speed occurs in the opposite direction of the cutting advance, with the cutting thickness progressively increasing from zero to a maximum value "Chigbogu, (2013)". In this movement, higher temperatures are found when compared to the movement, resulting in greater tool wear. This is due to the high friction at the beginning of the machining that occurs great heat generation. In the experimental test performed by "Hadi et al. (2013)" showed that the up-milling movement significantly affected the tension distribution during the removal of the material and also in the cutting performance, resulting in acceleration of the tool flank wear. On the other hand, when working with a machine with relative clearance this movement tends to attenuate the gap in the

machine, an opposite effect that happens in the matching movement, thus contributing to a good finish. Figure 01 demonstrates the up-millinging and down-millinging.

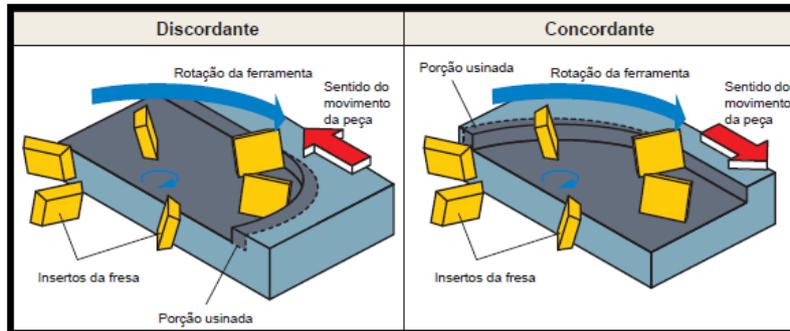


Figure 01. Moviment up-millinging and down-millinging (Catalog Mitsubishi,2015)

As in the machining phenomenon it involves elastic, plastic, friction and shear deformations, the temperature becomes a fundamental factor in the process influencing diverse aspects in the process such as dimensional values, surface roughness, shear force and tool wear. Most of the power consumed in the machining of the metals is converted to heat near the cutting edge of the tool and many technical and economic problems are caused directly and indirectly due to this heating "Trent, (1988)." Temperature in the primary zone of shear can reach up to 1200 ° C. In the milling operation the temperature factor becomes even more critical, because the milling is a cut-off process, the heat generated is done irregularly, that is, with each step of the cutting edge it abruptly heats in the the cutting input and when leaving the part until the return of the cut again it cools and then reheats when it comes in contact with the part again, this blinking of the cut causes great thermal shock in the tool compromising its life. Figure 02 shows the temperature generated during machining.

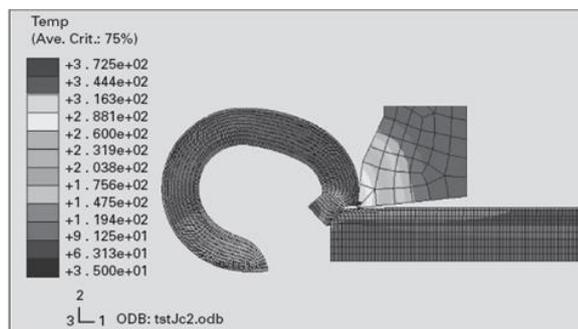


Figure 02.Example of temperature distribution obtained by FEM using a chip forming model
 “Machado,(2015)”.

Therefore, when machining a part using the same cutting parameters for both movements, the mean arithmetic deviations R_a and temperatures are different for both situations, so a prior study of which movements will be used before the beginning the operation. Successful milling is achieved when one finds the ideal way of contacting the cutting edge and material both at the inlet and outlet allied with satisfactory finish results and tool life.

2. MATERIALS AND METHODS

2.2 Materials

For the accomplishment of the experiments, test pieces in steel ABNT 1020, in the dimensions of 30 x 15 x 100 mm were used. The machining process was carried out in the conventional milling machine, Clark model FFH-2, from the machining laboratory of Newton Paiva University, Buritis campus, Belo Horizonte-MG. A milling cutter with 5 cermeted carbide of class P 25-40 was used. For the control and data collection of the mean arithmetic deviation - (R_a), a TIME brand TR-200 digital rugosimeter and a T8000 profilometer manufactured by Hommelwerk were used. For temperature measurement a FLIR i7 thermal camera, brand FLIR was used.

Figure 4 shows the conventional milling machine during the machining of test bodies.



Figure 03. Proof bodies

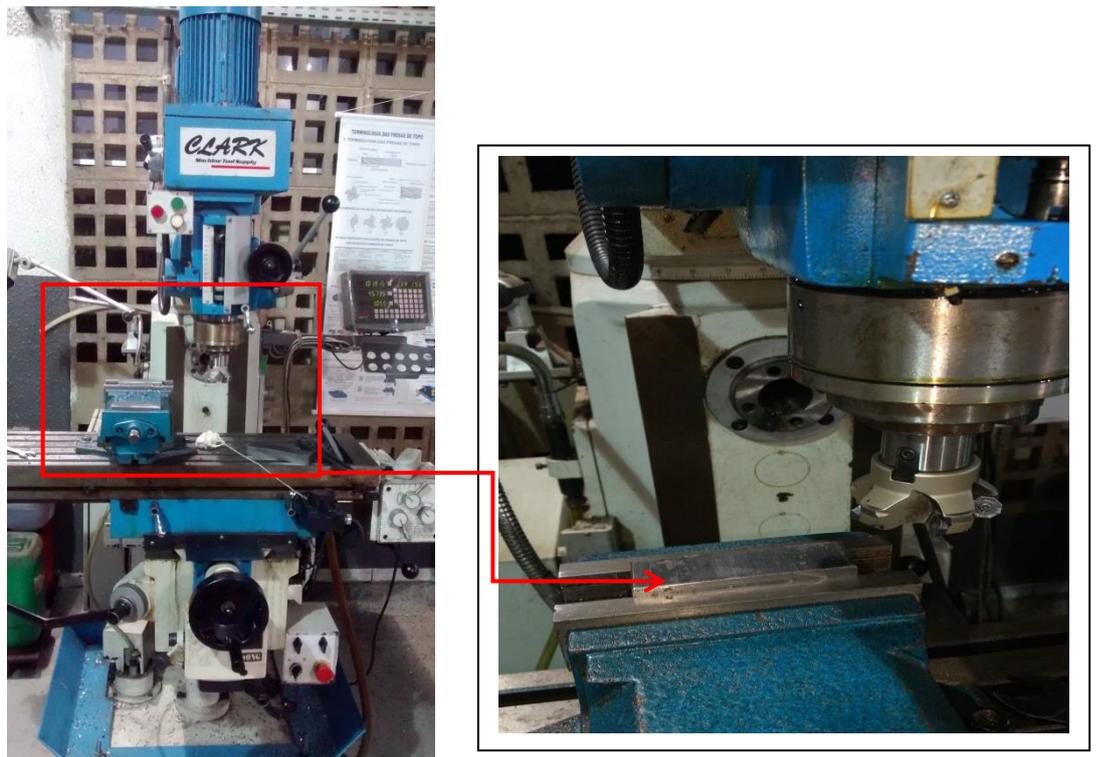


Figure 4. Tool milling machine (front milling)



Figure 5. Class P 25-40 cermented carbide

2.3 Methodology

It was considered for the milling test, the accomplishment of 10 passes in each test body corresponding to the up-milling and down movement. The test was performed without cutting fluid and new cutting edges were used for each test specimen. The cutting parameters of the test were: cutting speed (vc) 160 m / min; machining depth (ap) of 1 mm; feed per tooth (fz) 0.12 mm / edge; working penetration (ae) 30 mm and milling cutter diameter (Dc) of Ø 63 mm.

For each pass machined on the test specimens, the mean arithmetic deviation (Ra) measurements were taken with the digital roughness gauge in accordance with ISO 4287. A sampling length of 0.8 mm and length of 4 mm, for Ra values between 0.1 and 2 µm. The recommended values for the sampling and evaluation lengths are in accordance with ISO 4288 apud Machado et al., 2015. The three-dimensional profile was followed at the end of the test with the profilometer. The images were analyzed in the software Hommelmap expert 6.2. The temperature was collected during the thermal camera process, in which the focal point was directed over the cutting edge, acquiring the temperature on the surface of the chip. Regardless of the type of movement, the temperature in the adhesion zone can not be obtained by this technique.

3. RESULTS

3.1 Mean Arithmetic Deviation (Ra) and Temperature

Table 1 shows the values of (Ra) and temperature obtained during the milling operation.

Desvio aritmético médio -R _a [µm]			Temperatura °C		
Passes	Movim. Discordante	Movim. Concordante	Passes	Movim. Discordante	Movim. Concordante
1	1,132	1,691	1	135,0	73,8
2	1,236	1,923	2	122,0	94,6
3	1,114	1,675	3	73,0	62,0
4	1,085	1,741	4	93,0	63,0
5	0,903	1,608	5	90,0	65,0
6	0,905	1,708	6	98,0	78,0
7	0,931	1,663	7	92,0	75,0
8	0,897	1,687	8	87,0	69,0
9	1,010	1,654	9	95,0	72,0
10	0,901	1,525	10	83,0	69,0
Média	1,010	1,687	Média	96,8	72,14

Table 01. Mean Arithmetic Deviation (Ra) and Temperature Values.

4. DISCUSSION AND RESULT

4.1 Mean Arithmetic Deviation and Surface Finish

In order to verify the surface of the up-milling and down-milling movements, the three-dimensional profile of the surfaces of the two specimens after the milling operation was analyzed, as detailed in Fig. 6 and Fig. 7. The up-milling movement presented a better finishing and lower value of Ra, proving the existence of a significant difference in relation to the two movements.

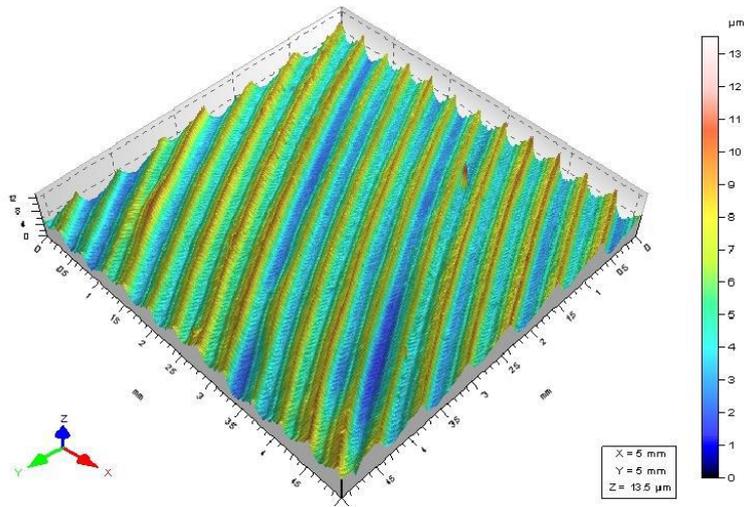


Figure 6. Three-dimensional profile for the up-milling movement

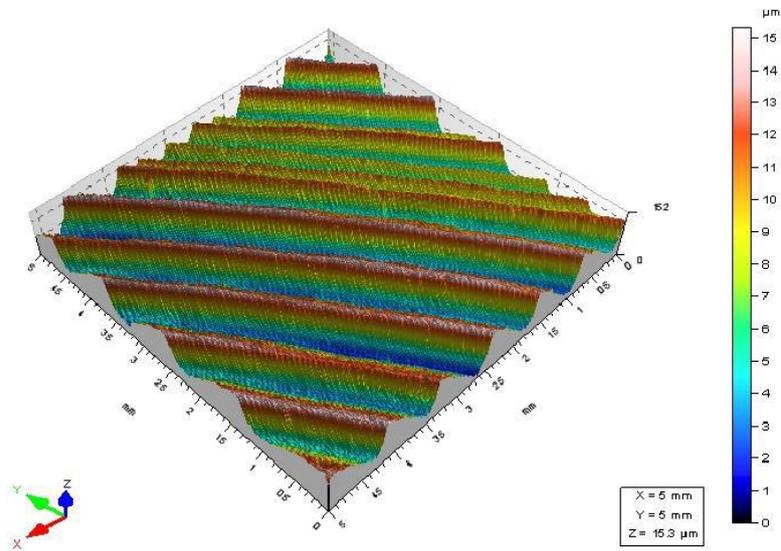


Figure 7. Three-dimensional profile for down-milling motion

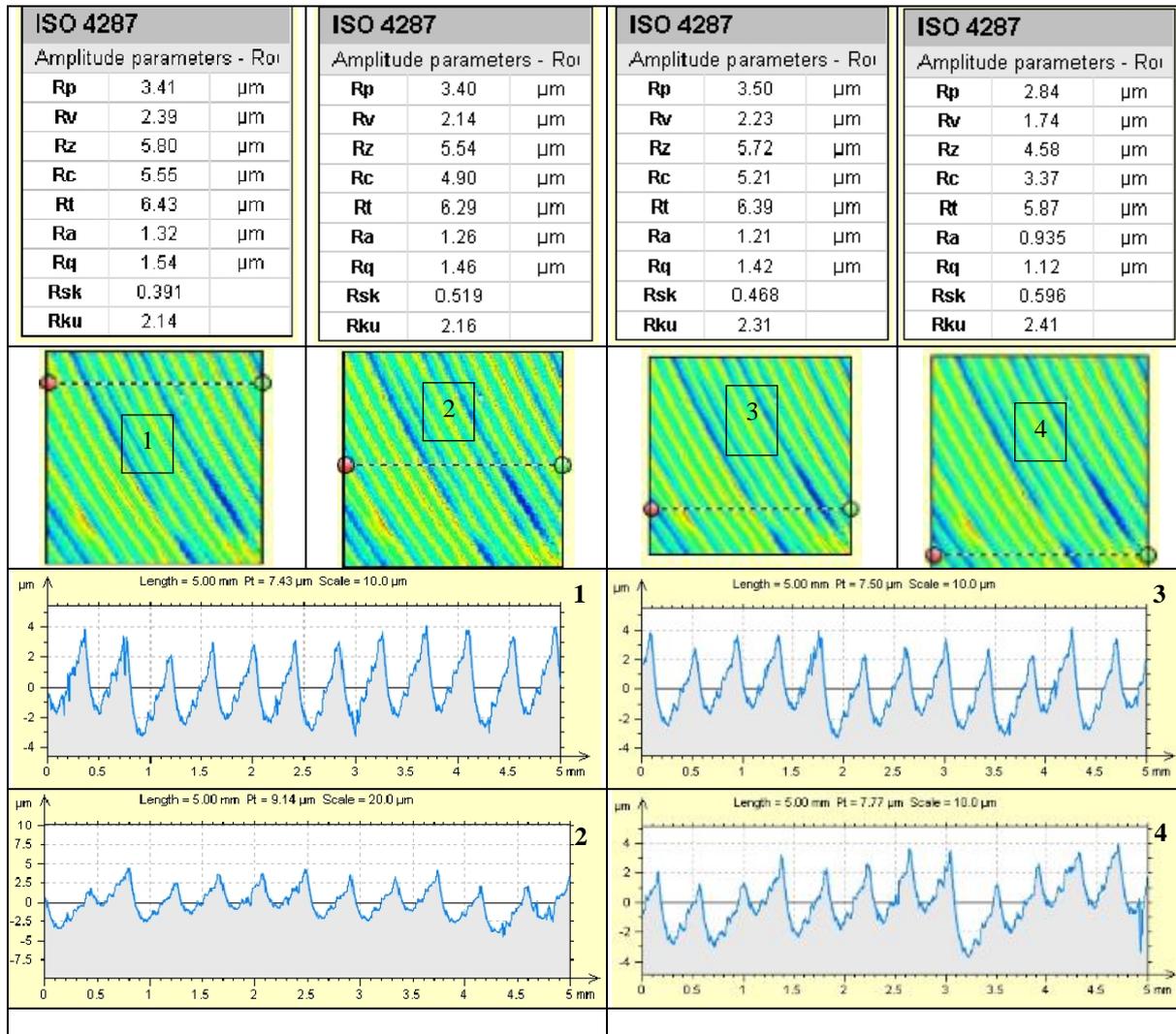


Table 2: Profile 2 D for the up-milling movement

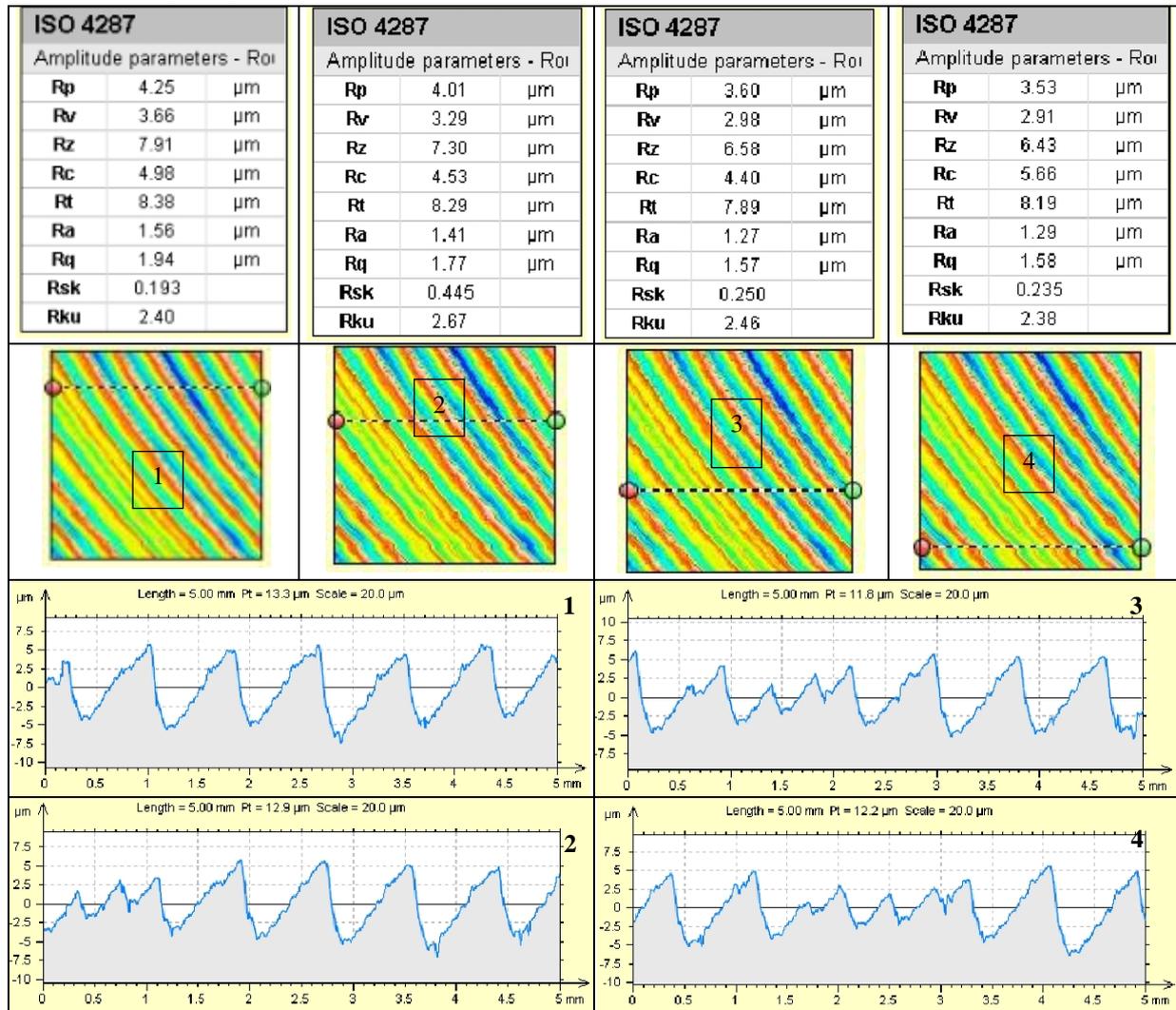


Table 03. Profile 2 D for the down-milling movement

The smaller arithmetic mean deviation R_a in the up-milling movement is justified, due to the fact of using a manual machine, because the slack of this equipment is in the opposite direction of the movement reducing the slack, assigning to better finishes. However, in the down-milling movement the largest arithmetic mean deviations were due to the existing gap in the machine, since the direction of the cut for this movement contributes to increase the gap and thus to damage the finish. The authors (Hutchings and Shipway, 2017) discuss the influence of the deformation mode on the degree of penetration (D_p), which in this case determines the exit angle in relation to the interfacial shear force, as detailed in Fig. the cutting thickness increases progressively from zero to the maximum value, so when the edge touches the part, it is forced into the part, creating an excessive friction that presents plastic deformation instead of chip formation and high temperatures. When the pressure of the cutting edge reaches a value capable of overcoming the rupture stress of the workpiece material, the tool penetrates the workpiece and with the machining movements draws out a portion of the chip. In this sense, as the shear thickness is initially lower, ie, the degree of penetration and the shear force are low, the mode of plowing occurs, in this way, there is no cutting of material but deformation, similar to what happens with the up-milling movement, as a consequence of a lower roughness of the material.

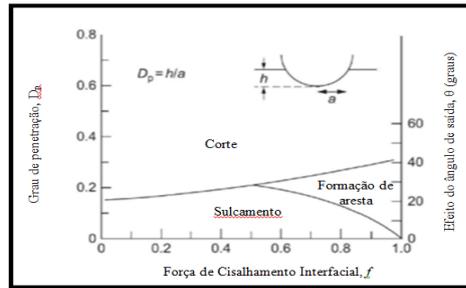


Figure 8. Deformation mode observed in a sliding of a hard bronze sphere in a plane of carbon steel (0.45%) and stainless steel (AISI 304), in which the degree of penetration of the sphere (D_p) determines the angle of effective output θ which is also plotted

4.2 Temperature

Figure 9 depicts the images collected by the thermal camera during the milling operation. According to the collected temperatures, the down-milling movement had lower values of temperature, while in the up-milling the temperatures were higher. It is known that the temperature influences the wear of the tools so for the up-milling movement the wear of the tool must be considered.

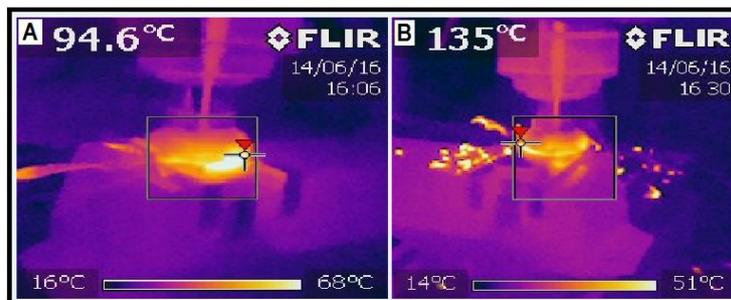


Figure 9. Temperature during milling operation a) down-milling movement; b) up-milling movement.

The higher temperature in the up-milling movement is justified because the heat generated in the milling is attributed to the plastic deformations of the material, the shear of the chip in the shear plane, the friction of the chip with the tool and the friction of the tool with the part, as in up-milling movement, the cut begins with a zero cut thickness and progressively increases the material withdrawal layer until it reaches its maximum value, the initial friction causes great heat generation. However in the down-milling movement the cutting thickness is maximum at the beginning of milling, thus the heat generated by friction becomes smaller.

4.3 Chip formation

For the up-milling movement to obtain of the discontinuous type and form of arch in the color gray and slightly yellowish.

For the down-milling movement to obtain of the discontinuous type and form of arc in the gray color.



Figure 10. Chips obtained in milling.

- A) Discontinuous chip obtained in the up-milling movement in the form of arc and in the color grayish and slightly yellowish.
- B) Discontinuous chips obtained in the down-milling movement in the form of an arc and in the grayish color.

The slightly yellowish color of the chip obtained in the up-milling movement is justified because the temperature in this movement was higher in relation to the down-milling movement that had a less heated chip.

The shape of the discontinuous chip occurs because the milling is a discontinuous or intermittent machining process, that is, each cutting edge of the milling cutter passing through and withdrawing material, until the next edge passes there is an interruption in the cut, which becomes a cut I do not continue, favoring the breaking of the chip. The shape of the archwire had no significant differences between the two movements.

5. CONCLUSIONS

It was concluded that for the up-milling movement smaller values of average arithmetic deviations were obtained, assigning a better finish, as observed in the three-dimensional profile. Regarding the temperature, the down-milling movement obtained smaller values when compared to the up-milling contributing to a longer tool life.

According to the machine available for milling operation the choice of which movement will perform the machining becomes paramount when considering the type of finish and temperature generated in the process. So we can do the following analysis;

When the milling operation is performed in a machine with relative clearance (conventional machines where the tests were carried out), the type of final finish of the workpiece being machined must be analyzed. If a better quality finish is necessary, the up-milling movement must be adopted, this is why it will work against the slack of the machine thus attenuating it and contributing to the good workmanship. But as the temperatures are higher in this movement, resulting in a more severe wear of the tool in relation to the matching movement, then the wear of the tool should be considered.

For machining on machines without clearance (CNC type), the matching down-milling movement must be adopted, as there is no risk of vibration in the process because the machine does not have suitable products for a good finish, in addition as a temperature is lower, thus contributing to a minor wear of the tool.

6. ACKNOWLEDGEMENT

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