

EXPERIMENTAL EVALUATION IN FACE MILLING PROCESS OF ABNT 1045 STEEL WITH DIFFERENT NUMBER OF INSERTS AND CONSTANT FEED RATE

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Abstract: *The milling is a machining operation with high employment in industry due to high current rate of removal of material, production of surfaces with high dimensional accuracy, as well as has high flexibility. Scientific research of the phenomena about various machining processes is very important for the technological advancement of this area of manufacturing engineering. Knowledge of the response variables, as well as the forces generated in the milling are important for the determination of various machining and wear mechanisms, which are decisive factors for the efficiency of the process of machining. The objective is to evaluate trends for strength and cutting power consumption in the operation of face milling ABNT 1045 steel, when used different numbers of teeth, entering angle and cutting speeds. For this, a plan was drawn up by randomized experimental levels, the fixed effect model. Analysis of the results, we concluded that, regardless of the angle of position and speed of cutting, cutting efforts are minimized when the average number of teeth used in the mill.*

Keywords: *Face Milling; Machining; Monitoring.*

1. INTRODUCTION

According to MELO (2003) and RICHETTI et al (2004), scientific research of the phenomena related to various machining processes is very important for the technological advancement of this area of manufacturing engineering. There are various studies that aim to obtain grants to help in the choice of optimal cutting parameters for machining which exert significant influence on several variables of the process.

During the face milling there are, among others, changes in cutting movements, cutting forces, surface texture, which are dependent on process parameters such as cutting fluid, number of teeth, cutting speed, tool geometry, etc. Such conditions motivated this research, allowing correlating the influence variables of process and their interdependencies when the machined ABNT 1045 steel on the face milling with multiple teeth, different cutting speeds and entering angle of mill.

Results show that there is a greater influence on the number of teeth simultaneous cutting compared to the increase of shear rate for increasing the power consumed in the face milling ABNT 1045 steel. Furthermore, the machining forces have not introduced proportional increases to the number of teeth in simultaneous cutting. Finally, all variables interfere in the machining efforts and they interact between themselves.

2. BIBLIOGRAPHIC REVIEW

2.1. Classification Of Milling

The milling operation was defined by FERRARESI (1973) as an operation of which tool called milling cutter has sharp tooth arranged symmetrically around an axis. It performs the removal of material through the cutting movement provided by the rotation of the tool on itself axis and the motion of the piece is done generally by the piece stuck to the table of the machine. It can be divided into peripheral milling and face milling.

DROZD (1983) *et al*, cited by POLLI (2005), observed that in the face milling, the machined surface result of combined action of the edge located at the periphery and in front of the milling cutter, which is generally perpendicular to the axis of the tool. Usually, surface finish is flat and does not correspond to the contour-tooth.

The face milling can be classified as: asymmetric, when the cut is not on the axis of symmetry of the piece; and symmetric, when the displacement of the axis of the cutter occurs on the axis of symmetry of the piece.

According AMORIN (2003) is important to take into account the life of the tool because, despite the symmetrical cutting tool to cause less wear, cutting asymmetrical allows better working conditions, reducing the vibration, the efforts for tooth and the impact on introduction of the edge in the piece.

To minimize the effect of mechanical shock between teeth and piece, DINIZ (2005) calls FILHO (1998), recommends using a value of "J" (Figure 1) of the order of 4% of the tool diameter, because the chip thickness (h_d) at

the entrance of the teeth tool decreases resulting in less impact on the entry of the tool. Another relevant factor for the maintenance of such a thickness greater than zero concern on the reduction of specific cutting pressure, and therefore cutting forces.

Still, DINIZ *et al* (2006), suggest that using asymmetric cut with small “j”, as shown in Figure 1, of the order of 5% the cutter diameter.

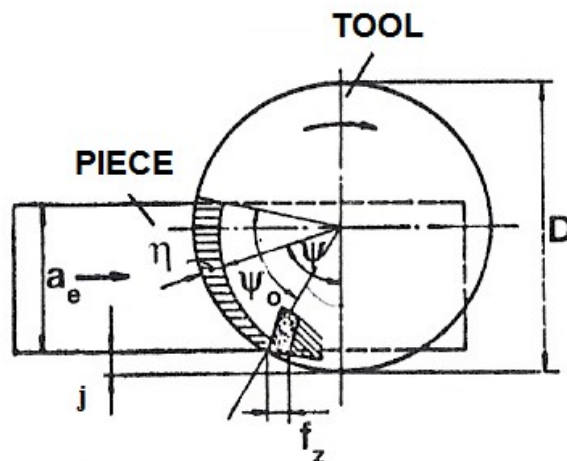


Figure 1. Asymmetric face milling process. (DINIZ, MARCONDES and COPPINI, 2006).

2.2. Positioning Of The Insert At Cutting

Second FILHO (1998) *et al*, the relative positioning mill-piece has a great influence on the result of machining, and some factors should be seen such as: entry of the cutting edge, leaving the cutting edge, cutting length, number of teeth in simultaneous cutting and cutting forces.

The correct determination of the number of teeth used has a direct influence on the surface texture, on the cutting force and power of cutting, on tool life and cutting time, and also on the power consumed in the process. For constant cutting conditions, an increase in the number of teeth results in higher specific energy of material removal (SILVA, 2001).

Mill with close pitch has several advantages in brittle materials machining, avoiding material edges breakage in the output of the tool, and resulting in a bad surface texture and more effort at the cutting edge. This condition is favorable in machining operations where an excessive number of teeth, cutting simultaneously, may cause vibration or in cases where the machine power is a limiting factor of the cutting process.

There must be adequate space for formation and leaving of the chip between consecutive teeth in the cutter, although an excessive space may weaken the teeth. An appropriate arrangement depends not only on the number of teeth on the cutter. Other design features can also help to reduce the vibration of the system, for example, the differential pitch, can help reduce the vibration unlike the milling cutters with constant step which generate cyclical shocks, increasing the vibration.

According to COSTA (2003) *et al*, the cutting forces in milling operations vary constantly during the operation due to the change of the chip section. This makes some comments are necessary, because this variation is the main cause of the end of tool life.

The milling force is decomposed into an active force, consisting of the sum vector of the cutting force and force of progress, where there is consumption of power by being in the work plan. Another passive strength such as the depth strength in the direction of adjustment the tool in the piece that is responsible for other actions such as buckling the door tools.

The most known and used model for determining the cutting force is to Kienzle, according to equation 1 (SILVEIRA and ARAUJO, 2003).

DINIZ *et al* (2006), mention that this is the component of force in machining has the highest values and each parameter of cutting influence that in a different way. The feed per revolution (f) and specific cutting pressure (K_s) are inversely proportional quantities. The depth of cut (a_p) has no significant influence on specific cutting pressure. Thus, the strength and depth of cut quantities are directly proportional. The influence of cutting speed (vc) in the specific cutting pressure, in normal ranges of use, is negligible.

$$F_c = K_s \cdot a_p \cdot f_z \quad (1)$$

Considering the variations of cutting force, chip thickness (h) and the number of edges in contact with the workpiece (z), it has variable power consumption during the milling operation. For this reason it is used an average value of specific cutting pressure K_s (K_{sm}) for an average thickness of cut (h_m). The average cutting power (P_c) is given by equation 2, and also the product of specific cutting pressure (K_s) and the removal rate of material machined in time, given by equation 3, where (a_e) is the cutting width, (a_p) is the depth of cut and (v_f) is the feed speed of cutter.

$$P_c = K_{sm} * h_m * b * v_c \tag{2}$$

$$P_c = K_{sm} * a_e * a_p * v_f \tag{3}$$

3. METHODOLOGY

At the experimental design, the experiments were distributed according to Table 1 with three conditions of the cutting edges (number of teeth): $z_1 = 2$, $z_2 = 4$ and $z_3 = 8$ and two cutting speeds: $v_{c1} = 360\text{m/min}$ and $v_{c2} = 440\text{ m / min}$. They were randomized at their achievements.

A constant depth of cut of 1.5 mm was used and the feed speed was 860 mm/min in all experiments.

Table 1. Distribution of tests according to an experimental design.

	Z1=2		Z2=4		Z3=8	
	vc ₁	vc ₂	vc ₁	vc ₂	vc ₁	vc ₂
$\chi_r = 45^\circ$	111a	121a	211a	221a	311a	321a
	111b	121b	211b	221b	311b	321b
	111c	121c	211c	221c	311c	321c

The experimental tests were conducted in a CNC milling machine Romi Interact IV model, with constant current engine. The maximum rotation is 4000 rpm and the electric power is 16.4 kW (22 HP). The workpiece material used is ABNT 1045 steel, rectangular with dimensions of 76mm X 58mm X 60mm, positioned on a platform dynamometer Kistler 9265B, responsible for monitoring the machining force components. F_y is of the feed direction of the cutter and F_x is crossed to this movement. F_z is the axial force (passive), as shown in diagram Figure 2.

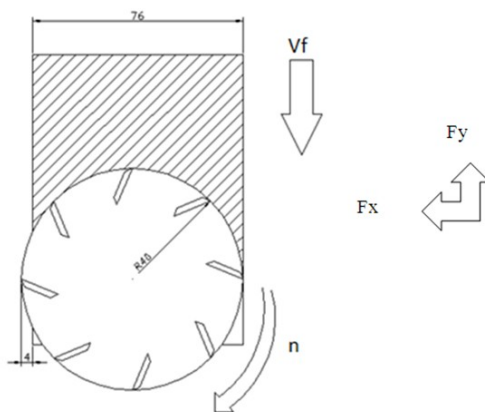


Figure 2. Scheme of positioning of the cutter and the work piece for milling machining.

The acquisition of power was made by monitoring the electrical current of the motor, using a Hall effect sensor, model NW-SCD-50-R, which the ampere range is 0(A) to 50 (A), the supply voltage of the system is ± 9 (VDC) and the output signal range is 0 (VDC) to 5 (VDC). The force and power signs are both converted from analog to digital (A/D) and then picked up by a Power DAQ system model PD2-MFS-8-500/14. For analysis of these signals were used a microcomputer and the software LabView 8.1 from National Instruments.

The tests were conducted using SANDVIK milling tools, show at Figure 3, which are: milling cutter A2B05 - 40 27 035, insert R245-080 Q27-12H and inserts R245-12 T3 M-PM 4230.



Figure 3. Tool and inserts specified for the tests.

In Figure 4, is showed the arrangement of monitoring equipment and assembly of all the machinery.



Figure 4. Equipment arrangement for conducting experiments.

4. RESULTS

For each test, in a specific condition, were monitored twelve signs of forces and powers whose average served as references for comparison with other tests results, as shown in Table 2 below.

Table 2. Average values of force and power for tests.

	vc1= 360 m/min				vc1= 440 m/min			
	F _x (N)	F _y (N)	F _z (N)	Pt (W)	F _x (N)	F _y (N)	F _z (N)	Pt (W)
Z=2	1140	941	339	4700	584	467	206	3580
Z=4	684	533	516	4602	646	521	531	4618
Z=8	959	786	677	5397	862	726	632	5341

With the increase of the teeth number, the chip deformed less, as shown in Figure 5, because the values of average thickness of the cross section decreased, consequently there was a general increase from the specific cutting pressure.

From the analysis of the graph of Figure 6, note that the specific cutting pressure increases when using a larger number of teeth, because the thickness of cut is lower when the number of teeth grown.

5. CONCLUSION

The results about asymmetrical face milling ABNT 1045 steel, it was considered the constant volume of material removed from that.

In the case of minor tree bending or reactions in the machine bearings, was used middle number of teeth and higher cutting speeds.

As for the condition of compression of the tree or greater effect of the edge on the piece surface (passive force F_z), the worst case occurred when used more edges as was to be expected.

For the condition of cutting, chip formation, it is recommended to opt for small cutting speeds and medium pitch.

The power consumed was higher when increasing the number of teeth, regardless of the increase in cutting speed (V_c).

The passive force (F_z) and the force of progress (F_y) tend to move closer when used more number of teeth.

6. ACKNOWLEDGEMENTS

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