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Study of the application of sunflower oil in the process of drilling ABNT 1045 steel

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ABSTRACT. The cutting fluids in machining, when chosen and applied adequately can contemplate in benefits during the manufacturing processes. The selected method should allow the cutting fluid to reach the closest possible of the cutting edge lubricating the chip-tool interface. The properties of the fluid are fundamental so that the same facilitates the machining process. However the fluid can represent a great problem for the environment and health of the operator. For that reason, several scientific and technological studies are constantly developed to investigate the performance and alternative applications of cutting fluids in machining operations. This work studies the effect of sunflower oil in the cutting forces for the drilling process of 1045 ABNT steel. The fluid was applied in the form MQL - Minimum Quantity Lubrication for different cutting conditions. The cutting speed, feed rate and the length of the hole were varied. Each one of the cutting variables two levels were used. The results suggest a good acting sunflower oil in the work accomplished.

Keywords: cutting fluids, drilling, 1045 ABNT Steel, MQL technical.

Estudo da aplicação do óleo de girassol no processo de furação do aço ABNT 1045

RESUMO. Na usinagem os fluidos de corte, quando escolhidos e aplicados apropriadamente, podem refletir em benefícios durante os processos de fabricação. O método selecionado deve permitir que o fluido de corte atinja o mais próximo possível da aresta de corte lubrificando a interface cavaco/ferramenta. As propriedades do fluido são fundamentais para que o mesmo facilite o processo de usinagem. No entanto o fluido pode representar um grande problema para o meio ambiente e saúde do operador. Por esse motivo, vários estudos de cunho científico e tecnológico são constantemente desenvolvidos para investigar o desempenho e alternativas de aplicações dos fluidos de corte nas perações de usinagem. Este trabalho estuda o efeito do óleo vegetal de girassol nas forças de corte para o processo de furação do aço ABNT 1045, o fluido é aplicado na forma MQL – Minimum Quantity Lubrication (mínima quantidade de fluido) para diferentes condições de corte. São variados a velocidade de corte o avanço e o comprimento do furo. São utilizados dois níveis, para cada uma das variáveis de corte. Os resultados sugerem bom desempenho do óleo de girassol na pesquisa realizada.

Palavras-chave: fluidos de corte, furação, aço ABNT 1045, técnica MQL.

Introduction

Nowadays the application of cutting fluids in machining operations are increasingly being employed by the technique of Minimum Quantity Lubricant (MQL) that acts on the principle of using small amounts of oil without waste. In this technology function is ensured by the oil lubrication and cooling, however small by the compressed air (ATTANASIO et al., 2006; ZHANG et al., 2012). This small amount of fluid is sufficient to reduce friction in cutting, reducing adhesion tendency of materials with such characteristics (BAGCI; OZECELIK, 2007; THAMIZHMANII; ROSLI, 2009).

According to Lawal et al. (2012) the heat generated in the cutting zone during machining is critical to the ultimate quality of the workpiece. The researcher points out that even though cutting fluids are widely used to decrease the temperature in machining, suggests the need to develop green alternatives healthy and easy to use for conventional cutting fluids on the basis of problems that can be caused to human and the environment. However Wang and Zhang (2008) emphasizes that environmental laws nowadays for the use of cutting fluids are reflections of changes in the society behavior against damages caused largely by the industries (OZCELIK at al., 2011).

The growing attention to environmental and governmental regulations industrial activities beyond the growing level of awareness of society has forced industries to reduce the use of cutting fluids based on mineral oil (LAWAL et al., 2012). Cutting fluids have been widely used in the last 20 years. Earlier consisted of simple oils applied with brushes to lubricate and cool the machine tool. As the machining operations have become more severe, there was the need to develop more efficient cutting fluids. There are currently several types of cutting fluids on the market and the most common types can be broadly classified as cutting oils or fluids miscible in water. It has been reported in literature, that different cutting fluids which are based on vegetable oil, can be a less harmful to the environment with similar performance achieved using fluids based on mineral oil for metals (BELLUCO; CHIFFRE, 2004; CAMPANELLA, 2010; CETIN et al., 2011; LAWAL et al., 2012).

This study was proposed to investigate the performance of sunflower vegetable oil applied as MQF, the drilling process with high speed steel drills. The focus is productivity coupled with environmental standards. In addition to supporting the environment, this work is justified by the proposed use of vegetable cutting fluid for drilling of ABNT 1045 carbon steel, widely used in industry to manufacture mechanical metal components of machines and equipment. This type of fluid is environmentally friendly and less aggressive human skin than other types of mineral-based fluids.

The objective of this work is to contribute to the machining industry to study the influence of vegetable oil like sunflower cutting fluids applied as MQF compared to the dry test drilling in ABNT 1045 steel in various cutting conditions (cutting speed, feed rate and depth of the hole), whereas the feed force as dependent variable.

Material and methods

Experimental tests were performed on a CNC machining center line Discovery model 560 with numerical control Siemens 810. The engine power C. A. Tree is 12.5 hp (9 kW) and total installed power of 15 KVA. Manufactured by industry ROMI S. A. Head with speed range 7-7500 rpm. The process of drilling with twist drills for metal HSS-G 10 mm in diameter with 135° point angle uncoated, DIN 338 manufactured by DORMER, was carried out in full, without stopping or return the tool to break the chip, with L = 1.5 x D and L = 5 x D, steel (ABNT 1045). New drills were used throughout the experiments. For measurement of forward forces and torque were used a dynamometer Kistler Type 9271A and a charge amplifier for piezoelectric sensors type 5006. The received signals from the amplifier were converted by an acquisition board amplified USB multifunction module type 1208FS, processed and stored on a notebook and a software developed using Borland Delphi 7 version that captures these signals and displays them in graphically. Figure 1 shows the layout of equipment for the acquisition of force and torque in this experiment.

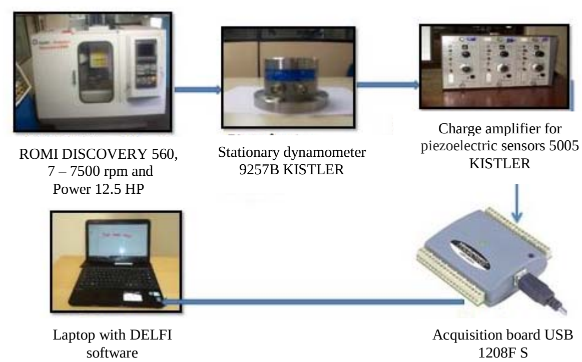


Figure 1. Arrangement of equipment for the acquisition of power and torque.

We used a spray fluid in the form of LFA application, O2AO-STD model manufactured by ITW Flowing Products Group operating under a steady flow of compressed air set at around 4 bar, and 'spray' fluid intermittently at a frequency of 1 pulse per second. This system consists of a reservoir for the cutting fluid to bypass valves for regulating the flow of compressed air and oil pressure gauge, conductive hose (air and liquid) and the second nozzles based magnetic clamping for external application of the mixture air-fluid on the tool-workpiece. The cutting fluid was driven through a hose of smaller diameter which reaches the nozzle inside another bigger one that leads the compressed air registering a flow rate of 50 mL h^{-1}.

Planning of tests

We defined four cutting parameters as input variables: cutting speed, feed rate, length of hole and cutting fluid and preset variations for each test a 24 factorial design considering the variation in two levels of the four variables relating to conditions of cut resulting in 16 experiments, considering a reply and a rejoinder will be 48 tests. The replies and rejoinders will be conducted for statistical analysis, as shown in Table 1.

Table 1. Matrix factorial design.

Test	Input Parameters			
	v_c (m min.$^{-1}$)	f (mm rot^{-1})	l (mm)	Cutting Fluid
1	17(-1)	0.10(-1)	15.0(-1)	sunflower (-1)
2	25(+1)	0.10(-1)	15.0(-1)	sunflower (-1)
3	17(-1)	0.20(+1)	15.0(-1)	sunflower (-1)
(4	25(+1)	0.20(+1)	15.0(-1)	sunflower (-1)
5	17(-1)	0.10(-1)	50.0(+1)	sunflower (-1)
6	25(-1)	0.10(-1)	50.0(+1)	sunflower (-1)
7	17(+1)	0.20(+1)	50.0(+)	sunflower (-1)
8	25(-1)	0.20(+1)	50.0(+)	sunflower (-1)
9	17(+1)	0.10(-1)	15.0(-1)	The Dry (+1)
10	25(-1)	0.10(-1)	15.0(-1)	The Dry (+1)
11	17(+1)	0.20(+1)	15.0(-1)	The Dry (+1)
12	25(-1)	0.20(+1)	15.0(-1)	The Dry (+1)
13	17(+1)	0.10(-1)	50.0(+1)	The Dry (+1)
14	25(-1)	0.10(-1)	50.0(+1)	The Dry (+1)
15	17(+1)	0.20(+1)	50.0(+)	The Dry (+1)
16	25(-1)	0.20(+1)	50.0(+)	The Dry (+1)

The specimens were initially cut on a bandsaw dimensions ϕ 104 x 54 mm gross and subsequently machined to final dimensions ϕ 90 x 50 mm. We also carried out the preparation of systems and fasteners / part machine. To optimize the number of holes, a CNC program was generated which allowed obtaining 42 holes per side, alternating rows of 6, 15 and 21 holes. The distances between each row were determined by the rays 15, 30 and 42 mm and spacing between the holes was 2.56, 2.56 and 5.70 mm, respectively.

Results and discussion

The results of tests carried out in the process of drilling ABNT 1045 steel, in order to investigate the influence of vegetable oil such as sunflower cutting fluid, which your behavior in relation to existing process (dry), the output parameter force advance (Fz), was analyzed as a factorial design already filed. The monitoring system of feed force during the cutting time correctly register the graphics of the efforts involved in the process, becoming similar to that presented in the manual Kistler (measure. analyze. Innovate).

Figures 2 and 3 show graphs characteristic of the feed force (Fz) versus time (s) for the tests (T1, T2, T3 and T4) (T5, T6, T7 and T8) of the drill ABNT 1045 steel, in lengths L = 1.5 x D and L = 5 x D vegetable oil sunflower as MQF with flow of 50 mL h^{-1}.

In these graphs can initially observing the influence of the input parameters involved in the process, being more significant than the breakthrough (f), because according to the literature (MACHADO et al., 2009), increased feed rate by directly increases the areas of shear planes primary and secondary cause an increase in strength of machining, in direct proportion, almost linear. Moreover, for greater heat generation and consequent reduction of shear strength of the material in the shear zones, and by a slight reduction in the contact area chip - tool, the machining force tends to suffer a slight decrease with increasing speed cutting, the cut length (L) and the fluid must be analyzed statistically for a better assessment.

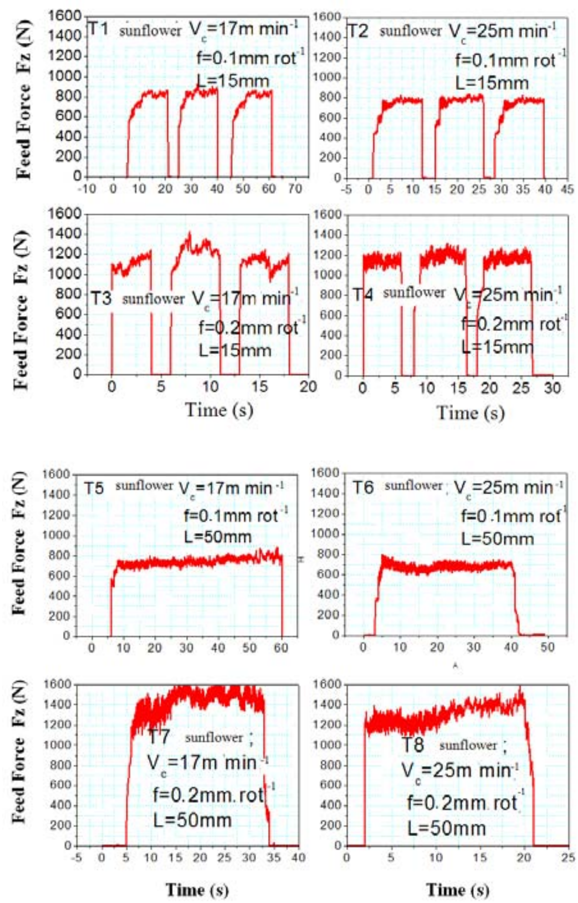


Figure 2. Graphs of feed force (Fz) function of time, the conditions in drilling T1 to T8; L = 1.5 x D and L = 5xD, sunflower MQF, flow = 50ml h^{-1}.

For best viewing results Table 2 shows the means and standard deviations for each test performed with a minimal amount of fluid MQF with sunflower oil and Figure 4 (a) shows the bar graph corresponding to these means, which confirm the discussion of parameters analyzed earlier. For comparison purposes, Table 3 shows the averages and standard deviations for each test run dry and Figure 4 (b) shows the bar graph corresponding to these averages.

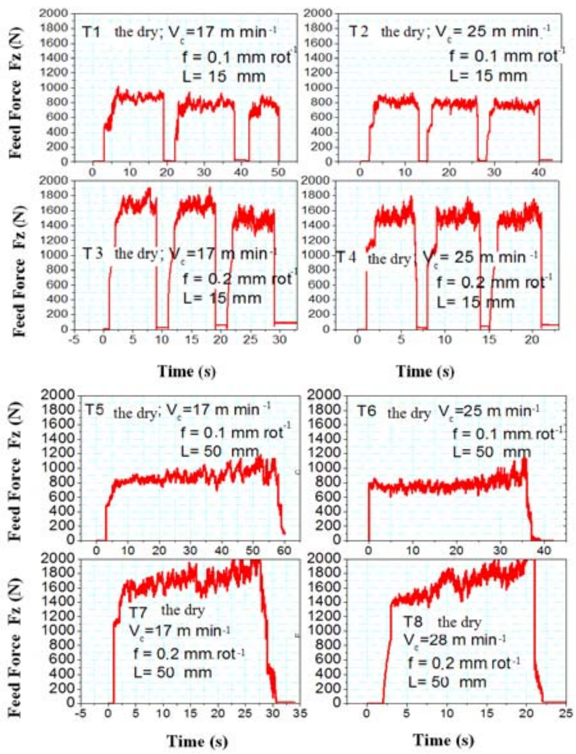


Figure 3. Graphs of feed force (Fz) function of time, the conditions in drilling T1 to T8 L = 1.5 x D and L = 5 x D, the dry.

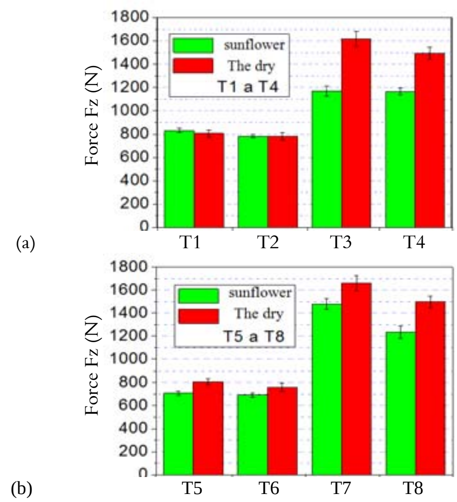
Table 2. Average force (Fz), standard deviation (sd) and coef. of variation (CV) of the tests 1-8, sunflower as MQF, Q = 50 mL h^{-1}.

Sunflower	T1	T2	T3	T4	T5	T6	T7	T8
Fz	831.6	783.01	1170.4	1165.7	709.1	693.3	1480.3	1233.4
Sd	19.1	11.7	43.2	30.7	18.3	18.3	48.1	54.3
CV%	2.3	1.5	3.7	2.64	2.6	2.6	3.24	4.4

Table 3. Average force (Fz), standard deviation (sd) and coef. of variation (C.V.), tests 1-8, the Dry.

The dry	T1	T2	T3	T4	T5	T6	T7	T8
Fz	805.7	781.9	1617.1	1494.2	808.5	761.6	1661.2	1497.4
Sd	28.1	34.1	65.6	51.6	27.7	34.2	63.4	50.1
CV	3.48	4.36	4.05	3.45	3.42	4.5	3.81	3.34

In Figures 4 (a) and (b) it is noted that the feed force increases with increasing since the increased feed rate means increases the area to be sheared, and increased contact area on the tool chip output surface (MACHADO et al., 2009). With increasing shear rate is observed a small decrease in forward forces, probably due to greater heat generation caused thereby at increased temperature. The application of cutting fluid MQF sunflower as compared to the same condition of dry machining, showed in general a better result ie values lower feed force, where the values of feed force average around 800 (N) advances to 0.1 mm rev^{-1} and increasing around 1600 (N) advances to 0.2 mm rev^{-1}, condition 2 (Vc = 25 m $min.^{-1}$, f = 0.1 mm rev^{-1} and L = 15 mm) application of the minimum amount of fluid MQF (sunflower oil) showed a better regularity of the process parameters, with lower coefficient of variation (CV) 1.5%.



Tests	Vc	f	L
T1	17	0.1	15
T2	25	0.1	15
T3	17	0.2	15
T4	25	0.2	15
T5	17	0.1	50
T6	25	0.1	50
T7	17	0.2	50
T8	25	0.2	50
Vc ($m.min^{-1}$); f ($mm.rev^{-1}$) e L (mm)			

Figure 4. Graph of mean and standard deviation of the feed force Fz in function tests, (a) MQF sunflower, Q = 50 mL h^{-1} and (b) the dry.

Statistical treatment of data

Obtaining an improved reliability in the results and the need to compare the searched data, statistical test was used for analysis of variance (ANOVA) 7.0 by StatSoft. Such analysis is to determine whether there are significant differences between groups of steps, and if so, which groups are significantly different from each other. According Martinazzo (2009) to confirm that this difference, it is necessary that the P-value is less than the interval of significance, which in this case is 0.05 (confidence interval 95%). If this is not checked, or if it is greater than or equal still must be analyzed values of F and F critical. If F is greater than F critical considered to be no difference between the groups. The following Tables 3 and 4 show the ANOVA for the feed force.

Table 5 shows the main effects of the input parameters which highlight the influence of advance (f) and the atmosphere. It was proved by the index 'p', the variables f, atmosphere and interaction of advancement (f) with significant atmosphere were in process for a reliability of 95%. Trend analysis can be made for these variables, as illustrated in the graphs of Figure 5.

Table 4. Results of the planning matrix.

Tests	V_0	f	L	Atmosfera	F_z
1	17	0.1	15	Sunflower	831
2	25	0.1	15	Sunflower	783
3	17	0.2	15	Sunflower	1170.3
4	25	0.2	15	Sunflower	1165.7
5	17	0.1	50	Sunflower	709.1
6	25	0.1	50	Sunflower	693.3
7	17	0.2	50	Sunflower	1480.3
8	25	0.2	50	Sunflower	1233.4
9	17	0.1	15	The dry	805.7
10	25	0.1	15	The dry	781.9
11	17	0.2	15	The dry	1617.1
12	25	0.2	15	The dry	1494.2
13	17	0.1	50	The dry	805.5
14	25	0.1	50	The dry	761.6
15	17	0.2	50	The dry	1661.2
16	25	0.2	50	The dry	1497.4

Table 5. Main effects of input variables.

	effect	p
average	1093.169	0.000000
(1)Vc	-83.712	0.075171
(2)f	643.563	0.000012
(3)L	24.112	0.547146
(4) atmosphere	169.813	0.006141
2 x 4	135.237	0.015228

When the shear rate was increased from 17 m min.$^{-1}$ to 25 m min.$^{-1}$ the feed force (F_z) decreased on average 83.712 (N) 7.65% Figure 5 (a), probably due to greater heat generation, thereby causing one rise in temperature, which contributes to reduced feed force. Increasing the feed rate 0.1 mm rev.$^{-1}$ to 0.2 mm rev.$^{-1}$ increases in average 643.563 (N) 58.87% Figure 5 (b), possibly by increasing the area of contact-piece tool. Increasing the length of the bore of 15 mm to 50 mm on average had a slight increase in feed force in 24.112 (N) 2.2% Figure 5 (c). With the use of sunflower oil instead of the dry cutting, there was a decrease in feed force, averaged 169.813 (N) 15.54% Figure 5 (d). This fact can be attributed to lack of lubrication / oil cooling by increasing the friction between the workpiece and the tool. Table 5 further indicates that the variables (2) advances, (4) sunflower oil and the combination of these two parameters (2 x 4) were significant adopting the significance level of 5%, it follows that the value of p is less this level, therefore, we conclude that there is a difference between the two factors for a reliability of 95%, highlighting also the cutting speed in decreasing the forces of progress.

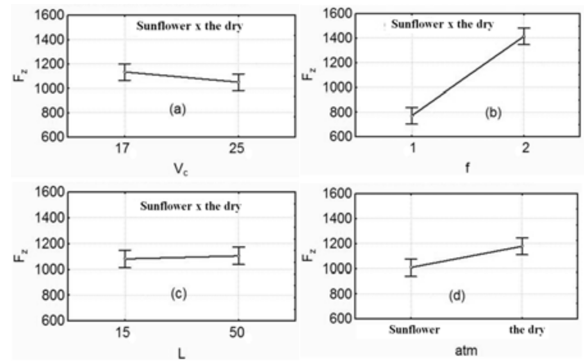


Figure 5. Trend graph of estimated effects of the input parameters (a) Vc, (b) f, (c) L, (d) atmosphere.

Conclusion

The results show generally statistically, a significant advancement as the vegetable oil and cutting fluids in the drilling process, when applied as MQF. The vegetable oil used in the form (MQF) graphically displays forward forces obtained by processes similar to those already used in drilling (dry). Sunflower vegetable oil in the form (MQF) can probably be an interesting alternative in the drilling process, because it is biodegradable and the global trend of reduction of cutting fluids petroleum in machining processes. It was found statistically that the combination of advancement and sunflower oil exerts a significant influence on the feed force. The cutting speed statistically showed a slight reduction on the feed force is not statistically significant in the process, the length of the hole also showed no statistically significant influence.

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