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EXPERIMENTAL METHODOLOGY TO EVALUATE THE EFFECT OF EDIBLE VEGETABLE OILS USED AS CUTTING FLUID IN DRILLING OPERATION

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Abstract. *The power consumed in metal cutting is largely converted into heat. This heat is dissipated by the four systems processing the material: cutting tool, workpiece, chip and the cutting fluid. The cutting fluid plays therefore an important role and many operations cannot be carried out efficiently without a fluid. Among their functions, cutting fluids are used to cool the cutting tool and workpiece. They may act as a lubricant at the chip tool interface, decreasing the temperature. The main objective of this work is the evaluation of the action of a cutting fluid in drilling operation. An experimental technique is proposed to evaluate the effect of edible vegetable oils when drilling gray iron. The cutting fluids used are: corn, sunflower, babassu oil and a commercial soluble oil (semisynthetic cutting fluid). Temperatures in three different positions are measured in the workpiece during the drilling process. Torque is measured during the operation. The results are compared to the effect of soluble oil and dry machining. The corn oil environment showed the best results and torque was lower for the cutting fluid environments than for the dry environment, although, in some tests, the temperature in the dry environment had the best performance*

Keywords: vegetable oil, drilling, cutting temperature.

1. INTRODUCTION

The phenomena of heat generation and dissipation in metal cutting are complex. High temperatures in the tool-chip interface zone are associated with metal cutting (Abukhshim; Mativenga; Sheikh, 2006). The amount of heat generated due to friction and plastic deformation increases the temperature of the process, causing changes in the mechanical and physical properties of the tool that accelerate its wear and, consequently, limit its use (Ferraresi, 1977; Machado *et al*., 2011).

In the process of drilling, for example, factors intrinsic to the drilling cut (cutting speed, drill geometry, feed rate, depth of cut, lubrication, and cooling, among others) and factors related to the material's properties (chemical, physical, and mechanical) directly contribute to the generation of heat (Souza *et al*., 2012).

The energy generated in cutting workpiece is almost entirely converted into heat. This heat is dissipated by the four systems involved: the cutting tool, the workpiece, the chip formed, and the cutting fluid (Trent and Wright, 2000). In the chip-tool interface, the effects of high temperatures on the cutting zone have been made known through practice; despite this, the behavior of the heat generated as well as explanations of the partition of its flow to the elements involved are virtually unknown (Silva *et al*., 2007).

Several studies have been conducted to predict the partition of the heat generated during the cutting operation. Direct experimental methods, like the tool work thermocouple method (Kaminise *et al*., 2012) and, more recently, indirect inverse models have been developed to quantify and measure the rate of partition to the part to be machined (Sousa *et al*., 2012).

There is no standardized experimental method that can confirm the transfer rates of heat to each element involved in these processes. Thus, more research and the development of new experimental methods are justified; moreover, findings may be applicable to some processes but not to others, thereby highlighting the need for more investigations. A better understanding of the partition of heat among tool, chip, and workpiece is required in order to produce more realistic models for machining processes that aim to optimize the cutting process by extending the life of the tool and improving the surface integrity of the workpiece (Silva *et al*., 2007; Sousa *et al*., 2012).

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Cutting fluids are used in machining processes for several reasons but mostly to lubricate the chip tool interface and/or to cool the cutting tool. Either of these two functions affects the temperature generated and may also affect the partition of heat. In general, vegetable-based cutting fluids (VBCF) have demonstrated a superior performance by reducing tool wear, surface roughness, and shear forces, which improves the surface finish and part dimensions as well as the tool life (Xavior and Adithan, 2009). Owing to the trend of decreasing or even eliminating the use of cutting fluids containing oil, VBCF have become an alternative that are less harmful to the environment and operator. This study evaluates the effects of the use of some edible oils as cutting fluids in drilling gray cast iron.

Gray iron was chosen for this study because of its structural characteristics. It presents a relatively large portion of the carbon in a free state in the form of flake graphite and the other portion in the form of Fe_3C, which combine to create good machinability concerning the type of chip formed.

2. EXPERIMENTAL PROCEDURES

In this study, cylinders of gray iron with dimensions of 20 mm in diameter and 40 mm in length was used as the test specimen (TS) in the drilling tests. During the drilling process, dry and applying cutting-fluid (vegetable-based fluids; Table 1), temperatures on the outside of the specimen were measured using three type K (CrAl) thermocouples with 2 m 30 AWG gauge wires insulated by Teflon (Omega). The data acquisition system AGILENT 34970A was used to adquire the temperatures. The specimens were ground and cleaned before the thermocouples were fixed to their surfaces equidistantly (at 10 mm, 20 mm, and 30 mm) and longitudinally along the length of the TSs (Fig. 1a).

Figure 1. 1a) Fixing equidistant thermocouples. 1b) Capacitive-welding materials used. 1c) Refractory concrete sifted.

To isolate the samples from the environment, inhibiting heat exchange, and ensure the stabilization of the thermocouples attached longitudinally, refractory concrete Castibar AL-87 [composition: Al_2O_3 (87%), SiO_2 (6%), Fe_2O_3 (0.3%) and 6% CaO Apparent Specific Gravity (MEA) = 2.80 g/cm³; Linear Dimensional Change (VDL) to 815 ºC = -0.2% Water kneading L/100 kg = 12; Compressive Strength (RC) at 110 °C = 60 Mpa Maximum Temperature of Use (TMU) = 1680 °C] was used during the tests. The concrete was sieved to optimize conditions for its embedding within the casing after kneading it in water (Fig. 1c).

The samples were embedded in an enclosure made of Tecnyl composed of an outer cylinder, a cover and a base. The system was prepared, and its dimensions are provided in Figure 2. The cutting fluids were applied using a device for intravenous drug infusion (buret) with a flow rate of 9.5 ml / min, for a total use of 19 ml. The cutting parameters were constant, cutting speed v_c of 7.48 m/min and a feed speed v_f of 37.5 mm/min. As the cutting tool, it was selected a HSS twist drill with a diameter of ¼ in (6.35 mm).

The specimen was machined for 60 s covering 45 mm (7.5 mm of outer casing cover and 37.5 mm of TS). The tests were performed using the Discover 760 reply and rejoinder CNC machining center (ROMI). During the machining operation, cutting forces (Fx, Fy, and Fz) and the torque (Mz) were measured using a rotary piezoelectric Kistler dynamometer, model no. 9265B. The temperatures (three thermocouples for each sample) were acquired for all environments tested. The seven environments tested are given in Table 1: one was a dry condition, and the others employed cutting fluid. It was also used one commercial cutting fluid, Vasco 1000, and the other fluids were edible vegetable oils. The results for canola oil and soybean oil are not presented because there were some technical problems during the tests. These fluids will be used in the future.

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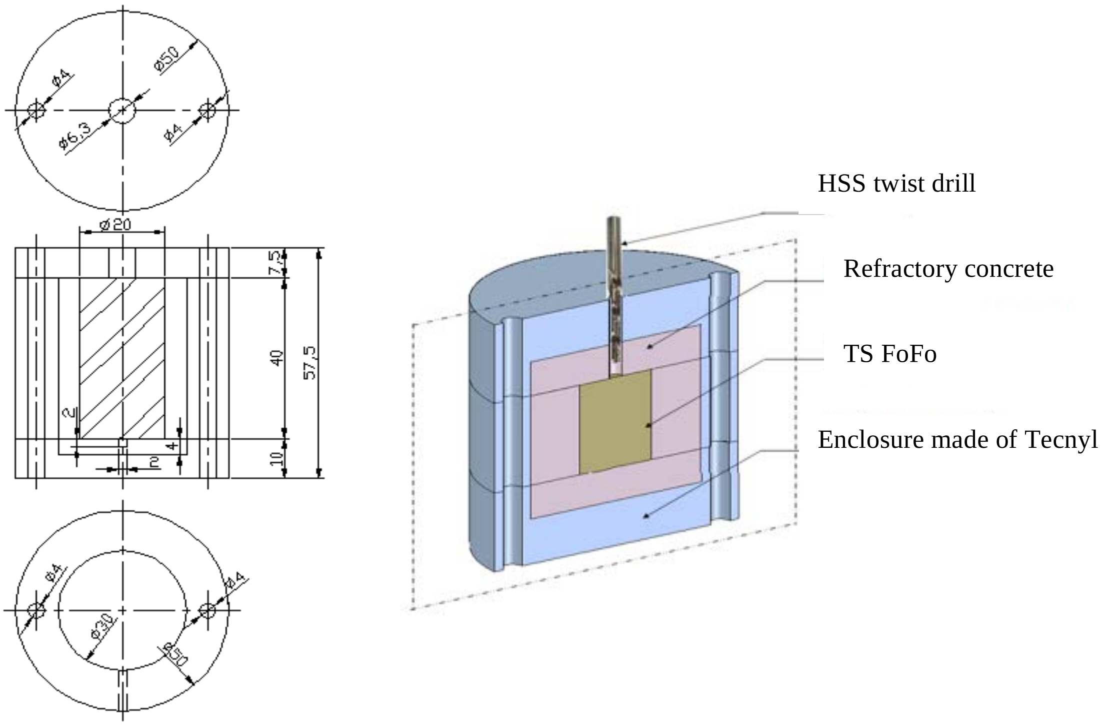

Figure 2. Samples embedded in the enclosure

Table 1. Properties of environments in which the tests were conducted (vegetable oil).

Type of Environment	Base	Source	Viscosity at 40°C	Viscosity at 60°C	Acid Value (mgKOH/g)
Fluid	Vegetal	Corn	34,69	18,44	1,083
Fluid		Babassu	28,79	14,99	0,552
Fluid		Sunflower	34,04	18,29	0,814

3. RESULTS AND DISCUSSION

Twenty-one drilling tests (three tests in each of the seven environments) were performed. The results are provided according to the average values obtained.

The tests were performed using reply and rejoinder in every tested environment. The temperature behavior in all environments tested was similar. Temperatures increased similarly in all environments (the temperature curves for canola oil and soybean oil also showed the same behavior) during the drilling process and started to fall just after the end of drilling. Figures 3-5 contain typical results for the corn oil, commercial cutting fluid, and dry conditions. The depth of all holes was 45 mm, (7.5 mm and 37.5 mm of the lid of the specimen), which was sufficient to incorporate the third thermocouple attached laterally to the samples.

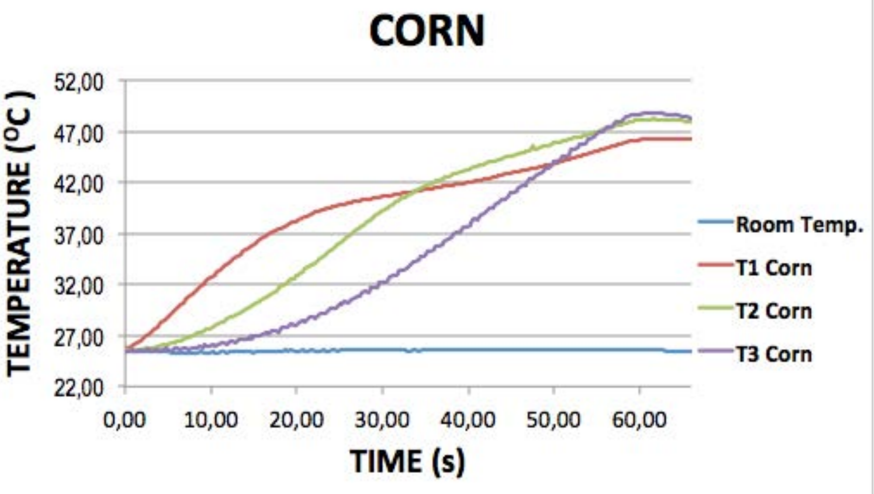

Figure 3. Comparison of the temperatures measured in all three thermocouples fixed in TSs in the corn oil environment and temperature of the test environment

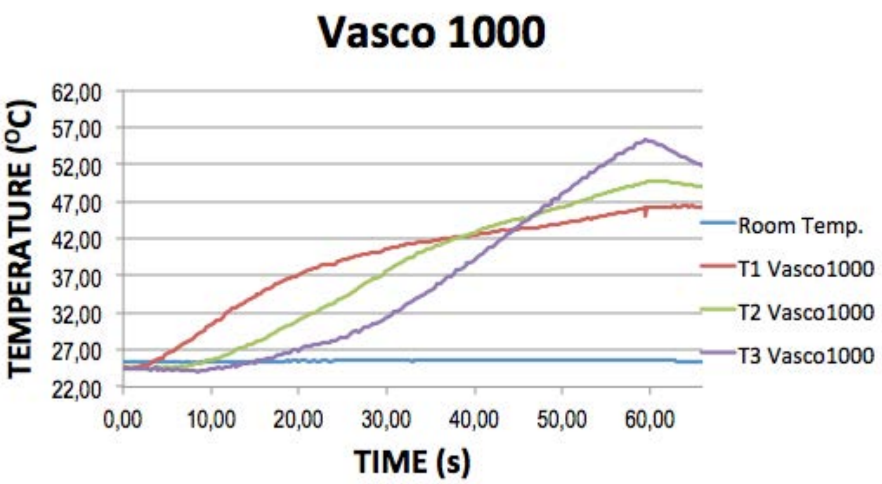

Figure 4. Comparison of the temperatures measured in all three thermocouples fixed in TSs in the commercial cutting fluid (Vasco 1000) environment and temperature of the test environment.

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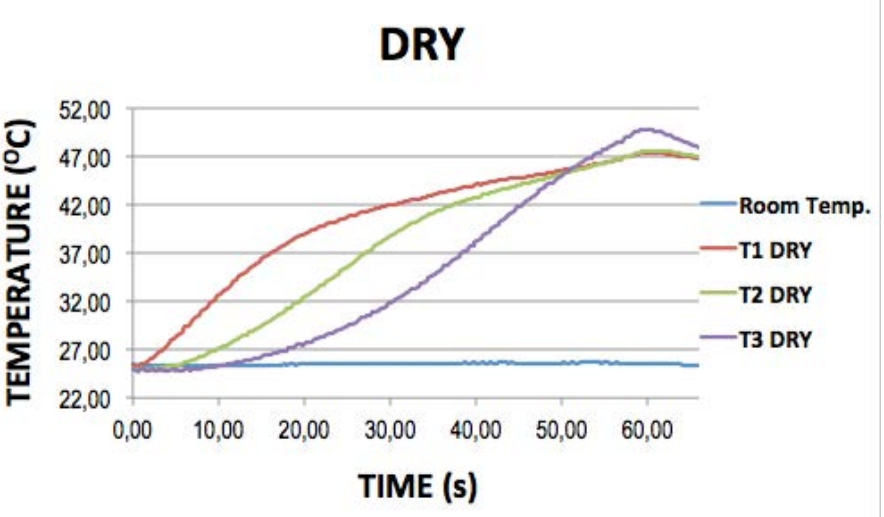

Figure 5. Comparison of the temperatures measured in all three thermocouples fixed in TSs in the dry environment and temperature of the test environment.

The maximum temperatures measured by thermocouples fixed in the TSs were obtained in each attachment position (at depths of 10 mm, 20 mm, and 30 mm, respectively) and tested environment (Fig. 6a, 6b, and 6c). For the 10 mm setting, the highest maximum (48.97 °C) and the lowest minimum (24.52 °C) temperatures as well as the largest variation between the maximum and minimum temperatures were measured in the babassu oil environment (Fig. 6a). For the same setting, the lowest maximum (46.31 °C) temperature and also the smallest variation between the maximum and minimum temperatures was measured in the corn oil environment (Fig. 6a). Among the thermocouples fixed in the second position (20 mm), the sunflower oil environment had the highest maximum (53.77 °C) temperature and the greatest (28.28 °C) variation between the maximum and minimum temperatures. For this same position, the dry environment had the lowest maximum (47.63 °C) temperature, with a reduction in the temperature of the specimen of 6.14 °C (11.5%). The results obtained for the thermocouples fixed in third position (30 mm) again showed the highest maximum (63.98 °C) temperature and the greatest variation (38.48 °C) between the maximum and minimum temperatures in the sunflower oil environment. The corn oil environment had the lowest maximum (48.79 °C) temperature for this position, also keeping the specimen about 15% colder in comparison to the sunflower environment. According to table 1, the corn oil has a higher viscosity compared to the others two vegetable oil. Viscosity is an important property when lubrication is concerned. And lubrication is the main action of a cutting fluid in such low cutting speed. Also, lubrication is important in drilling operation, as there is a need to expel the chip from the cutting zone through the flutes.

Concerning the torque moment, corn oil had the lowest average torque (1.55 Nm), followed by the commercial vegetable-based oil (1.68 Nm). These two fluids performed very close to the first and second positions of the thermocouples. The highest average torque was obtained in the sunflower oil environment (2.22 Nm), which is consistent with the higher maximum temperature obtained by the thermocouple fixed in the third position in this environment, which recorded the TS temperature as 151% (63.98 °C) higher than the room temperature (25.52 °C) of this position, whereas the corn oil environment recorded the TS temperature at 92% (48.79 °C) higher than the room temperature. Both oils were cited with worse and better performance, respectively, in terms of their coolant capacities.

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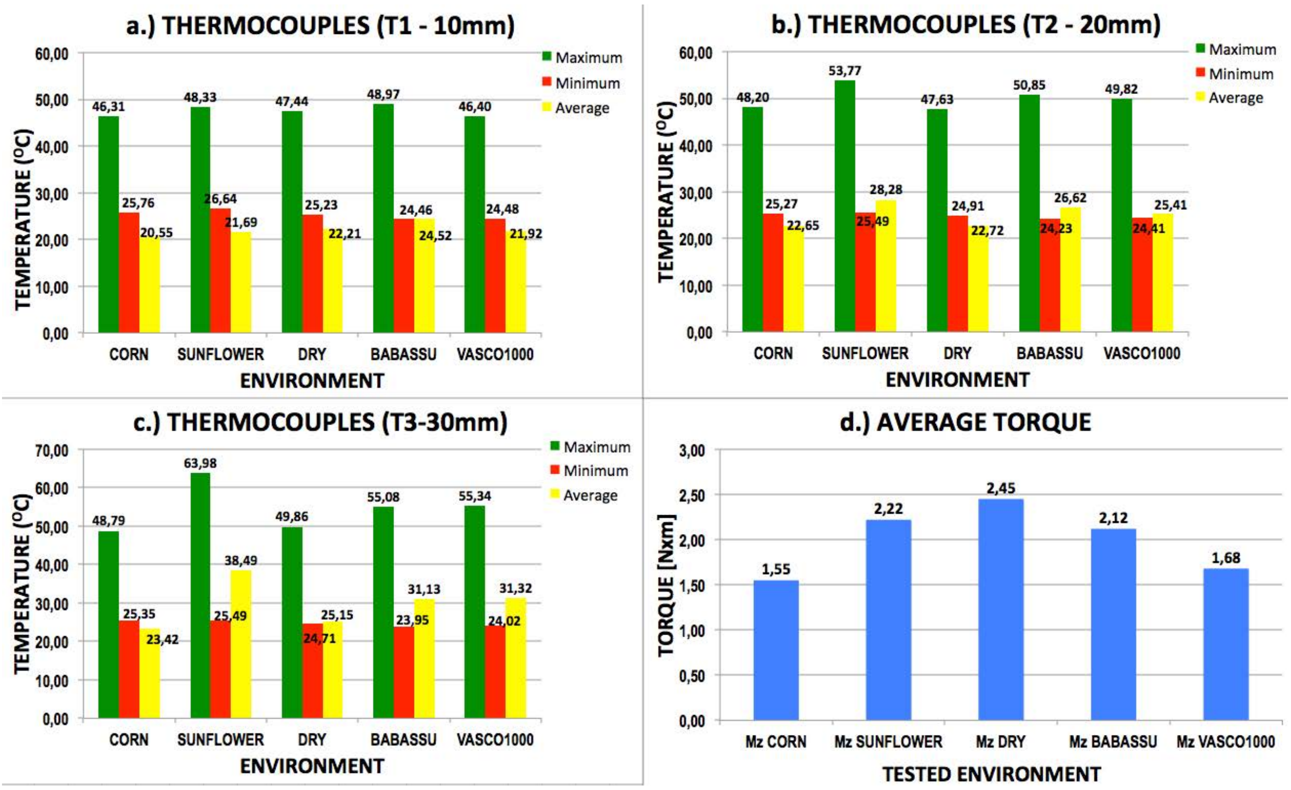

Figure 6. 6a), 6b), and 6c) present the maximum, minimum, and the variation between temperatures, according to the position of the thermocouples in each tested environment. 6d) gives the average torque values obtained in each environment tested.

The behavior of the measured temperatures in the five tested environments is provided in accordance with the position of the thermocouples attached along the length of the TSs in Figures 7a, 7b, and 7c. This temperature profile can be used for the numerical simulation of future tests because the performance curve obtained by the temperature measurements in all environments was as expected (i.e., no drop in temperature before the end of the test), confirming the ability of the structure to prevent heat exchange between the TS and the external environment. This behavior is necessary for the numerical simulation of heat distribution in the specimen using the technique of inverse problems (Sousa et al., 2012).

By analyzing the lubricating and cooling capacities of the selected fluids, the possible coolant capacity of the model used for the tests can be inferred; however, the tests need to be expanded before the lubricating capacity of this system can be obtained. Further investigations will be performed to account for errors encountered during the experiment, such as a periodic variation in the measured torque and the fact that the dry condition resulted in lower temperature at position 2

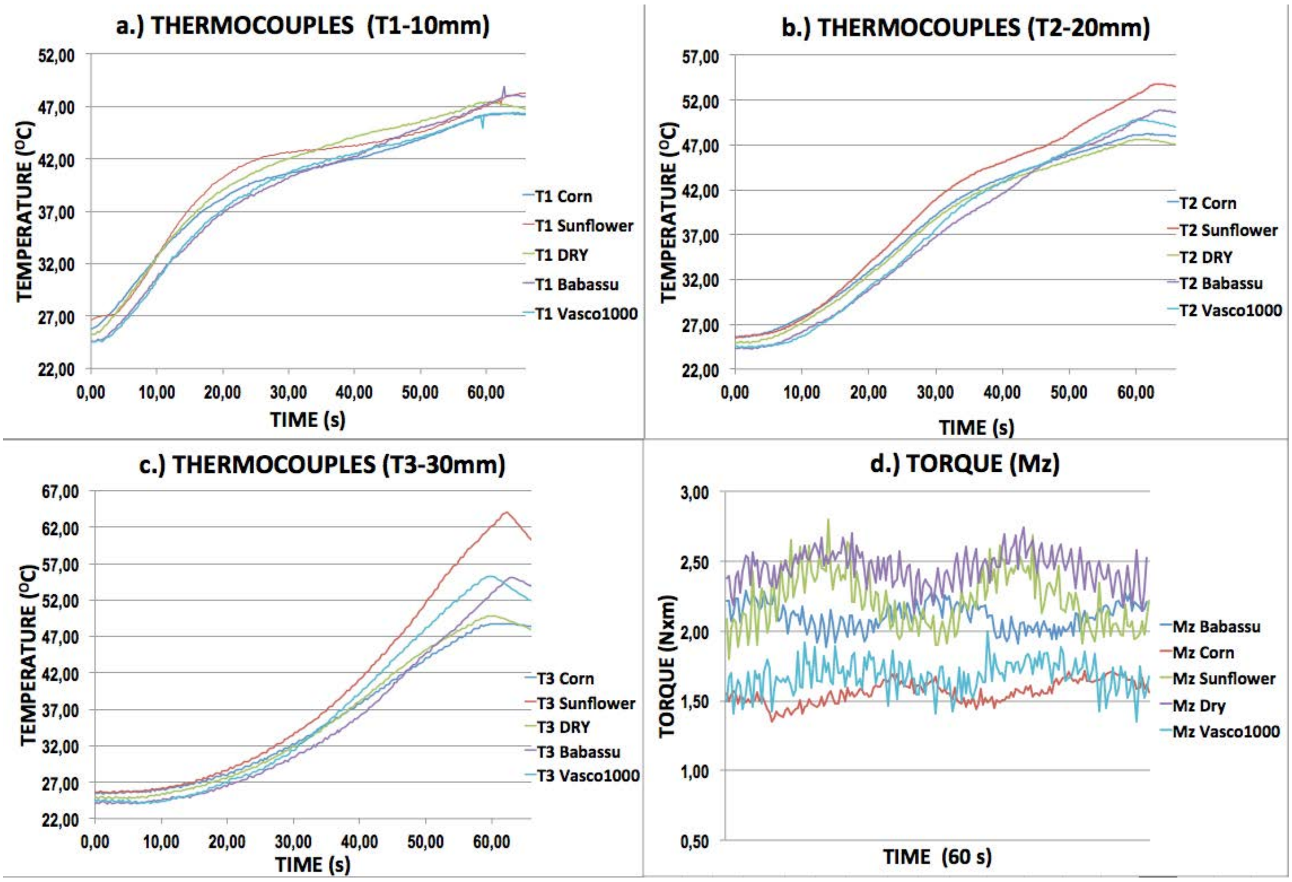

Figure 7. 7a), 7b), and 7c) present the maximum and minimum temperatures and the variance between them according to the position of the thermocouples used for measuring and comparing the two fluids. 7d) gives the torque obtained in each test environment.

4. CONCLUSION

The corn oil environment showed the best results when compared to sunflower oil, babassu oil, and Vasco 1000. A similar performance was also observed for corn oil when compared to the dry environment. Although the best choice of the machined material was the chip FoFo (the shape of which facilitates removal during the drilling process), some problems in obtaining torque and temperature were observed. The torque was lower for the cutting fluid environments than for the dry environment, although, in some tests, the temperature in the dry environment had the best performance.

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6. REFERÊNCIAS

ABUKHSHIM, N. A.; MATIVENGA, M. A.; SHEIKH, M. A. Heat Generation and Temperature prediction in Metal Cutting: A Review and Implications for High Speed Machining. *International Journal of machine Tools & Manufacture*, n. 46, p. 782-800, 2006.

FERRARESI, D. 1977. *Fundamentos da Usinagem dos Metais*. São Paulo: EdgardBlücher.

KAMINISE, A. K., GUIMARÃES, G., DA SILVA, M. B. 2012. "Influence of Tool Holder Material on Interfacial, Insert and Tool Holder Temperatures During Turning Operation of Gray Iron" In: *ASME 2012 - International Mechanical Engineering Congress & Exposition,* Houston, USA.

MACHADO, A. R.; ABRÃO, A. M; COELHO, R. T.; SILVA, M. B., 2011. *Teoria da Usinagem dos Materiais*. 2. ed. São Paulo: EdgardBlücher. 397 p.

SILVA, F. C. S. E., Marobin, D.S., DA SILVA, M. B. Efeito do Desgaste da Ferramenta na Morfologia do Cavaco no Torneamento de Aço Inoxidável ABNT 304 In: COBEF - Congresso Brasileiro de Engenharia de Fabricação, 2007, Águas de São Pedro. *IV COBEF*. , 2007. v.1. p.1 - 10

ISSN 2176-5480

SOUSA, P. F. B., Borges, V. L., PEREIRA, I. C., DA SILVA, M. B., GUIMARÃES, G. Estimation of Heat Flux and Temperature Field During Drilling Process Using Dynamic Observers based on Green's Function. *Applied Thermal Engineering*, v.48, p.144 - 154, 2012.

TRENT, E. M. and WRIGHT, P. K., 2000. *Metal Cutting*. 4. ed. Boston: Butterworths. 446p.

XAVIOR M.A., ADITHAN M., 2009. Determining the influence of cutting fluids on tool wear and surface roughness during turning of AISI 304 austenitic stainless steel. *Journal of Materials Processing Technology*. 209:900–9.

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