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# PERFORMANCE EVALUATION OF A SYNTHESIZED CUTTING FLUID BASE, MADE FROM MODIFIED GLYCERINE, USING ALUMINUM BARS IN TURNING OPERATION

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***Abstract.*** *This is a complementary work of a study initiated using 1020 steel bars, published at the "Congresso Brasileiro de Engenharia de Fabricação – COBEF 2017", under the title "Comparative analysis of the performance between conventional cutting fluids and chemically modified glycerin fluid in the turning of 1020 steels."*
*In this work, the performance of two bases made of chemically modified glycerin was evaluated and compared to different types of commercial cutting fluids (mineral, vegetable and semi-synthetic). The purpose of this work was to investigate the behavior of glycerin, after physical-chemical transformation, used as cutting fluid in turning operation. For this, the effect over the roughness of Aluminum bars was analyzed after turning operation using six different kind of fluids. These fluids were: water, commercial fluid 100% vegetable based, commercial fluid 100% mineral based, semi-synthetic, two fluids, non-commercial, made of glycerin chemically modified. Three different cut depths were used, $a_p$=0.5 mm, $a_p$=1.0 mm, $a_p$=1.5 mm, machined length (l) of l=50 mm. The initial diameter (Ø) of the steel bars was Ø=28.00 mm and the feed rate used f = 0.122 [m/min]. The turning operations were performed on a turning CNC, Romi brand, model Centur 30D. The roughness tests ($R_a$) were performed with a cut-off=0.80mm and length l = 4.00mm. The equipment used was a Taylor Hobson rugosimeter, model Suntronic s128 and the tests were performed inside the machining laboratory of the Pontifical Catholic University of Minas Gerais - PUC-MG.*

*Results showed that the fluid made of glycerin chemically modified presented similar performance when compared to the commercial fluids, in some conditions the results were even better. This work indicated the possibility of formulating a cutting fluid with complementary additives using modified glycerin. Subsequently, complementary studies shall be carried out with this new fluid to evaluate the physic-chemical behavior of this new product in order to guarantee the quality of the product.*

***Keywords*** *turning operation, machining, cutting fluid, glycerin, aluminum*

## 1. INTRODUCTION

The production of biodiesel is made by the transesterification process (vegetable oil, methanol and catalysts), generating biofuel, as well as glycerol, also known as crude glycerin. In the last decade, with the significant increase in biodiesel production, there has been also a dizzying increase in the generation of glycerin as co-product of this process. It was estimated that from 2008 to 2010, glycerol production around the world has practically doubled to 250,000 tons, making it unfeasible to absorb this product in the market due to oversupply. Currently, the most destination of this glycerin is to be discarded in rivers (Fernandes, 2017, apud Vera *et. al*, 2011) or be burned in blast furnace (Cordoba, 2016), generating relevant environmental impact (Fernandes, 2017, apud D'Avino *et. al.*, 2015).

An alternative idea for the destination of this glycerin would be using it as vegetable base for the development of cutting fluids used in machining operations. The cutting fluids are liquid or gaseous elements and perform several specific functions, being the four principals: lubrication, refrigeration, anti-oxidation and removal of chips. Costs associated with the use of these inputs typically range from 7 to 17% of total costs production. It is a significant amount if compared, for example, to the 4% of tool costs (Fernandes, 2017, apud King *et. al.*, 2011).

Cutting fluids role, a very important play in machining operations, what has already been widely studied and supported by the abundant bibliography available for the subject. They influence not only the quality of the produced pieces, but also the tool set (Machado *et. al.*, 2009; Xavior, Adithan, 2009 and Silva *et. al.*, 2011). The fluids help to lubricate bearings and prevent the deposition of tailings between the rolling parts of the machine, thus preventing its premature wear. Inside the factory of Fiat Chrysler Automobiles – FCA it could be determined that dry machining accelerates the machine´s wear increasing maintenance time. Cutting fluids are also relevant for the surface integrity of the machined piece (Lawal, 2014) and in some cases, can the determinant in quality of a process.

Using glycerin as an input for the production of cutting fluid can be feasible both economically and technically. Winter et al. (2012) successfully used glycerol as Metal Working Fluid – MWF on a grinding machine process. D´avino et. al. (2015) searched environmental benefits of crude glycerin, co-product in biodiesel production, in metal working fluid formulation. Important to emphasize that previous tests, started analyzing fluids behavior under the same conditions, but using 1020 Steel bars (Fernandes et. al 2017), demonstrated good results using chemically modified glycerin as cutting fluid, where good roughness values could be found in the 1020 steel bars turning operation.

Since crude glycerin is actually a reject being discarded as a waste, it could be a good input for producing MFW, with a high potential for being an environmental friendly product and having economic advantages, especially because of its low market value. In this way, the main objective of this work is to evaluate find complementary studied in how the glycerin behaves when turning aluminum parts. Here also the fluid was made by the *Grupo de Tecnologias Ambientais-GUTAM* of the *Universidade Federal de Minas Gerais - UFMG*. Based on the preliminary results of this study, further works will be done with the main goal to use the crude glycerin to develop a new MWF in the near future. The procedures adopted to make this evaluation are described below.

## 2. MATERIALS AND METHODS

### 2.1 Materials and equipaments

For the accomplishment of this work, the following materials were used:

1) Six different cutting fluids: mineral water (I), commercial fluid, 100% vegetable based (II), 100% mineral based (III), semisynthetic (IV), synthesized from glycerin, "A" (V) and "B" (VI);
2) Six aluminum bars with total length of $l = 185mm$, initial diameter $\emptyset = 28.00\ mm$;
3) Six inserts Kyocera, TNMG 160404 AH KW10.

Operations were performed on a CNC turning, Romi brand, model Centur 30D. The concentration of the emulsifiable fluids (II, III and IV), as well as of the bases synthesized from the glycerol (V and VI), were adjusted in 10% and measured using a Atago bench refractometer, serial number 80017. $R_a$ roughness criteria were measured using a digital rugosimenter, Taylor Hobson brand, model Suntronic s128.

### 2.2 Experimental methods

The methodology in this work is the same as in Fernandes (2017). Turning of aluminum bars was performed with shear rate, $v_c = 339\ m/min$ at *4000 RPM*. The feed rate was determined at $f = 0.122\ m\ /\ min$. A pass with length $l = 50mm$ was performed, varying the depth of the cut defined in: $a_{p1}=1,5mm$, $a_{p2}=1,0mm$ and $a_{p3}=0,5mm$, according to the scheme of Fig. 1.

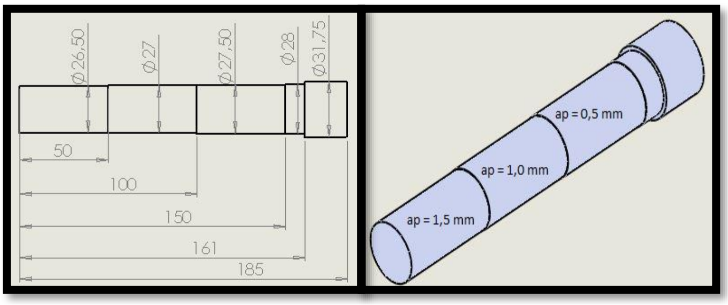


Figure 1. Final diameter of the aluminum bars (left) and depths of cut (right.)

Each one of the six bars were machined using one of the fluids (I to VI). Emulsifiable fluids (II, III and IV) were adjusted at a concentration of 10% and the synthesized bases (V and VI) were mixed in water in a ratio of 10% of base with 90% of fresh water. After the turning operations, the roughness *Ra* were measured with a digital rugosimeter and using the following parameters: *cut-off=0.80* mm and *l=4.00 mm*. For each distinct depth of cut (*ap*), three roughness measurements were taken separated by an angle of 120º, in order to avoid false results. The mean of the three values for each *ap* was calculated. Figure 2 shows the way that fluid was applied. Since the cutting fluid amount was limited, there was no control about pressure and mass flow.

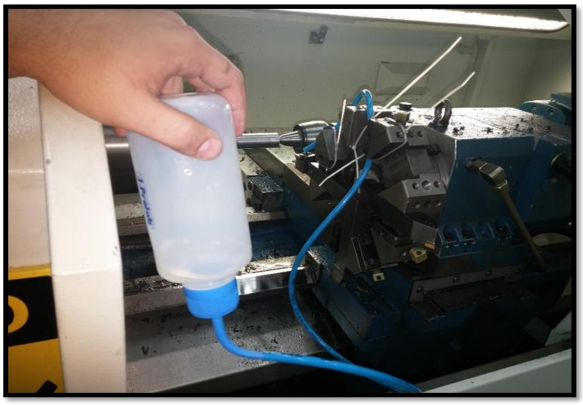

Figure 2. Schematic for applying cutting fluid over the tool edge

## 3. MATERIALS AND METHODS

Table 1 shows the machining parameters used during turning operation of aluminum and Fig.3 shows roughness measured ($R_a$ and $R_z$) obtained from the tests in Tab. 2 to Tab. 7.

**Table 1. Turning operation parameters**

| **Cutting Speed *Vc* [m/min]** | **Feed rate *f* [mm/min]** | **Rotation [rpm]** | **Diameter Ø [mm]** |
|---|---|---|---|
| 339 | 0,12 | 4000 | 28 |

TABLE 2 - TURNING - ALUMINUM - H2O

| | Ap (0,5 mm) | | Ap (1,0 mm) | | Ap (1,5 mm) | |
|---|---|---|---|---|---|---|
| | Ra [µm] | Rz [µm] | Ra [µm] | Rz [µm] | Ra [µm] | Rz [µm] |
| H20 (I) | 1,18 | 6,41 | 1,35 | 6,90 | 1,56 | 8,44 |
| | 1,19 | 6,20 | 1,39 | 7,59 | 1,57 | 7,75 |
| | 1,21 | 6,25 | 1,51 | 8,19 | 1,47 | 7,34 |
| **AERAGE** | **1,19** | **6,29** | **1,42** | **7,56** | **1,53** | **7,84** |

TABLE 3 - TURNING - ALUMINUM - 100% MINERAL

| | Ap (0,5 mm) | | Ap (1,0 mm) | | Ap (1,5 mm) | |
|---|---|---|---|---|---|---|
| | Ra [µm] | Rz [µm] | Ra [µm] | Rz [µm] | Ra [µm] | Rz [µm] |
| 100% MINERAL (III) | 1,2 | 6,16 | 1,43 | 7,57 | 1,46 | 7,23 |
| | 1,23 | 6,31 | 1,14 | 6,1 | 1,68 | 9,28 |
| | 1,23 | 6,46 | 1,32 | 6,98 | 1,37 | 6,93 |
| **AVERAGE** | **1,22** | **6,31** | **1,30** | **6,88** | **1,50** | **7,81** |

TABLE 4 - TURNING - ALUMINUM- (SEMI-SYNTHETIC)

| | Ap (0,5 mm) | | Ap (1,0 mm) | | Ap (1,5 mm) | |
|---|---|---|---|---|---|---|
| | Ra [µm] | Rz [µm] | Ra [µm] | Rz [µm] | Ra [µm] | Rz [µm] |
| SEMI-SYNTHETIC(IV) | 1,2 | 6,35 | 1,48 | 7,58 | 1,31 | 6,88 |
| | 1,19 | 6,1 | 1,29 | 8,65 | 1,61 | 8,32 |
| | 1,18 | 6,09 | 1,51 | 7,14 | 1,99 | 8,78 |
| **AVERAGE** | **1,19** | **6,18** | **1,43** | **7,79** | **1,64** | **7,99** |

TABLE 5 - TURNING - ALUMINUM - 100% VEGETAL

| | Ap (0,5 mm) | | Ap (1,0 mm) | | Ap (1,5 mm) | |
|---|---|---|---|---|---|---|
| | Ra [µm] | Rz [µm] | Ra [µm] | Rz [µm] | Ra [µm] | Rz [µm] |
| 100% VEGETAL (II) | 1,2 | 6,54 | 1,38 | 7,4 | 1,34 | 7,46 |
| | 1,23 | 6,77 | 1,24 | 6,6 | 1,67 | 8,47 |
| | 1,26 | 6,55 | 1,44 | 7,99 | 1,6 | 7,69 |
| **AVERAGE** | **1,23** | **6,62** | **1,35** | **7,33** | **1,54** | **7,87** |

TABLE 6 - TURNING - ALUMINUM - GYCERIN "A"

| | Ap (0,5 mm) | | Ap (1,0 mm) | | Ap (1,5 mm) | |
|---|---|---|---|---|---|---|
| | Ra [µm] | Rz [µm] | Ra [µm] | Rz [µm] | Ra [µm] | Rz [µm] |
| GLYCERIN "A" (V) | **1,23** | **6,93** | **1,43** | **7,29** | **1,15** | **6,32** |
| | 1,07 | 5,82 | 1,31 | 6,63 | 1,51 | 7,51 |
| | **1,1** | **5,81** | **1,35** | **7,37** | **1,42** | **7,33** |
| **AVERAGE** | **1,13** | **6,19** | **1,36** | **7,10** | **1,36** | **7,05** |

TABLE 7 - TURNING - ALUMINUM - GYCERIN "A"

| | Ap (0,5 mm) | | Ap (1,0 mm) | | Ap (1,5 mm) | |
|---|---|---|---|---|---|---|
| | Ra [µm] | Rz [µm] | Ra [µm] | Rz [µm] | Ra [µm] | Rz [µm] |
| GLYCERIN "B" (VI) | 1,39 | 7,98 | 1,29 | 7,49 | 1,9 | 9,63 |
| | 1,27 | 7,05 | 1,44 | 7,24 | 1,54 | 8,12 |
| | 1,37 | 7,16 | 1,3 | 6,9 | 1,28 | 0 |
| **AVERAGE** | **1,34** | **7,40** | **1,34** | **7,21** | **1,57** | **5,92** |

Figure 3. Roughness ($R_a$ and $R_z$) for turning operation using Al-Si, Fluids I to VI.

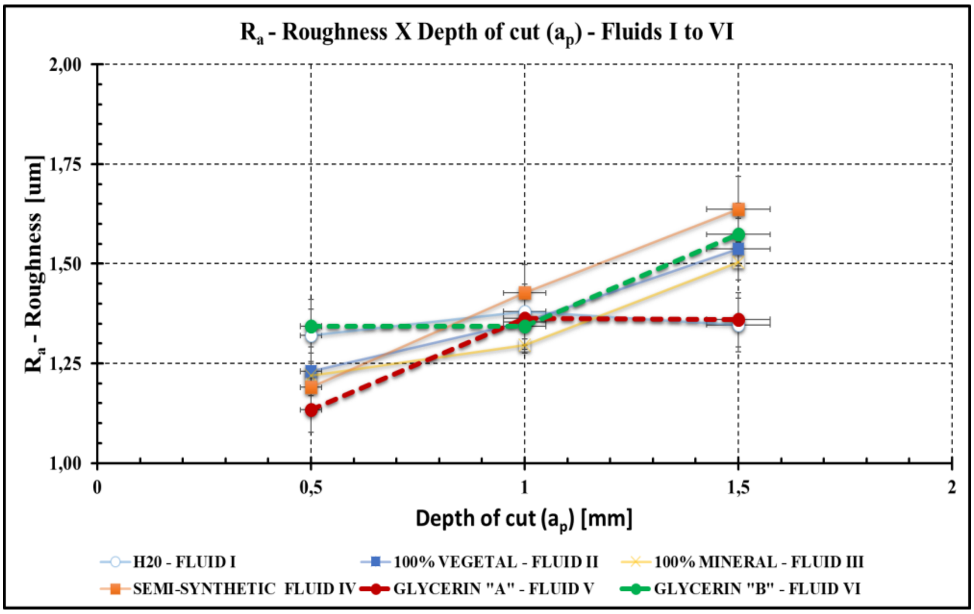


Figure 4. Roughness ($R_a$ ) X Depth of cut ($a_p$) for turning operation using Al-Si, Fluids I to VI.

The results obtained, in ascending order, of Ra values, for the fluids from I to VI according to each depth of cut:

a) **Depth of cut (ap=0,5mm):** Glycerin "A" (*Ra=1,13um*); semi-synthetic(*Ra=1,19um*); 100% Mineral (*Ra=1,22um*); 100% Vegetal (*Ra=1,23um*); $H_2O$ (*Ra=1,32um*); Glycerin "B" (*Ra=1,34um*).

b) **Depth of cut (ap=1,0mm):** 100% Mineral (*Ra=1,30 um*); Glycerin "B" (*Ra=1,34um*); Glycerin "A" (*Ra=1,36um*); H2O (*Ra=1,38um*); 100% Vegetal (*Ra=1,35um*); semi-synthetic (*Ra=1,43um*).

c) **Depth of cut (ap=1,5mm):** $H_2O$ (*Ra=1,35um*); Glycerin "A" (*Ra=1,36um*); 100% Mineral (*Ra=1,50um);* 100% Vegetal (*Ra=1,54um*); Glycerin "B" (*Ra=1,57um*); semisynthetic (*Ra=1,64um*).

Results obtained for the fluid based on Glycerin "A" (V fluid) presented good roughness values of Ra in relation to the other fluids, having similar performance to the 100% mineral based fluid. The V fluid had the lowest values of Ra with cut depth of 0.5 (*Ra=1,13um)*. On the other hand, the glycerin based fluid "B" presented a not so good performance compared to the other fluids. It is noteworthy that this fluid becomes biphasic almost instantaneously after shaking, which can make a negative effect over the tool chip interface, since the effects of lubricity may not have acted properly, but it isn´t enough to discard the possible of using modified Glycerin "B" to formulate cutting fluids. In relation to *Rz* roughness, Fig. 5 shows the results obtained from Tab. 2 to 7 for the roughness values in the aluminum turning.

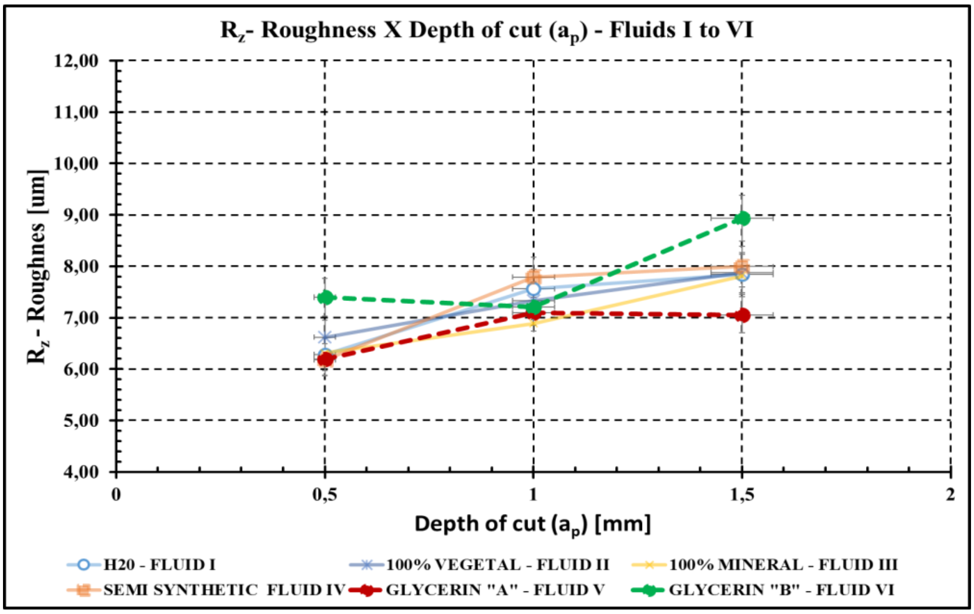


Figure 5. Roughness (*Rz* ) X Depth of cut ($a_p$) for turning operation using Al-Si, Fluids I to VI.

The results obtained, in ascending order, of *Rz* values, for the fluids from I to VI, according to each depth of cut:

a) **Depth of cut (ap=0,5mm)**: Semisynthetic (*Rz=6,18 um*); Glycerin "A" (*Rz=6,19 um*); H2O (*Rz=6,29 um*); 100% Mineral (*Rz=6,31 um*); 100% Vegetal (*Rz=6,62 um*); Glycerin "B" (*Rz=8,93 um*);.

b) **Depth of cut (ap=1,0mm):** 100% Mineral (*Rz=6,88 um*); Glycerin "A" ( *Rz=7,10 um*); Glycerin "B" (*Rz=7,21 um*); 100% Vegetal (*Rz=7,33 um*); H2O (*Rz=7,56 um*); Semisynthetic (*Rz=7,79 um*);.

c) **Depth of cut (ap=1,5mm):** Glycerin "A" (Rz=7,05 um); 100% Mineral ( *Rz=7,81 um*); H2O (Rz=7,84 um); 100% Vegetal (*Rz=7,87 um*); Semisynthetic (*Rz=7,99 um*);. Glycerin "B" (*Rz=8,93 um*);

Values presented in *Rz* basically had the same behavior as in *Ra* values. Once again glycerin "A" (fluid V) had good results for all the circumstances. Glycerin "B" had the poorest results, exception for ap=1,0mm, but it to confirm this tendency other tests should be done.

## 4. CONCLUSIONS

Based on the roughness results obtained from the machining tests there is an evidence, albeit preliminarily, that cutting fluids developed from inputs such as glycerin have potential to be used in general machining processes. The bars machined with V fluid, glycerin "A", presented interesting roughness values, having even higher performance than other commercial fluids already widely used by market. The fluid VI, glycerin "B", in turn, did not obtained good results, presenting the worst values of roughness. It becomes biphasic almost instantaneously after shaking, which could have made a negative effect over the tool chip interface, since the effects of lubricity may not have acted properly. The results for aluminum bars were basically the same as for the 1020 steel bars executed before.

From the results of this work, the *Grupo de Tecnologias Ambientais – GRUTAM* of the *Departamento de Química da* UFMG, in partnership with other institutions and related companies, will continue the development of a cutting fluid using chemically modified glycerin. The idea in a first step is to develop a useful base for a cutting fluid from pure glycerin. After exhaustive mechanical and chemical works in MWF made of glycerin the next step will be to pass to the use of the so-called crude glycerin, which can be obtained as a reject from the biodiesel production process, and then to elaborate a new cutting fluid. Further testing and analysis, both mechanical and chemical, of this new product will be carried out in a timely manner to guarantee the quality of the product.

## 5. ACKNOWLEDGEMENTS

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