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CHEMICAL AND RHEOLOGICAL CHARACTERIZATION OF A VEGETABLE-BASED EMULSION

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Abstract. *The initial objective of this study is to characterize a vegetable-based emulsion that will be used in the lubrication-cooling in the jet lubrication and MQL (Minimum Quantity of Lubricant) methods. Some tests were performed using a viscometer where the kinematic and dynamic viscosities were measured, as well as the specific mass of the emulsion at different temperatures and concentrations. In this sense, different tests will be proposed in order to analyze the reduction of the coefficient of friction between the tool and the sample during machining and to study the degree of wettability of the emulsion in some types of Cast Iron in order to find the best scenario for its use. Considering its composition with organic base the fluid in question is an excellent alternative to be applied as cutting fluid (CF) since its disposal can be carried out more easily and with less damage to the environment compared to the synthetic fluids that are usually used in this machining.*

Keywords: *Vegetable-based, Emulsion, MQL, Organic, Cast Iron*

1. INTRODUCTION

During the machining process, a large amount of heat is generated due to friction between the tool and workpiece. This causes the materials involved in the process to undergo thermal expansion, a fact that corroborates premature tool wear and thermal crack generation. To transform this scenario, Frederick Winslow Taylor was one of the pioneers in the search for methods that optimized the machining process. In his water tests, he noted that he could increase the cutting speed by more than 30% without any premature tool wear compared to dry testing.

Subsequently, the demand for cutting fluids capable of optimizing the most varied machining scenarios has increased considerably, as their main functions are lubrication, cooling, removal, contaminant removal, temperature control and corrosion in order to increase tool performance. (Stoeterau, 2004; De Oliveira and Alves, 2006; Mang and Dresel, 2007).

Most cutting fluids used in the industry are based on minerals as they have several important machining characteristics and are relatively inexpensive compared to synthetic ones, which are superior to minerals in some respects as the higher maintainability of their machining. physical properties under stress (Upadhyay, 2012). However, they present low biodegradability and considerable toxicological potential as pointed out by (Skovic, 2001).

To minimize environmental impacts, dependence on non-renewable sources and, especially, the risks involved in the production process caused by this type of lubricant (Jiang et al., 2008), herbal fluids have proven to be a viable and sustainable alternative to this scenario.

In this context, this work aims to characterize a vegetable emulsion focusing on the use as cutting fluid in two different application types, jet and MQL (Minimum Quantity of Lubricant).

2. METHODOLOGY

Fig. 1 shows the stages of the experimental procedure, which are divided into carried out and future

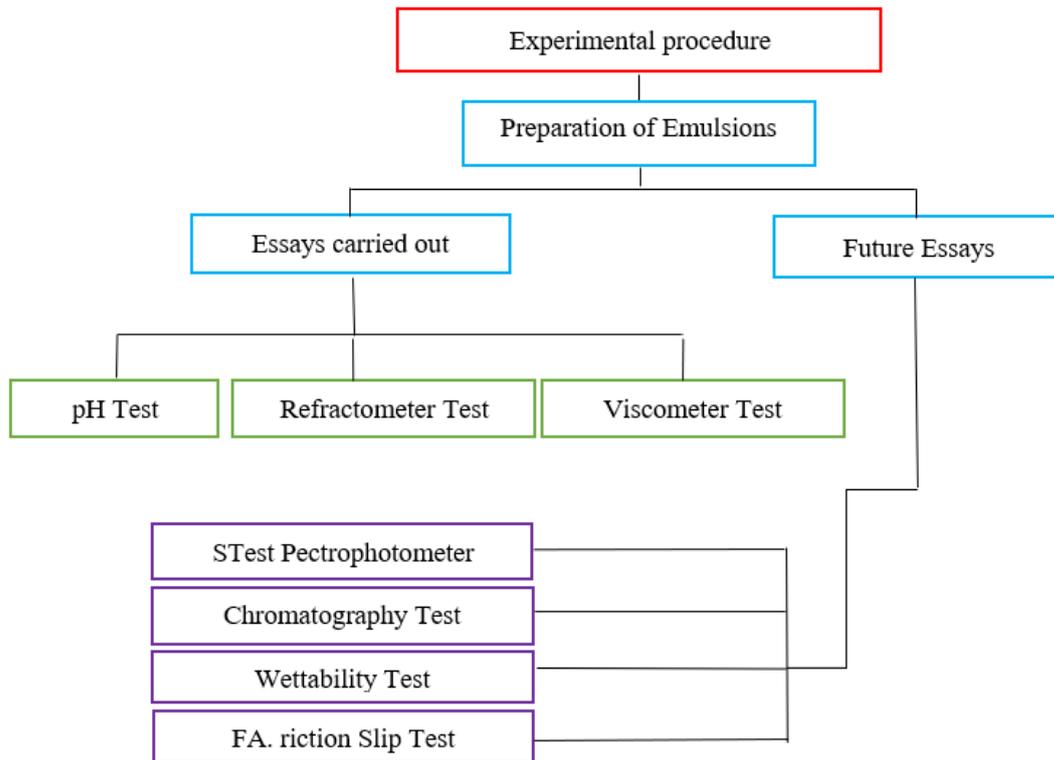


Figure 1. Flowchart of the experimental steps.

2.1. pH test

The pH (Hydrogenionic potential) of a cutting fluid is an important parameter that should be evaluated in the process, since it is directly related to undesirable events such as oxidation and contamination by microorganisms that cause fluid degradation and consequent loss of its characteristics (TRIM, 2006). A fact that affects the efficiency of the fluid, the finishing of the workpiece and the tool life. The decrease of pH is intimately linked to the proliferation of microorganisms in emulsifiable cutting fluids since its metabolic activities are responsible for the generation of acids (mostly carbonic acid) and CO₂.

For a good performance of the cutting fluids, the pH should be constantly monitored, since the control contributes to an increase in the lifetime of the emulsions, decreases the disposal and consequently the Environmental degradation.

The tests were performed at the IQ-UFU research laboratory using the PG1800 Digital ph-meter at an ambient temperature of 25 ° C. After calibration of the instrument according to the manufacturer's manual, the pH of the three solutions and the pure fluid was measured. The records were carried out after stabilization of the value delivered by the appliance. Also, at the end of each measurement, the electrode was cleaned with distilled water and dried by a paper in order to remove the excess solution. Fig. 2 shows the equipment used.

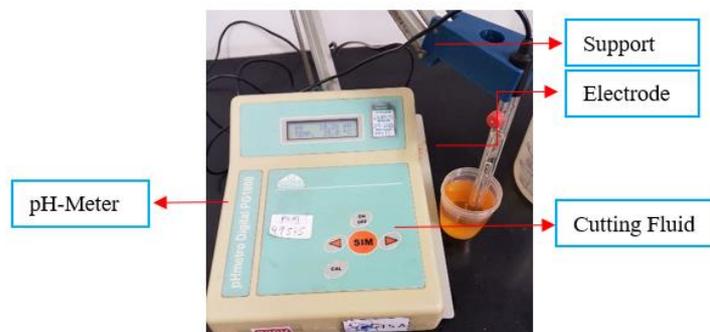


Figure 2. PH-Meter used in the tests.

2.2. Refractometer Test

The emulsion concentration is an important process variable that should be checked periodically as it avoids undesirable situations in machining such as surface finishing problems, higher risk of microbiological contamination, decreased life of the tool, the efficiency of CF in addition to the risks to the operator's health as a higher risk of nebulization, irritation of the skin and airway.

The tests were performed in the research laboratory LEPU-FEMEC using the analogue refractometer RH32 with error scale of ± 0.3 Brix at an ambient temperature of 20 °C. After the calibration of the instrument using distilled water, the BRIX grade of the three solutions and the pure fluid were measured. At the end of each measurement, the prism was cleaned with distilled water in order to remove the excess solution. Fig.3 in the shows a schematic of a refractometer.



Figure 3. Scheme of RH32 refractometer.

Available from: <https://ru.aliexpress.com/item/Handheld-Portable-2-in-1-Brix-salinity-refractometer-0-32-brix-0-28-salinity-with-Auto/32806012771.html>

2.3. Viscometer Test

A cutting fluid besides good coolant should have good lubrication capacity coupled with a good detergency so that the cutting surface is free of chips generated in the process, these characteristics are directly related to their viscosity (measure of resistance of the liquid to the slip at a given temperature) and consequently to its Viscosity index (VI), which evaluates the viscosity variation with the increase of temperature, the higher For its most stable index becomes the fluid (SANTOS, 2017).

For the viscosity, tests used the stabinger viscometer SVM 3000 which gauge the specific mass ($\frac{g}{cm^3}$), kinematic ($\frac{mm^2}{s}$) and dynamic viscosity ($mPa \times s$) of a fluid. The Viscometer was calibrated according to the manual of the fabricant. Four measurements were made for each temperature and at the end of the tests, the equipment was cleaned with a solvent suitable for this. The FIG.4 of them shows a model of the equipment used in the tests.



Figure 4. Model of Viscometer used in the tests.

Available from: <https://ortus.rtu.lv/science/en/innovations/133>

2.4. Spectrophotometer test (Future)

Spectrophotometry is a technique that can be used to perform a follow-up of the fluid absorbance in order to verify a possible alteration in its chemical properties. The test consists of the emission of light by a lamp that will pass through a monochromator and then by the sample where part of it is absorbed, the remaining light photons reach a detector that will receive the data and send to a computer that it transforms the signal received in absorbance data. The first Test will provide an absorbance value which will be set as the default for the emulsions in question so if this value changes over time will

be evidence that there has been a change in the chemical composition of the fluid. Fig. 5 shows the schematic of a Spectrophotometer.

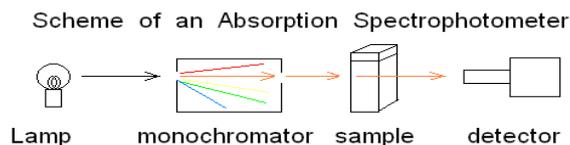


Figure 5. Simplified scheme of the absorbance Spectrophotometer.
Available from: http://biochimica.bio.uniroma1.it/AdvancedCourses/L04_NoveHrady2016.htm

2.5. Chromatography Test (Future)

Gas chromatography, coupled to mass spectrometer is a technique that can be used to know how bacterial contamination and natural degradation alter the molecular chains of cutting fluid.

In order to perform the experiment, two distinct chemical species were selected, being one the stationary phase and the other the mobile phase, these substances are chosen based on the chemical affinity of the sample with each one. The sample is then vaporized and introduced together with the mobile phase that passes through the chromatographic column that contains at the end a detector that identifies and quantifies the exit of the column. This detector is coupled to a computer that makes the treatment of noises and signals in order to assemble a curve where the sample composition will be studied. Fig. 6 presents a gas chromatography scheme.

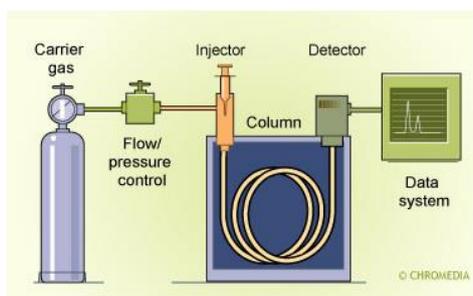


Figure 6. Simplified scheme of Gas Chromatography.

Available form:

<http://www.chromedia.org/chromedia?waxtrapp=xqegzCsHiemBpdmBIIEcCzB&subNav=tlpbfDsHiemBpdmBIIEcCzBsB>

2.6. Wettability test (Future)

The wettability test evaluates the degree of wetting between a fluid and a surface and is directly linked to the chemical affinity of the two. The test consists of dropping a drop of CF on the material that will be machined and measuring the contact angle formed between a plane tangent to a drop and a plane containing the surface of the material, and the smaller this angle is the greater will be the degree of wetting of the fluid on this surface, extremely important during machining because if the angle is large the fluid does not spread well on the surface of the material, and there will be deficiency in lubrication and refrigeration of the part as there are points that will be dry-machined. Fig.7 in the shows how the angle of contact between the fluid and workpiece is measured.

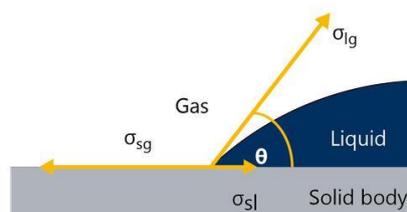


Figure 7. Measurement of Contact Angle.

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wiki.eecs.umich.edu/wiki/index.php?title=Contact_angle_measurements&mobileaction=toggle_view_desktop

2.7. Friction slip Test (Future)

This Technique aims to evaluate the reduction of static and dynamic friction coefficients between the two materials in order to evaluate the lubricity of the fluid.

3. RESULTS

The results of the tests performed (Fig. 1) described in the methodology (2.1; 2.2; 2.3) will be discussed.

3.1 pH Test

The results of all tests showed pH values above 8.5, that is, alkaline which guarantees the bactericidal properties of the fluid, and makes it difficult for the pH to become acidic (below 7) during machining. Tab. 1 shows the results obtained at an ambient temperature of 25° C.

Table 1. Experimental Results for PH tests in emulsions.

Cutting Fluids evaluated	pH
Pure cutting Fluid	10.51
50% Cutting Fluid	10.26
25% Cutting Fluid	9.99
10% Cutting Fluid	9.68

3.2 Refractometer Test

To interpret the data, the test was performed as pure fluid to measure the BRIX degree, and then the procedure for the solutions was repeated. The objective is to evaluate whether the prepared solutions were correct whether there was any variable that interfered in the dissolution, such as human error or some alteration in the fluid. Tab. 2 shows the data obtained.

Table 2. Experimental Results for refractometer test in fluids.

Cutting Fluids evaluated	% BRIX	Error (%)
Pure curtting Fluid	22.4 ± 0.3	0
50% Cutting Fluid	10.2 ± 0.3	-0089
25% Cutting Fluid	6.2 ± 0.3	+ 0107
10% Cutting Fluid	4.2 ± 0.3	+ 0.25

After data treatment, it was possible to perceive that there was an increase in the deviation of the value that occurred in the sense of the reduction in the percentage of fluid present in the solution. This difference may have been caused by the accuracy of the equipment since the solutions were prepared by the mass percentage method using a balance with precision of four decimal places (where the specific mass was measured in a viscometer using as the basis of the same temperature as the Refractometer test would be performed) and all the solutions were stored under the same conditions.

It Is noteworthy that the solutions with the highest amount of water are more prone to increase in concentration since the water evaporates more easily than the fluid since the solutions were not stored in hermetically sealed containers.

3.3 Viscometer Test

As four tests were made for each temperature, the values presented below are the respective averages obtained. Moreover, it is noteworthy that the boiling points of the fluid and water present in the solutions, considering the local atmospheric pressure that is 1020 hPa, did not allow the tests to be performed at temperatures above 70 (°c).

The following graphs show, respectively, the comparison between density, kinematic and dynamic viscosity between pure fluid and solutions of 25% and 50%.

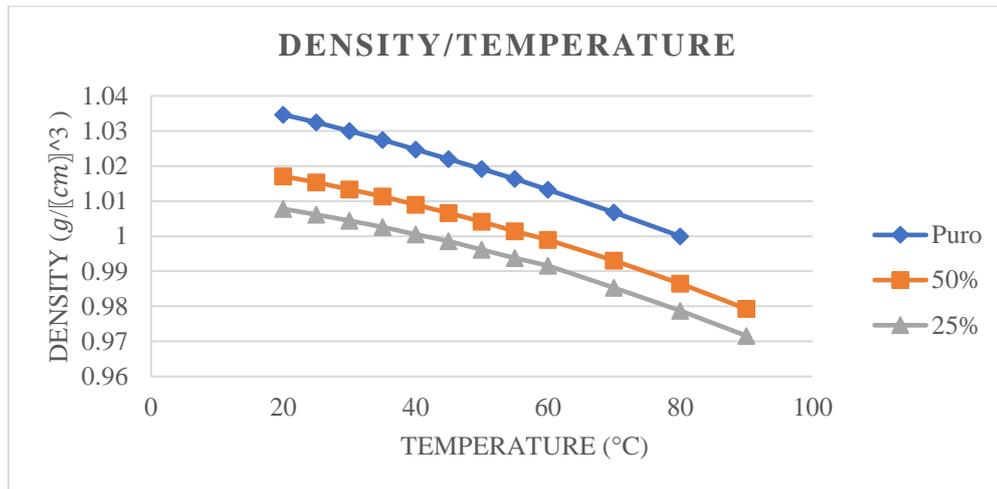


Figure 8. Comparison of the density variation between the fluids

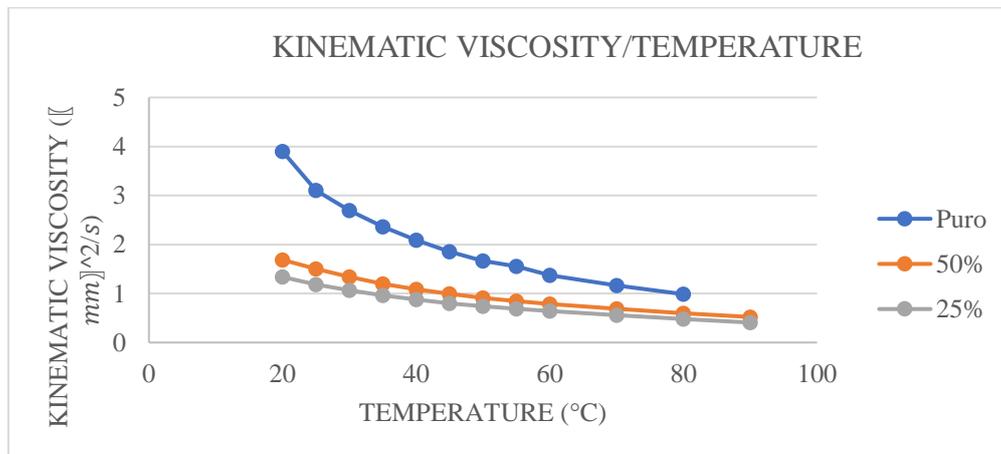


Figure 9. Comparison of kinematic density between cutting fluids.

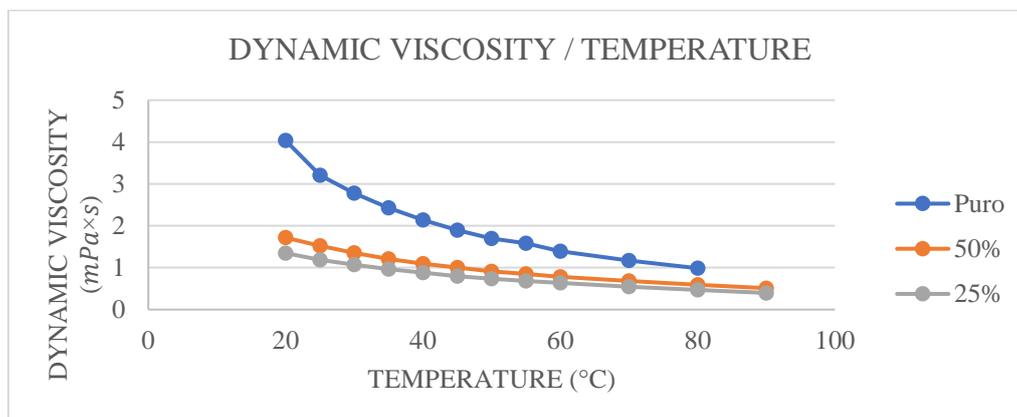


Figure 10. Comparison of dynamic viscosity between cutting fluids.

Analyzing The above graphs, it was possible to perceive that the decrease in concentration is not a determinant factor for the density variation but rather of the viscosities (Kinematics and Dynamics) as it is possible to perceive in Fig. 3.7 and 3.8.

From This data and the problems related to the previously described boiling point, we would have to interpolate the data to find a viscosity index for the fluids in question since the standard NBR 14358 based on the ASTM method 2270 determines the temperature range between 40 and 100 ° C.

3. CONCLUSIONS

For the studies carried out, the following conclusions were obtained:

- Emulsions presented physical properties such as specific mass, boiling point, kinematic viscosity and dynamics similar to pure water, which reinforces the need to study additives that provide physical properties close to synthetic fluids.
- The average pH values of the emulsions were all above 7, i.e. slightly alkaline, which increases the protection of the fluid against possible microorganisms and the longevity of the cutting fluid.
- Even two weeks after the emulsions were prepared, they showed no visible signs of contamination and structural change.
- The fluid in question proved promising, however, it is essential to perform the future tests presented in the methodology since they will provide important information that will direct the study to a better optimization of the emulsion (better refrigeration, lubricity, wettability, higher boiling point, resistance the pressure, among others) which will provide better results in regard to the workpiece finish and tool longevity.

4. REFERENCES

- OLIVEIRA, J. F. G. de; ALVES, S.M. Novos fluidos de corte adequados ao desempenho mecânico da retificadora e ao meio ambiente. MÁQUINAS E METAIS. São Paulo, p. 28-43, jan. 2006.
- Jiang, Z. G.; Zhang, H & Luo, X. (2008). Study on cutting technology based on green manufacturing. Key Engineering Materials, 375-376, 158-162.
- MANG, T. and DRESEL, W. 2007. "Lubricants and lubrication". Wiley-VCH Verlag GmbH, 2nd Ed., Weinheim, Germany, 850 p.
- SANTOS, E.S; Camargo, ana paula de paula ; Faria, edália azevedo de ; Oliveira Junior, francisco adriano ferreira de ; Alves, salete martins ; Barros Neto, eduardo lins de . The Lubricity Analysis of Cutting Fluid Emulsions. Materials Research-Ibero-american Journal of Materials, v. 20, p. 644-650, 2017.
- Sokovic, M., Mijanovic, K. "Ecological aspects of cutting fluids and its influence on quantifiable parameters of the cutting processes". Journal of Materials Processing Technology, Slovenia, n. 109, p. 181-189, 2001.
- STOETERAU, R. L.; LEAL, L. C, 2004. "Apostila de Tribologia". Departamento de Engenharia Mecânica, Universidade Federal de Santa Catarina.
- TRIM, 2006. "Characteristics of Metalworking Fluids – The Importance of pH+ and Reserve Alkalinity".
- Upadhyay, Vikas; Jain, Pramod Kumar & Mehta, Narinder Kumar (2012). Minimum Quantity Lubrication Assisted Turning - An Overview, Chapter 39 in DAAAM International Scientific Book 2012, pp. 463-478, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3- 901509-86-5, ISSN 1726-9687, Vienna, Austria.