23rd ABCM International Congress of Mechanical Engineering
December 6-11, 2015, Rio de Janeiro, RJ, Brazil

DEVELOPMENT AND EVALUATION TRIBOLOGICAL OF AN ENVIRONMENT FRIENDLY CUTTING FLUID

Edja Iandeyara Freitas Moura
Erinéia da Silva Santos
Federal University of Rio Grande do Norte, Av. Senador Salgado Filho – S/N, Lagoa Nova, Natal-RN
erineia.ufcg@gmail.com

Ana Paula de Paula Camargo
Federal University of Rio Grande do Norte, Av. Senador Salgado Filho – S/N, Lagoa Nova, Natal-RN
camargoanap94@gmail.com

Edália Azevedo Faria
Federal University of Rio Grande do Norte, Av. Senador Salgado Filho – S/N, Lagoa Nova, Natal-RN
edalia_azevedo@yahoo.com.br

Francisco Adriano Ferreira de Oliveira
Federal University of Rio Grande do Norte, Av. Senador Salgado Filho – S/N, Lagoa Nova, Natal-RN
adrianojr15@hotmail.com

Salete Martins Alves
Federal University of Rio Grande do Norte, Av. Senador Salgado Filho – S/N, Lagoa Nova, Natal-RN
saleealves@ect.ufrn.br

Abstract. *Nowadays, manufacturing processing has occupied a great part of the industrial process and consequently, the use of cutting fluid has increased. In addition to this, environmental agencies and public authorities have been keen to facilitate the harmony between industrial activities and the environment. Thus, many researchers have been developing a formulation of biodegradable cutting fluid that is less aggressive to the operator and the environment, as well as provide significant improvement to the tool's lifetime. The vegetable-based cutting fluids have been an alternative to these problems as they are environmentally friendly, less corrosive, have an excellent lubricity, low volatility and good viscosity/temperature characteristics. This study aims to develop and evaluate the performance of an emulsifiable vegetable oil, comparing it to a conventional cutting fluid. To evaluate the wear of the sample, a dynamic test was performed on a nonconforming contact tribometer HFRR (High Frequency Reciprocating Rig), using ball/plane configuration. The results showed that the emulsifiable cutting fluid had advantages related to the emulsion with mineral oil. Regarding it's physical and chemical properties as well as dynamic test and it was concluded that the emulsifiable cutting fluid showed much better characteristics than cutting fluids based on conventional oil.*

Keywords: *Cutting Fluid, Biolubricant, Tribological Performance*

1. INTRODUCTION

The increased technological advances obtained in the development of new materials and machine tool has allowed an increase of productivity in manufacturing processes. In the machining processes, tools constantly suffer high wear due to friction generated during the cutting process. This can cause various undesirable effects such as changes in dimensions and the generation of internal stresses that can compromise the use of the tool.

Cutting fluids are used to minimize these types of problems decreasing the heat generated during this process. The fluids remove metal chips generated by the cut and helps lubricate the working piece and the tool (Alves, 2005).

The efficiency of the lubricant depends of the characteristics and its ability to penetrate the region between the chip and the tool, forming a film with lower shear resistance than the strength of the material at the interface. Both the surface of the chip as the tool is not perfectly smooth. They are rough, or have tiny protrusions, asperities in the form of peaks and valleys of the order of micrometers. The highest peaks rub-up, wearing tool, generating heat and friction. To reduce this friction, the cutting fluid penetrates into the rough interface by capillarity. Consequently, it reduces a part of the heat generation. Also to reduce power consumption, the force required to cut

There are a variety of cutting fluids available in the market; they are divided into four classes which are integral oil, soluble oil, semi-synthetic, and synthetic. Each fluid type has its own characteristics, advantages and limitations. The choice of a more suitable fluid depends on the type of machining process and materials.

With the large growth of manufacturing processes, there is an increase in the use of cutting fluids, not only in the large metal–mechanic industries, but mainly in the services suppliers and small companies, due to the tendency of outsourcing services of large companies, given the seasonality of the market. However, treatment and waste disposal processes are expensive and must undergo the rigor of the environmental laws. They are substances, that when used inappropriately, have negative impact in the ground, air, fauna, flora and water resources, causing serious damage to the environment and humans (Alves and Oliveira, 2007). About 80% of operations with cutting fluids use mineral oils that cause damage to the operator's health by direct contact, such as, irritation and allergy due to attack by microorganisms, bacteria and fungi (Shashidhara, 2010).

Public authorities and the environmental agencies have been keen to facilitate harmony between industrial activities and the environment. Thus, new formulations of biodegradable cutting fluid have been developed in order to promote less aggression to the environment and the operator's health, and also providing a significant improvement in the tool's lifetime.

The use of vegetable base cutting fluids has been used in manufacturing because they combine cooling and lubrication functions in addition to their environmental characteristics. They have been an alternative to replace mineral oil as they are environmentally friendly, biodegradable, less corrosive and have excellent lubricity, low volatility and suitable viscosity / temperature characteristics (Ehran, 2006).

Vegetable oils have excellent lubricating properties, being suitable for most machining operations, ensuring high performance and high surface finishing. However, they have higher foaming tendency than semi synthetic or synthetic fluids (Guimarães, 2006).

The interaction between the surfaces is responsible for generating contact forces that oppose the motion and part of their energy is dissipated as heat. This contact causes noise and wear. When a fluid doesn't have adequate lubricity, its ability to reduce friction and wear between the surfaces in contact is impaired (Hutchings, 1992)

According to Kumar et al (2010), the emulsion lubricity is related to the variation of the surfactant concentration. They influence the oil droplet size, resulting in a lower coefficient of friction between the surfaces. Small oil droplets have a better performance in the lubricity than larger droplets, because they are more easily transported to the metal surface (Sy-Wei, 2013)

The aim of this study was to present an evaluation of tribological performance of vegetable based cutting fluid. An O/W emulsion was developed from sunflower oil and the effect of surfactant concentration on emulsion lubricity was studied.

2. MATERIAL AND METHODS

2.1 Epoxidation of Sunflower Oil

Sunflower oil was epoxidized using formic peracid, which was prepared in situ from a mixture of formic acid hydrogen peroxide (35% in the molar ratio of 1:11:5 (double bonds/hydrogen peroxide/formic acid).

The reaction procedure consisted of mixing formic acid and vegetable oil (sunflower oil) under stirring and heating for 30 minutes. Then hydrogen peroxide is added dropwise to the reaction mixture in approximately 20 minutes. After complete addition of hydrogen peroxide, the mixture was kept for 4 hours and 30 minutes under stirring at a temperature of 50 ° C.

After this procedure, the epoxidized oils was washed with distilled water at the temperature of 70 ° C in order to reduce the pH to around 6-7.When the pH reached 6-7, sodium bicarbonate was added, helping the epoxidized oil to arrive at the desired pH and be able to act as a buffer solution. Then the lubricating oil is dried at 90-100 ° C for about 4 h.

2.2 Preparation of emulsions

The O/W emulsions were made with different concentrations of surfactant (1%, 2.5% and 5%), and a quantity of epoxidized sunflower oil (10g).

The emulsions were prepared separately in a becker of 250 mL, the surfactant (soap base compound of coconut oil and 95% tallow (beef fat)) was solubilized at a temperature of 60 ° C under mechanical stirring at 700 rpm. After this procedure, 10 g of epoxidized oil was added and so the mixture was stirred for 10 minutes (Frange, 2009).

2.3 Triblogical Performance by HFRR (Higth Frequency Reciprocating Rig)

A disc (AISI 52100) was sanded and polished to obtain roughness superficial of Ra = 0.02 micrometers. After this procedure, the disc and the ball were washed with detergent and dried with paper towels. Then the disk and the ball were placed in a bath of toluene for 7 minutes. After that, they were dried in hot air and kept in acetone for 3 minutes in an ultrasonic bath. At the end of the cleaning, they were dried with hot air and used in tribological testing.

The tribological pair (ball-disc) was placed on the supports and the HFRR test was carried out using the conditions shown in Table 1. The test was performed according to ASTM D 6079 -. 04.

Table 1: Test conditions lubrication.

Parameters used in the High Frequency Reciprocating Rig Equipment				
Frequency	Load	Displacement	Temperature	Time
50 Hz	2 N	1 mm	60 º C	75 min

Figure 2 shows a schematic drawing of the HFRR test, which is an apparatus for tribological testing with reciprocate movement. The disc was placed under the fully submerged oil condition. During the friction test, the coefficient was measured by a piezoelectric force transducer and the formation of electrically insulating films at the sliding contact was measured by the ECR (Electrical Contact Resistance) technique.

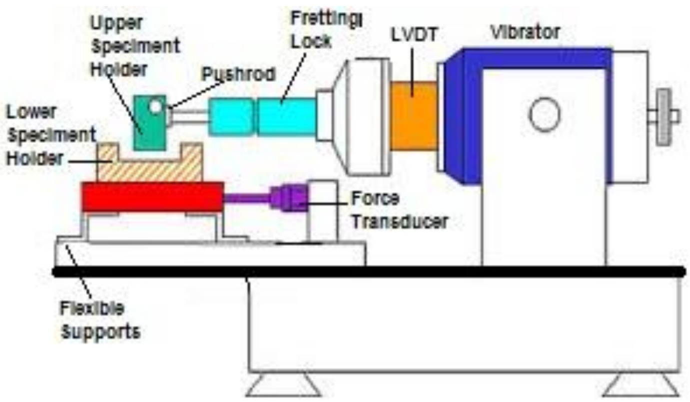

Figure 2: Schematic of the HFRR (Jaasklainen, 2014).

After the HFRR test, the ball and disk were removed, cleaned by immersion in toluene for 7 minutes and dried with hot air. Then immersed for 3 minutes in acetone. The wear scar in the ball was measured by an optical microscope with magnification of 100 times. All experiments were performed in duplicate,

3. RESULTS AND DISCUSSION

The performance of the O/W emulsions, with different concentration of surfactants, was evaluated thorough the HFRR test. This tribological performance was evaluated based on the friction coefficients and percentage of films formed, as seen on Figures 3 and 4, respectively.

The friction coefficient shows low value for the emulsion with 1% of surfactant when compared with others concentrations. It is possible to observe that the increase in surfactant concentration caused the increase of the friction coefficient, Kumar *et al* (2010) explain that the size of the oil particles is influenced by the amount of surfactants present in the emulsion, affecting thus the lubricity system, resulting in a smaller or larger friction coefficient. The emulsion with 5% of surfactant presents lower time of instability around 1200 s, while for others emulsions this time is around 2000 s. Probably, this occurs due to the direct contact between the surfaces of the system, because the lubricant film is still in development.

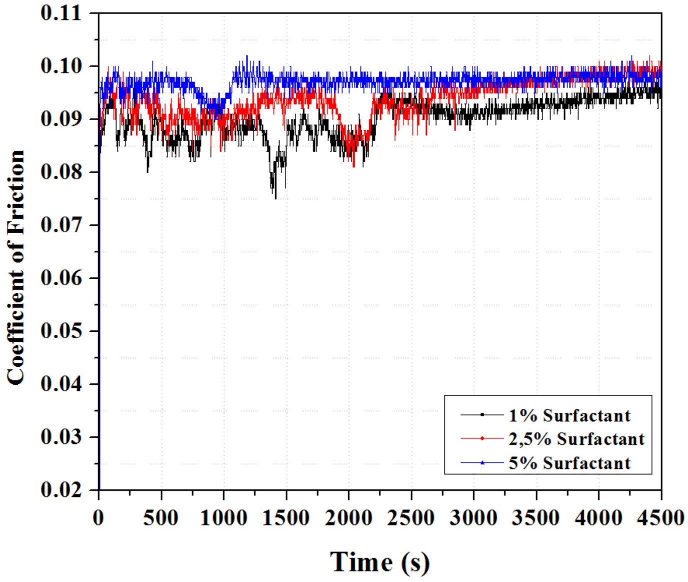

Figure 3: Coefficients of friction the emulsions, varying surfactant concentration.

It is observed that the film formation for the emulsion with 10% epoxidized oil initially occurs for the emulsion with higher surfactant concentration (5%) rather than the other concentrations (1% and 2.5%). The film formation begins at approximately 700s and shows superiority compared to the other concentrations (1%, 2.5%) up to 2570 s. From that time, the emulsion with higher surfactant concentration shows lower percentage of film formation than other concentrations (1% and 2.5%). Also, this time for film formation correspond to instability time in friction coefficient graph.

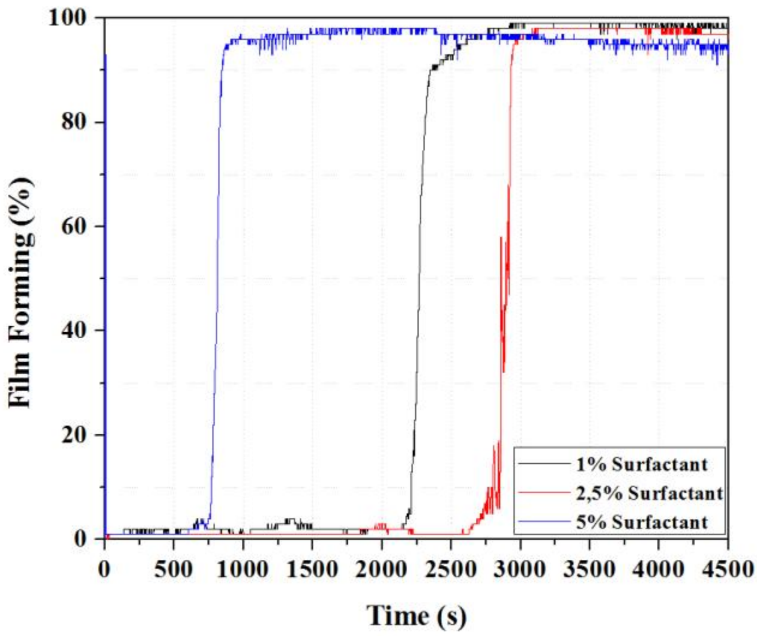

Figure 4: Percentage Film in function of surfactant concentration.

This type of behavior is explained by the phenomenon of adsorption of the micelles formed on the metal surface. The larger amount of surfactant causes the formation of a micelle monolayer, which facilitates its adhesion to the surface and the formation of a protective film. According to Santos (2014) the addition of a surfactant soluble O/W emulsion decreases the electrostatic repulsion barrier between the oil and the surface, this occurs because the droplet oil will be nearest the surface, substituting water and increasing lubrication. Sy-Wei Lo *et al.* (2013) explain that the smaller oil droplets have better lubricating performance than the larger droplets because they are easily transported to the metal surface.

When the film formation is lower than all other concentrations, this can be attributed to the reciprocate movement that causes a breakdown of these micelles, that leads to the easily removal of the film and the direct contact between surfaces is established, resulting in abrasive wear.

According to Alcides Neto (2009), the results are consistent because the increase in the content of surfactant has a better efficiency in covering the metal. Emulsions with higher wear are emulsions with lower concentrations of surfactant (1% and 2.5%). This fact is confirmed by the higher wear value of wear scar diameter (WSD), seen in Figure 5.

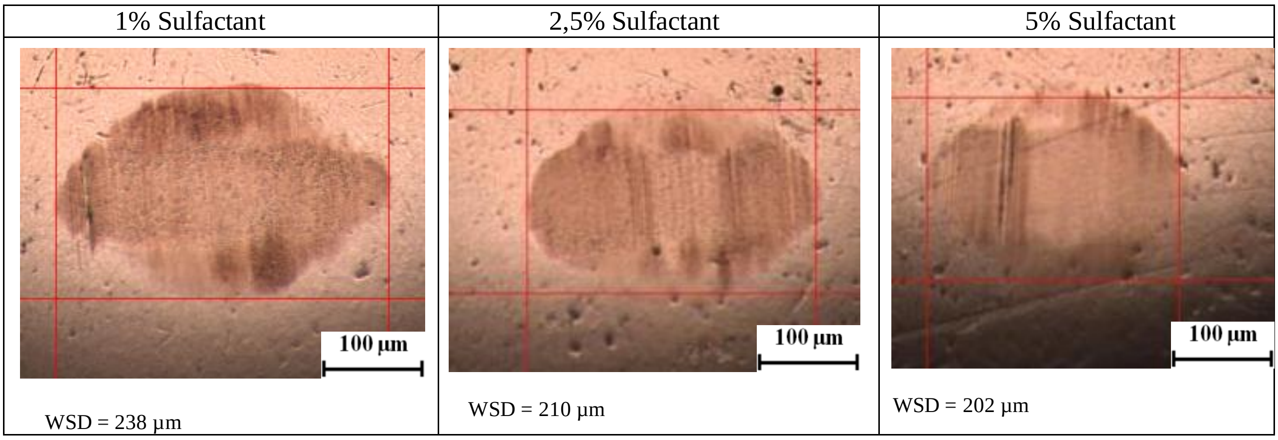

Figure 5: Picture of wear scars on steel ball AISI 52100. Average diameter measured for the emulsion with 10% epoxidized oil varying the surfactant. Magnification: 100 times.

The worn surfaces have few grooves indicating that there was not virtually abrasive wear, with a more uniform wear. The emulsions had higher abrasive wear emulsions were those with lower concentrations of surfactant (1% and 2.5%).

4. CONCLUSION

Based on the results obtained, the lubricity of the emulsions was more efficient for the emulsion with the lowest concentration of surfactant, showing a low friction coefficient. The behavior of the film formation observed in the graph showed that all emulsions have a long time to initiate the formation of the film. The emulsion with the highest concentration of surfactant (5%) showed lower formation time than other concentrations (1% and 2.5%). The time for film formation caused an oscillation in friction coefficient values. However, the emulsion with 5% of surfactant presented a little higher friction coefficient than other emulsions, but it showed more film formation ability and, consequently lower wear (WSD).

5. REFERENCES

Alcides Neto. O. W., 2009. Aplicação de Sabões de Ácidos Graxos Epoxidados como Inibidores em Óleo Dutos. 2009. 224f. Tese (Doutorado Química) Universidade Federal do Rio Grande do Norte, Natal.

Alves S.M.; Oliveira J.F.G., 2007. Adequação ambiental dos processos usinagem utilizando Produção mais limpa como estratégia de gestão ambiental. Produção.. v. 17. n 1.p. 129-138.

Alves S.M. Adequação Ambiental de Processo de Retificação através de um Novo Conceito de Fluido de Corte. 2005. 158f. Tese (Doutorado em Engenharia Mecânica). Escola de Engenharia de São Carlos, São Paulo, 2005.

Ehran, S.Z., et al., 2006 Oxidation and Low Temperature of Vegetable Oil Based Lubricants. Industrial Crops and Products.. v. 24: p. 292-299.

Frange, R.C.C; Garcia, M.T.J. Desenvolvimento de emulsões óleo de oliva/água: Avaliação da Estabilidade Física. Rev Ciênc. Farm. Apl. 2009: v.30. n.3. p. 263-271.

Guimarães A. P., 2006. Estudos de Formulação e Recuperabilidade em Fluidos de Corte à Base de Óleo Mineral Solúvel. 132f. Dissertação (Mestrado em Engenharia Química) Universidade Federal do Ceará, Fortaleza.

Hutchings, I.M., 1992. Tribology - Friction and Wear of Engineering Materials. 1º ed., Combrige: Edward. Angrold, 273p.

Kumar, D.; Daniel, J.; Biswas, S.K., 2010. Tribology of Steel/Steel Interaction in Oil-in-Water Emulsion; a Rationale for Lubricity. Journal of Colloid and Interface Science. v.345: p. 307–315.

Lo Sy-Wei et al. The lubricity of oil-in-water emulsion in cold strip rolling process under mixed lubrication. *Tribology International.* V66. p. 125–133, 2013.

Santos, E. S.; Faria, E. A.; Barros, E. L. N.; Alves, S. M.. Desempenho Tribológico de Emulsão para Aplicação em Fluidos de Perfuração. In: VIII Congresso Nacional de Engenharia Mecânica, 2014. *Anais do CONEM 2014*,Minas Gerais, Brazil

Shashidhara, Y.M.; Jayaram, S.R. Vegetable Oils as a Potential Cutting Fluid - An Evolution. Tribology International. 2010. v.43. p. 1073–1081.

Sy-Wei, L.; Yang.; Tzu-Chun.; Lin, Heng-Sheng., 2013. The lubricity of oil-in-water emulsion in cold strip rolling process under mixed lubrication. Tribology International. v.66: p. 125–133.

Hannu Jaaskelainen. "Fuel Property Testing: Lubricity*". 30 Dec. 2012* <http: www.google.com.br>.

6. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.