24th ABCM International Congress of Mechanical Engineering
December 3-8, 2017, Curitiba, PR, Brazil

COBEM-2017-1356
INFLUENCE OF ROUGHNESS AND SURFACE FINISH TO REDUCTION OF WEAR AND FRICTION

Diana Roberta da Silva Medeiros
Federal University od Rio Grande do Norte, Departament os Mechanical Engineering. Natal, RN. Brazil.
e-mail: dianaroberta.sm@gmail.com

Edália Azevedo de Faria
Federal University od Rio Grande do Norte, Departament os Mechanical Engineering. Natal, RN. Brazil.
e-mail: edaliaazevedo@yahoo.com.br

Valdicleide Silva e Mello
Federal University od Rio Grande do Norte, Departament os Mechanical Engineering. Natal, RN. Brazil.
e-mail: valdkqi@hotmail.com

Salete Martins Alves
Federal University od Rio Grande do Norte, Departament os Mechanical Engineering. Natal, RN. Brazil.
e-mail: salete.martins@gmail.com

Abstract. *The roughness can significantly interfere with the tribological and mechanical properties of materials. It can influence on surface-liquid interaction, consequently, affects the lubrication. Rugged surfaces tend to reduce friction and wear. The paper aims to discuss the influence of roughness on the effect of a synthetic lubricant in the coefficient of friction reduction in rolling steels and to find the average range of roughness in which the coefficient of friction and wear are reduced. To verify this effect were carried tribological tests lubricated with based oil in tribometer HFRR (High-Frequency Reciprocating Rig), with contact alternate in the plane sphere configuration. The roughness was modified in the discs of the tribological pairs by surface finishing with different sandpaper (#36, #80, #220, #600 e polished). The wear was observed by scanning electron microscopy (SEM). Through the tribological tests was found that the polished samples obtained the worst results under the permanent regime. However, the samples with finishing to # 80and # 220 showed satisfactory results in the reduction of the coefficient of friction.*

Keywords: *Roughness, Wear, Surface, Friction.*

1. INTRODUCTION

Friction is a tribological phenomenon inevitably present in metallic interfaces in motion. The friction conditions interfere directly in tool life, piece integrity, surface quality, among other events (Kang *et al.*, 2017). Therefore, choosing the roughness that best fits the desired result, together with an effective lubricant, is essential for a successful reduction of friction.

How the effects of the roughness events exert significant influence on the tribological and mechanical properties of metallic components, it is important to understand this effect when the surfaces in contact are in of maximum mechanical request conditions (Krupka *et al.*, 2016). Despite the importance of the study of surface roughness in tribological behavior, this subject has been little investigated in recent years (Kogovsek *et al.*, 2013).

The texturization of metal surfaces represents the insertion of micro grooves in the surfaces of the materials, modifying the roughness in order to achieve beneficial tribological performances. Different surface textures reflect different tribological properties, with a more significant effect on the friction results, in a lubricated or dry condition, and on the formation of a protective film (Dzierwa, 2017). Studies suggest that texturing can be used to increase the efficiency of lubricating films in mixed lubricated contacts, considering aspects such as friction, film thickness, wear, among other factors (Vrbka et al, 2010).

Rough surfaces improve surface-liquid interaction and can be used in many practical applications, for example, in improving lubrication. For this type of surface, the reduction of the friction and wear tends to be more efficient than in relation to the polished surfaces (Kubiak *et al.*, 2011).

The choice of oil and its characteristics will directly influence the tribological properties being studied. Alpha-olefin poly (PAO) oils are saturated hydrocarbons which are synthesized by polymerization of alpha-olefins followed by hydrogenation and are characterized by high viscosity index, high flash point, low pour point, low toxicity, low volatility and good thermal-oxidative stability (Jiang *et al.*, 2015). Due to its high thermal stability, this lubricant is widely used in engine oil (Yue *et al.*, 2011).

The materials in contact with the oil undergo significant modifications due to the liquid / solid interaction and the constant changes of formulations and surface finishes, being this one of the difficulties found described by the lack of understanding between the oil and the superficial interaction (Cousseau *et al.*, 2016).

The purpose of this work is to discuss the influence of different roughness of metallic surfaces in the performance of the synthetic Pao lubricant in reducing the friction coefficient and the wear in rolling steels. Thus, in order to find the average range of roughness in which the coefficient of friction and wear are the smallest possible.

2. EXPERIMENTAL PROCEDURE

2.1 Preparation of materials

The lubricant poly alpha-olefins (PAO) base oil classified as Group IV was used in the tribological tests. On tab. 1 are shown the typical properties of this type of lubricant (Murakami *et al.*, 2010).

Table 1. Typical properties of the poly-alpha-olefin (PAO).

Typical properties of the PAO				
ISO viscosity grade	**Density (Mg/m^3)**	**Kinematic viscosity (m^2/s)**	**Viscosity index**	**Composition (mass%)**
VG68	0.835	66×10^{-6} (133 K), 10×10^{-6} (373 K)	50 º C	60 min

The bodies and against bodies used were Steel ASTM 52100. The spheres were polished (Ra = 0.05μm) and the discs received varied superficial finishes so that it was possible to analyze the tribological behavior for different roughness. Four types of # 36, # 80, # 220, # 600 and polished conditioners were used..

2.2 Tribological tests

The tribological performance of the lubricant in contact with different surface textures was evaluated in the tribometer HFRR (*High Frequency Reciprocating Rig*). This equipment operates in alternating motion with lubricated sphere-plane contact, as shown in fig. 1.

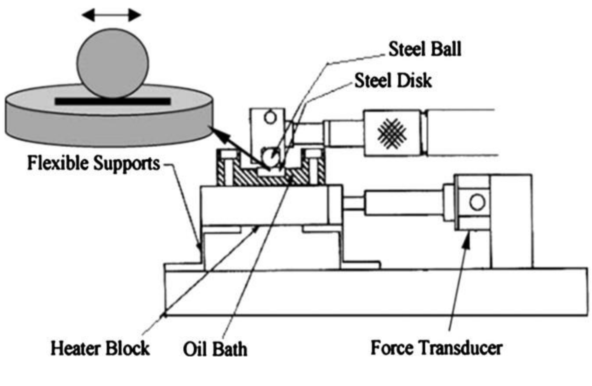

Figure 1. Schematic diagram of the assay at tribometer HFRR by Alves *et al*. (2016).

The bodies and against bodies were previously cleaned in an ultrasonic bath and then coupled to the appropriate support in which they remained submerged in 2 ml of the PAO lubricant throughout the test. In Table 1 we have the parameters that were used in the tribometer. The tests were performed in triplicate and at the end the coefficients of friction were analyzed for each condition.

Table 2. Test parameters in the tribometer HFRR.

Parameters used in the equipment High Frequency Reciprocating Rig				
Frequency	**Load**	**Displacement**	**Temperature**	**Time**
20 Hz	10 N	1 mm	50 º C	60 min

2.3 Analyzes

At the end of the tribometer tests the disks were cleaned in ketone for 10 minutes in an ultrasonic bath. After that, the wear on the disks were analyzed by scanning electron microscopy (SEM).

3. RESULTS AND DISCUSSION

The figure 2 shows the results of the coefficient of friction of the tests performed for the different surface textures.

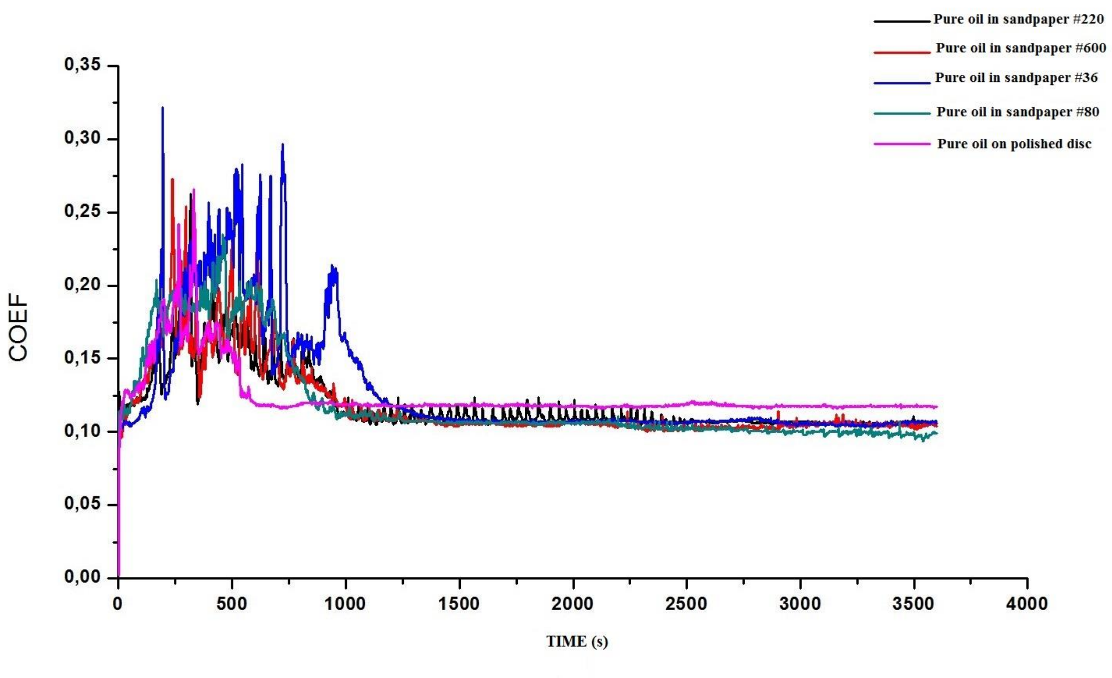

Figure 2. Coefficient of friction of the tests performed.

During the runnin-in step shorter times were observed for the samples under polished conditions, indicating that the film formation occurred more rapidly than the other conditions. However, even with the fast film formation compared to the other samples, during the permanente regime the polished samples presented higher coefficients of friction throughout the test, proving that there was no good interactio beteween lubricant/surface. According to Kubiak et al (2011), that discusses that rough surfaces improve surface-liquid interaction.

From the sanded samples tested, the which obtained the most time for protective film forming, with a run-in up to 1200s, and higher values of coefficient of friction during this step were samples with finish with #36. This may have been caused by the difficulty in smoothing the surface due to deeper grooves. Once the contact roughness is initially broken, these can remain between the surfaces in contact, favoring increased friction and wear. Samples finished to # 80, # 220 and # 600 obtained similar results with respect to the coefficient at this running-in stage of approximately 900s.

In the permanent regime, the samples finished with #36, #220 and #600 obtained similar performance, with friction coefficients lower than the polished sample and remaining stable until the end of the test. However, the lowest coefficient of friction in the permanente regime were observed in the samples of #80. According to the tribological test progresses, the friction coefficient of the sample #80 decreases, confirming the lubricant/surface interaction more efficient in lowering friction.

The figure 3 shows the wear scars on discs after the tribological tests.

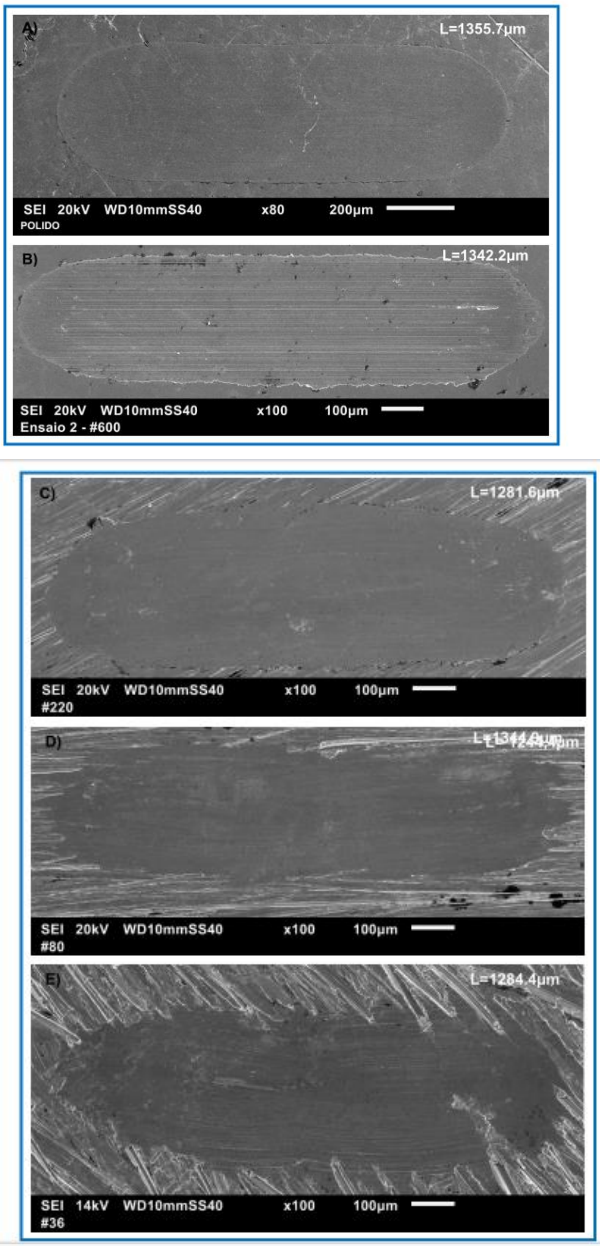

Figure 3. Wear scars on discs after the tribological tests. a) polished; b) #600;c) #220; d) #80; e) #36.

Through SEM images it is possible to observe that the samples with the largest initial grooves (# 36 and # 80) obtained surface smoothing, where the contact roughness was broken by the reciprocating movement. Severe wear on the surface and wider, non-uniform wear trails characterized by tearing of the material is noticeable. The polished sample and # 600, obtained similar results, having thick wear tracks. The sample of # 220 obtained the lowest thickness of wear, which can be associated with good oil/matrix interaction. Slots inserted under these conditions have favored reduced friction and wear.

The observation of only the friction coefficient is not sufficeint to evaluate the conditions of better tribological performance, it is necessary to use complementary techniques to discuss the best aspects.

The effect of surface texturization is directly influenced by the roughness and density of the texture in the contact. According to Vrbka et al. (2010), the preferred applications of surface microtextures on charged surfaces function as micro-reservoirs of lubricants and reduce the interactions between the contact roughness. As occurred for samples # 80 and # 220.

4. CONCLUSION

In view of the analysis of the obtained results, it can be inferred that:

- Roughness is a factor that directly influences the tribological characteristics of components;
- The protective film formation of the polished sample occurs faster than in the other samples, but the coefficient of friction is the highest during the permanent regime;
- The coefficient of friction of samples # 220 and # 600 had similar behavior, both in the running-in phase and throughout the permanent regime, but the sample of # 80 obtained the best result in the reduction of friction, which indicates that the insertion of superficial roughness acts in the improvement of the tribological properties;
- The best results were shown for samples with # 80 and # 220, which demonstrated low coefficient of friction associated with the low wear of the surfaces in contact;
- The coefficient of friction must be analyzed combined with other techniques to be able to prove the lowest wear rates.

5. ACKNOWLEDGEMENTS

The authors wish to express thanks to the Analytics Chemical, DEMAT and Tribology laboratory laboratories of UFRN by the availability of equipment for test and supported by CAPES, ECT, PPGEM and UFRN.

6. REFERENCES

Cousseau, T., Acero, J.S.R. and Sinatora, A. 2016. “Tribological response of fresh and used engine oils: The effect of surface texturing, roughness and fuel type”. *Tribology International*, Vol. 100, p. 60–69.

Dzierwa, A. 2017. “Influence of surface preparation on surface topography and tribological behaviours”. *Archives of civil and mechanical engineering*, Vol. 17, p. 502–510.

Jiang, S., Li, S., Liu, L., Wang, L. and Mominou, N. 2015. “The tribological properties and tribochemical analysis of blends of poly-alpha-olefins with neopentyl polyol esters”. *Tribology International*, Vol. 86, p. 42–51.

Kang, S.H., Oh, Y.S. and Lee, H.W. 2017. “Frictional sensitivity and effect of surface roughness in boss and rib test”. *Tribology International*, Vol. 112, p. 108–116.

Kogovsek, J., Remskar, M., Mrzel, A. and Kalin, M. 2013. “Influence of surface roughness and running-in on the lubrication of steel surfaces with oil containing MoS2 nanotubes in all lubrication regimes”. *Tribology International*, Vol. 61, p. 40–47.

Krupka, I., Sperka, P. and Hartl, M. 2016. “Effect of surface roughness on lubricant film breakdown and transition from EHL to mixed lubrication”. *Tribology International*, Vol. 100, p. 116–125.

Kubiak, K.J., Wilson, M.C.T., Mathia, T.G. and Carval, P.H. 2011. “Wettability versus roughness of engineering surfaces”. *Wear*, Vol. 271, p. 523–528.

Murakami, T., Kaneda, K., Nakano, M., Xia, Y. and Sasaki, S. 2010. “Tribological properties of Fe_7Mo_6-based-alloy lubricated with poly-alpha-olefin containing PN additive”. *Tribology International*, Vol. 43, p. 312–319.

Vrbka, M., Šamánek, O., Šperka, P., Navrat, T., Křupka, I., & Hartl, M. 2010. “Effect of surface texturing on rolling contact fatigue within mixed lubricated non-conformal rolling/sliding contacts” Tribology International 43.8 (2010): 1457-1465.

Yue, W., Sun, X., Wang, C., Fu, Z., Liu, W. and Liu, J. 2011. “A comparative study on the tribological behaviors of nitrided and sulfur-nitrided 35CrMo steel lubricated in PAO base oil with MoDTC additive”. *Tribology International*, Vol. 44, p. 2029–2034.