World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:10, No:1, 2016

Evaluation of PTFE Composites with Mineral Tailing Considering Friction, Wear and Cost

Antônio P. de Araújo Neto, Ruy D. A. da Silva Neto, Juliana R. de Souza, Salete K. P. de Medeiros, João T. N. de Medeiros

Open Science Index, Materials and Metallurgical Engineering Vol:10, No:1, 2016 publications.waset.org/10003498.pdf

Abstract**—**The tribological test with Pin-On-Disc configuration measures friction and wear properties in dry or lubricated sliding surfaces of a variety of materials and coatings. Polymeric matrix composites loaded with mineral filler were used, 1%, 3%, 10%, 30%, and 50% mass percentage of filler, to reduce the material cost by using mineral tailings. Using a pin-on-disc tribometer to quantify coefficient of friction and wear resistance of the specimens. The parameters known to performing the test were 300 rpm rotation, normal load of 16N and duration of 33.5 minutes. The composite with 10% mineral filler performed better, considering that the wear resistance was good when compared to the other compositions and an average low coefficient of friction, in the order of $\mu \leq 0.15$.

Keywords**—**Microcomposites, microparticles tailings of scheelite, PTFE, tribology.

I. INTRODUCTION

THE polytetrafluoroethylene (PTFE) is a polymer with a great versatility in the usual segments of industry. Offers an excellent combination of chemical properties, electrical, mechanical, and thermal and non-stick; has a low coefficient of friction ($0.01 \leq \mu \leq 0.1$) and is chemically inert. No other material adheres to its surface, in this way, chemical treatment is necessary to perform bonding. With an excellent electrical insulator, this does not suffer aging phenomena even in contact with air and other products. For these reasons, it is commonly used in tribological applications such as bearings, seals, and tapes. However, it presents poor resistance to sliding wear, which limits their use as solid lubricants. Tanaka, Briscoe, Bahadur, e Lancaster are some of the pioneers in the study of friction and wear behavior of PTFE [1]-[5]. Great deal of research has focused on reducing the high wear rate of PTFE by incorporation of various fillers. In 1982, Tanaka published an article on the non-effectiveness of nanoparticles loads in reducing wear of the PTFE [4]. However, in recent years, much progress has been found with the use of nanoparticles. In more recent works, such as carbon fillers [6], alumina [7], and zinc oxide [8], the nanoparticles have been used to improve the durability of PTFE. The test using setting of pin-on-disk do the measures of friction and properties of wear in slip of dry surfaces or lubricated a variety of materials and coatings. It aimed to develop polymeric composites with PTFE matrix using it tailings of scheelite as filler, also enabling environmental remediation processes.

The tailings of scheelite proposed as filler for composite chosen for this work fits in the development of environmental polymeric structural materials and functionally suitable for mechanical components with effective systemic tribological responses. In Brazil, the last four decades, the northeastern has been the largest producer of calcium tungstate, having excelled mining of scheelite, as Brejuí and Bodó mines in Rio Grande do Norte, bequeathing in the sky open piles of tailings, Fig. 1.

Fig. 1 Photo (by the author) panoramic Mine Brejuí, Currais Novos-RN and his pile of tailings in the sky open

A pin-on-disc tribometer operates on the following principle: a plan, pin, or ball it is loaded in a test sample with a precisely known weight load. The highly rigid elastic arm ensures an almost fixed contact point, therefore, a stable position on the friction track. Dynamic friction during the test is determined by measuring the bending of the elastic arm by direct measurement of the change in torque. The normal load, rotational speed, and the diameter of the wear track all parameters are normally controlled

II. EXPERIMENTAL

The tribometer with setting of pin-on-disk, it was used to characterize the dynamic friction coefficient and wear resistance of the composites used in this work, Fig. 2. An AISI 52100 steel ball with a diameter of 10 mm was used as pin. The disc rotation speed used was 300 rpm and the wear track radius was 10 mm. The pin is loaded against the sample load of 16 N. The tests lasted 33.5 min. The dynamic coefficient of friction and wear resistance were monitored through electronic sensors, and this data is received, displayed and stored on your computer using tribometer software.

Antônio P. A. Neto is with the Federal University of Rio Grande do Norte, Mechanical Engineering Department, Natal/RN, Brasil. (corresponding author, phone: +55 84 996660682; e-mail: tonypaulino14@hotmail.com).

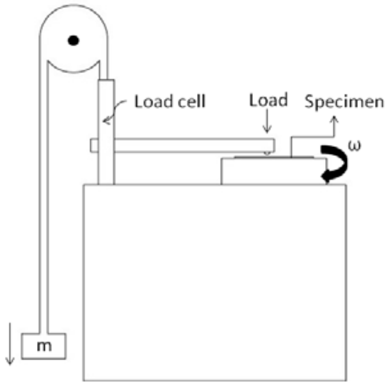

Fig. 2 Schematic of pin-on-disk

III. RESULTS AND DISCUSSION

According to the results of Fig. 3, which represents the variation of the values of coefficient of friction (COF) during the pin-on-disc tests for the evaluated composites, you can see that, as expected, the composition with 1% mineral filler had the lowest COF, due to a higher percentage of PTFE, with an average to below 0,125. With the addition of mineral filler, you can see the increase in COF already from 3%, with higher values for compositions with 30% and 50% of filler. It is also observed that the results for the composites of 3% and 10% remained in the same friction coefficient range, marking a possible transition in the behavior of these composites.

With lower values identified in the first quartile of each composition register the effect of the PTFE with the wear by delamination, supported by evidence from the SEM image in Fig. 4, the composite with 10% filler, while in the fourth quartile records the influence of the mineral filler with abrasive wear by two and / or three bodies.

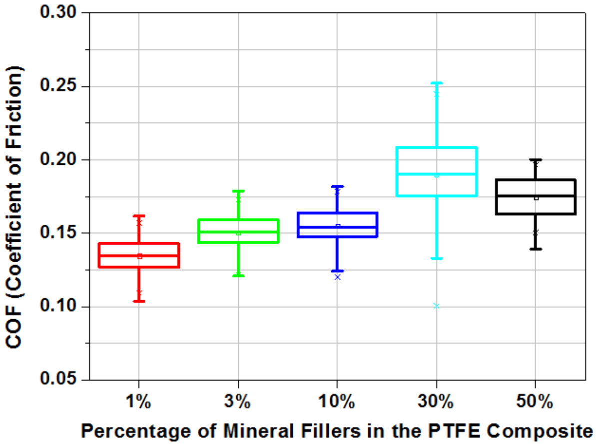

Fig. 3 COF based on the percentage of mineral filler

For a better view of the effect of the mineral filler in the composite due to the sliding distance, the graphs of Figs. 5 and 7 have been developed.

The composite with 50% filler has a growing behavior after sliding 400m, probably due to the influence of the third body (debris) promoting streaks on the wearing course, as can be seen in Fig. 6 (a), unlike the composite with 1% filler, which for the same sliding distance tends to decrease by occurrence of delamination wear (active lubrication mechanism) shown in Fig. 6 (b).

Considering that one of the objectives of these materials is to keep the COF as low as the pure PTFE, the composition of 50% would not satisfy this requirement. This is because this composite has an excessive amount of mineral filler, the load operation being a strong influence on the results of COF.

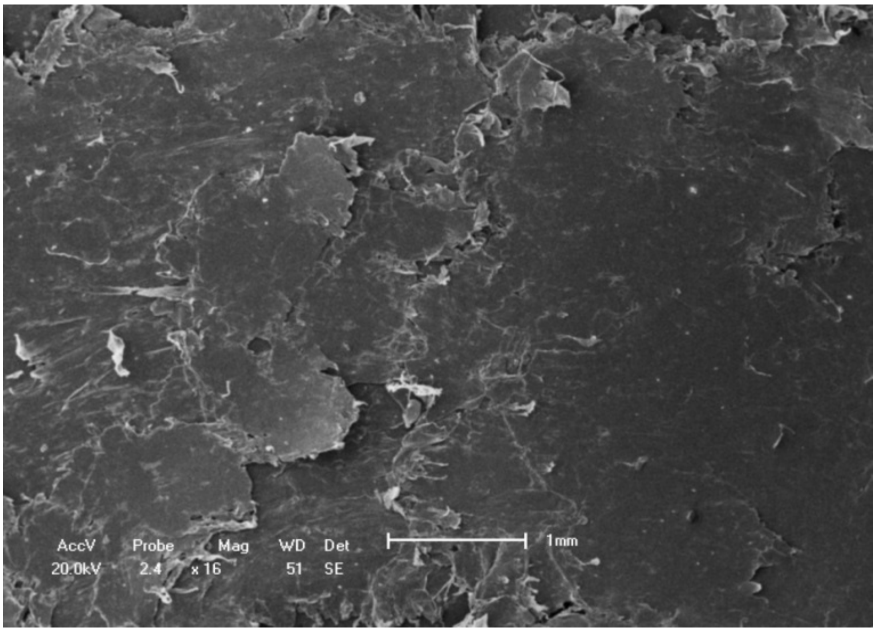

Fig. 4 SEM of the surface of the wear track of composite with 10% mineral filler exhibiting delamination and debris

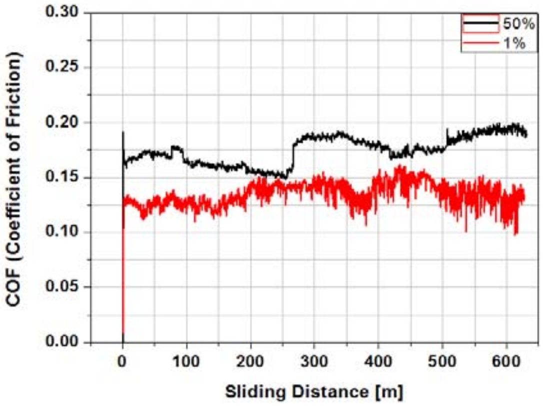

Fig. 5 Composites with 1 and 50% mineral filler

The exhibition of a high COF for the composite with 30% mineral filler in comparison with the composite 3 and 10%, which does not satisfy the conditions of low coefficient of friction can be identified, Fig. 7. During the sliding path up to 30%, it appears in the graph marked variation in the curve with similar periods, which can be the stick-slip phenomenon.

The results for the wear resistance (sinking of the track) can be seen in Fig. 8. It is noted that first of all studied the compositions 30 and 50% mineral filler are those with the lowest track sinking obtained, with the 1, 3 and 10% of the greatest sinking found.

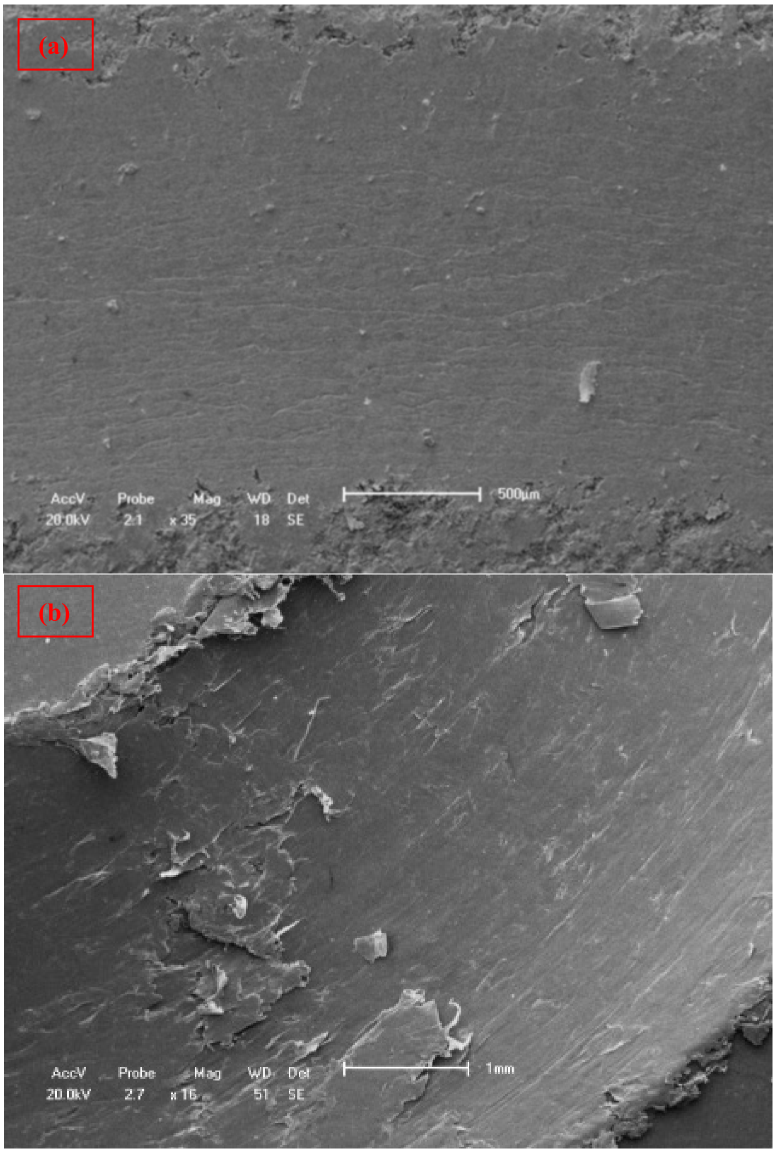

Fig. 6 SEM of the surface (a) composite wear track 50% mineral filler exhibiting debris and streaks, (b) composite wear track 1% mineral filler exhibiting delamination

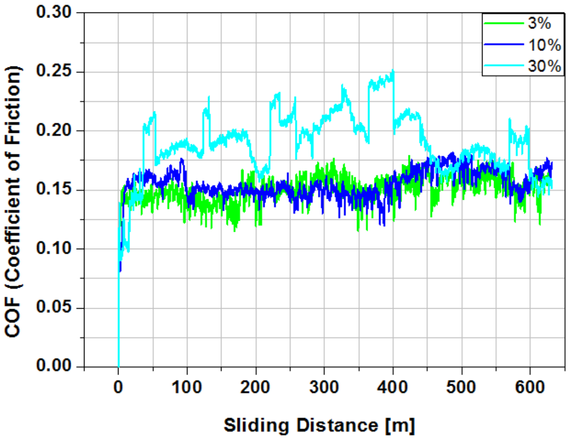

Fig. 7 Composites with 3, 10 and 30% mineral filler

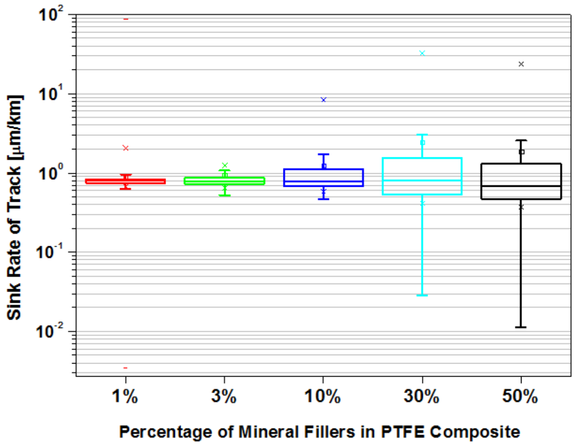

Fig. 8 Track sinking based on the percentage of mineral filler

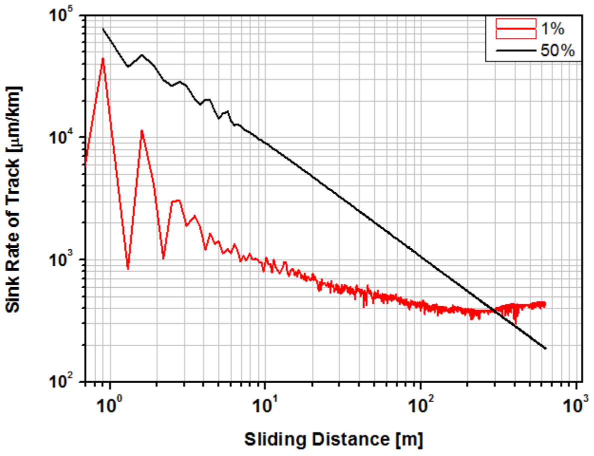

Fig. 9 Track sinking rate as a function of the sliding distance for composites 1 and 50% mineral filler

In Fig. 9, it is shown that the sink rate curves for the composites 1 and 50% filler. At the beginning of the test, it is noticed that most sink rate occurred for the composition with 50% load due to the high contact pressure due to the amount of mineral filler of this composition. While for the composite with 1% filler, the sink rate is lower. However, after 300 m the influence of the third sliding body ceases to operate in the collapse decreasing contact for the composite of 50% and increasing to 1%, which was expected due to the filler content.

In the sink rate curves of the composite 3, 10 and 30% filler, shown in Fig. 10, is also observed immediately after the settling time (7 - 13 m), the range of intersection between the curves; it turns the inversion behavior in the sink rate.

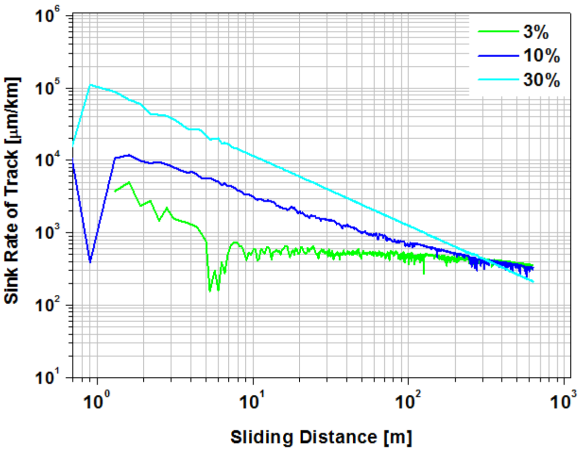

Fig. 10 Track sinking rate as a function of the sliding distance for composites with 3, 10 and 30% mineral filler

When analyzing the costs of materials used in this research for develop composites, it was found that 1 kg of pure PTFE in powder form costs about US $ 20. The tailings of scheelite to the present day is not marketed and to see how much it would cost his kg was taken as the base price WO_3 1 ton of concentrate, this amount being worth $ 320,000 as the site king Island scheelite [9]. In this way, we came to the approximate value of US $ 0.0325, considering that exists in the tailings scheelite a minimal amount of WO_3 (ppb ~ 0.1%). Given these values was developed Fig. 11, the cost of each percentage of composites, suggesting its value to a possible sale, excluding the amounts involved in the processing, how to choose the optimal particle size, the mixture of powders, hot forming, among others.

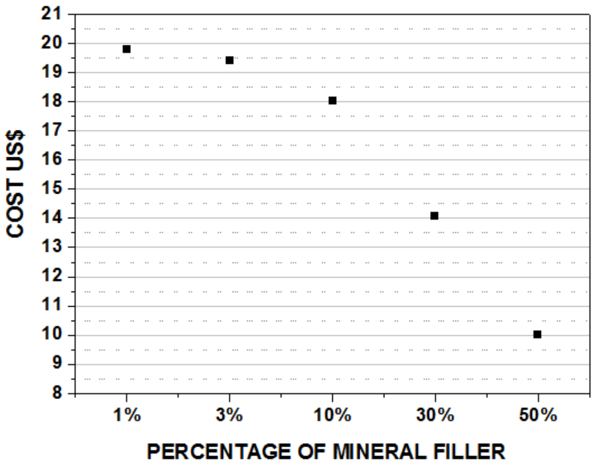

Fig. 11 Material costs involved in the production of composites

IV. CONCLUSION

It concludes that the composite with 10% mineral filler is ideal for applications where you need low coefficient of friction and a good resistance to slip because this composition keeps the COF as low as the pure PTFE and a lower sink rate that the 1% load and at 1% 400 µm/km and 10% 300 µm/km. The composite of 50% mineral filler had the lowest sink rate, which was expected due to the excessive amount of mineral, however, for applications where you need low COF it is not indicated. Although the composite of 3% and 10% show a possible transition band, not very differentiating their behavior, is indicated that the used composition with increased amount of waste, 10%, will reduce the cost of the material.

ACKNOWLEDGMENT

The authors thank all the members of the Group of Tribology Studies and Structural Integrity of UFRN, who helped directly and indirectly in the discussions of results and guidance for achievements of this research. Also, the Mechanical Engineering Department, Mechanical Engineering Coordination and Center of Technology. The authors are grateful to brazilian mining company Brejui Mine by furnishing scheelite tailing samples necessary to this investigation. The author (Araújo Neto) is grateful to Brazilian Agency CNPq for the financial support. And the other authors (Souza) is grateful to Brazilian Agency CAPES by support her scholarship.

REFERENCES

[1] Biswas, S. K.; Vijayan, Kalyani. Friction and wear of PTFE – a review. Wear. (s.I.), p. 193-211. out. 1992.

[2] Bahadur, S.; Tabor, D.. The wear of filled polytetrafluoroethylene. Wear. (s.I.), p. 1-13. nov. 1984.

[3] Lancaster, J K. The effect of carbon fibre reinforcement on the friction and wear of polymers. Journal Of Physics D: Applied Physics, (s.l.), v. 1, n. 5, p.549-559, 1 maio 1968. IOP Publishing. DOI: 10.1088/0022-3727/1/5/303.

[4] Tanaka, Kyuichiro; Tanaka, Kyuichiro. Effect of various fillers on the friction and wear of polytetrafluoroethylene-based composites. Wear. (s.I.), p. 221-234. jul. 1982.

[5] Briscoe, B.J; Steward, M.D.; Groszek, A.J.. The effect of carbon aspect ratio on the friction and wear of PTFE. Wear. (s.I.), p. 99-107. abr. 1977.

[6] Lee, Jeong-yeop; Lim, Dong-phill; Lim, Dae-soon. Tribological behavior of PTFE nanocomposite films reinforced with carbon nanoparticles. Composites Part B: Engineering. (s.I.), p. 810-816. Oct–Dec 2007.

[7] Mcelwain, Steven E. et al. Effect of Particle Size on the Wear Resistance of Alumina-Filled PTFE Micro- and Nanocomposites. Tribology Transactions, (s.l.), v. 51, n. 3, p.247-253, maio 2008. Informa UK Limited. Doi: 10.1080/10402000701730494.

[8] Li, Fei et al. The friction and wear characteristics of nanometer ZnO filled polytetrafluoroethylene. Wear. (s.I.), p. 877-882. nov. 2001.

[9] http://www.kingislandscheelite.com.au/. Accessed on 13 April 2015.