DRY SLIDING WEAR TEST ON BORIDED AISI 1018 STEEL UNDER PIN-ON-DISC CONFIGURATION

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INTRODUCTION

During the relative motion between two surfaces, a progressive loss of material is generated, influenced by different parameters; this phenomenon is called wear [1]. This is one of the most important parameters to evaluate the industrial applications of the metal components of machinery.

AISI 1018 steel is used in gearboxes for turbines, camshafts, weapons, and automotive parts or of agronomic machinery, which require high tribological performance [2]. The industrial sector reports millionaire losses in terms of maintenance every year, due to failures generated in mechanical components for different types of wear, associated with the adhesive contact of elements in mechanical systems [3]. The mechanical properties on the surface of the components have not fair values to work in optimum conditions and to be able to resist the mechanisms of failure generated by wear, fatigue, and friction. The improvement of the superficial properties of the mechanical components has been a subject of great technological and scientific importance during the last decades.

Although other superficial treatments have been used to improve the mechanical properties of different materials, such as nitriding, carburation, and boriding to reduce the wear damage of the surface. The powder-pack boriding process (PPBP) offers advantages in regards of the mechanical properties of the material, as it improves hardness, wear, and wear resistance at high temperatures [4][5]. The PPBP treatment is a surface hardening process in which boron atom particles diffuse on the surface of different ferrous and non-ferrous materials at temperatures from 1123 to 1273 K with 1 to 10 h of exposition [5-8]. The result of the treatment for an iron-based alloy consists of a single layer of Fe2B or a bilayer of FeB/Fe2B, with flat morphology or saw teeth that depend on the alloying elements.

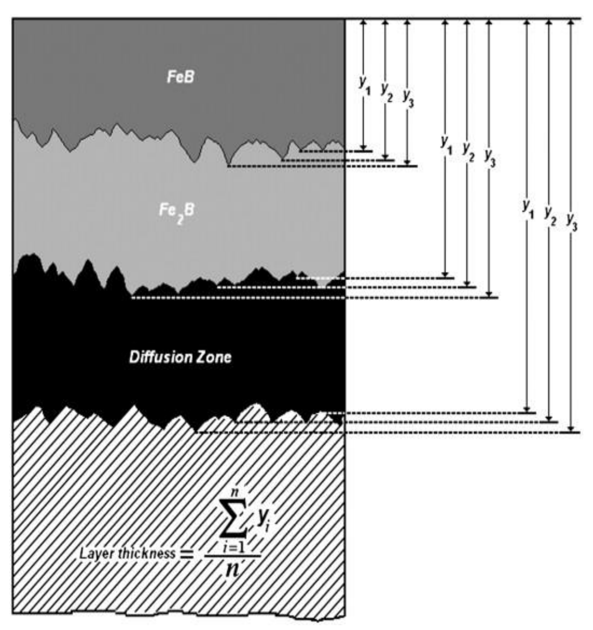
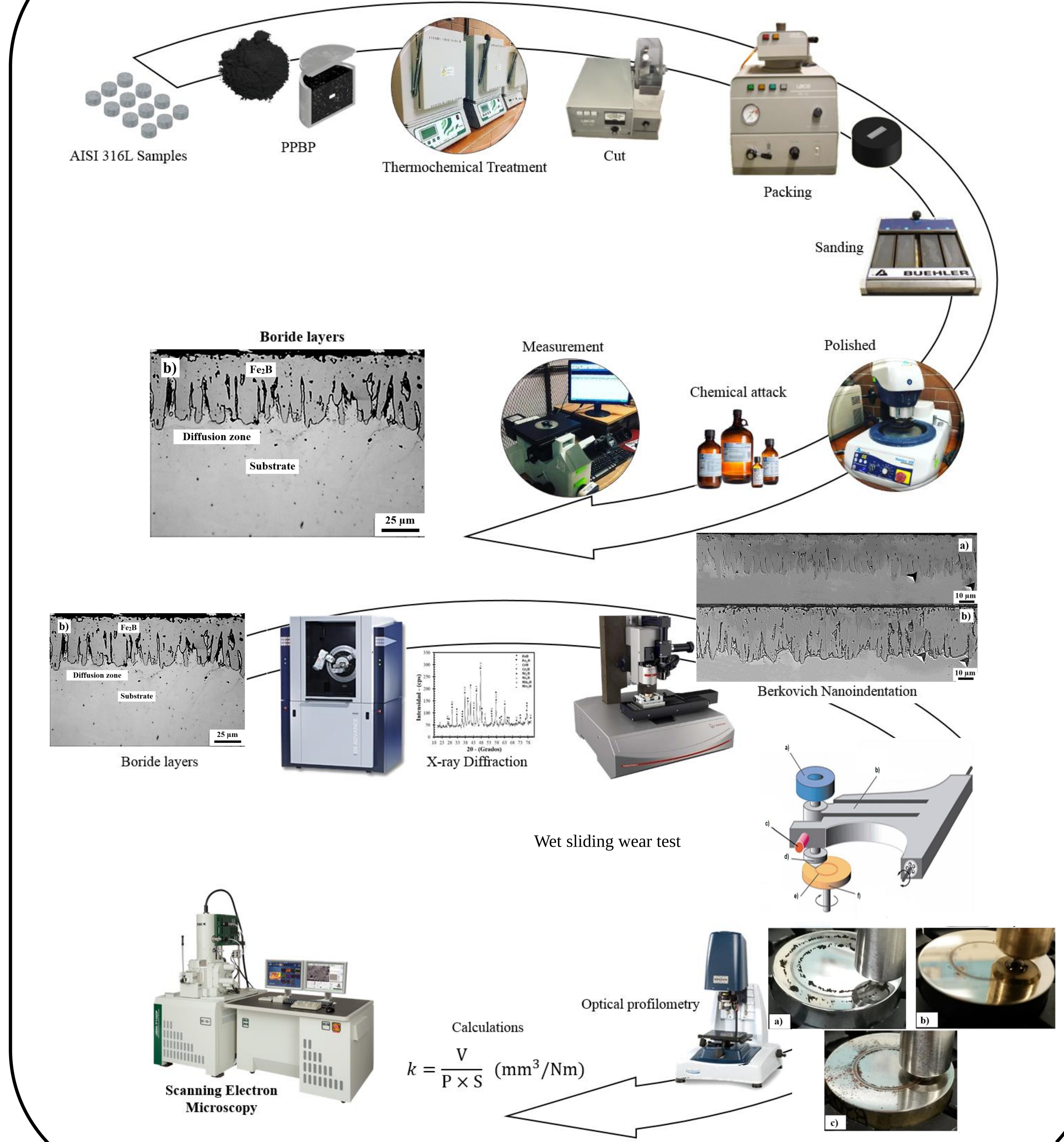


Figure 1. Representation of the formation of iron borides and measurement.

METHODOLOGY



OBJECTIVE

This study presents new results about the influence of a small iron borided layer (~36 µm) obtained at 1273 K with 20 min of exposure on AISI 1018 steel for thermochemical treatment and 1273 K with 60 min thermal treatment (PPBP and PPBP+DAP, respectively), which reduces the energy consumption and costs generated during the treatments. In regards of the wear tests, a ball-on-disc configuration under severe conditions of sliding distance (up to 500 m) with different tribopairs (Al2O3 and WC) was used to evaluate the wear performance of the FeB+Fe2B and Fe2B layers, thus obtaining a better comprehension of the wear behavior for wind turbine gearbox or automotive applications [9-10].

RESULTS

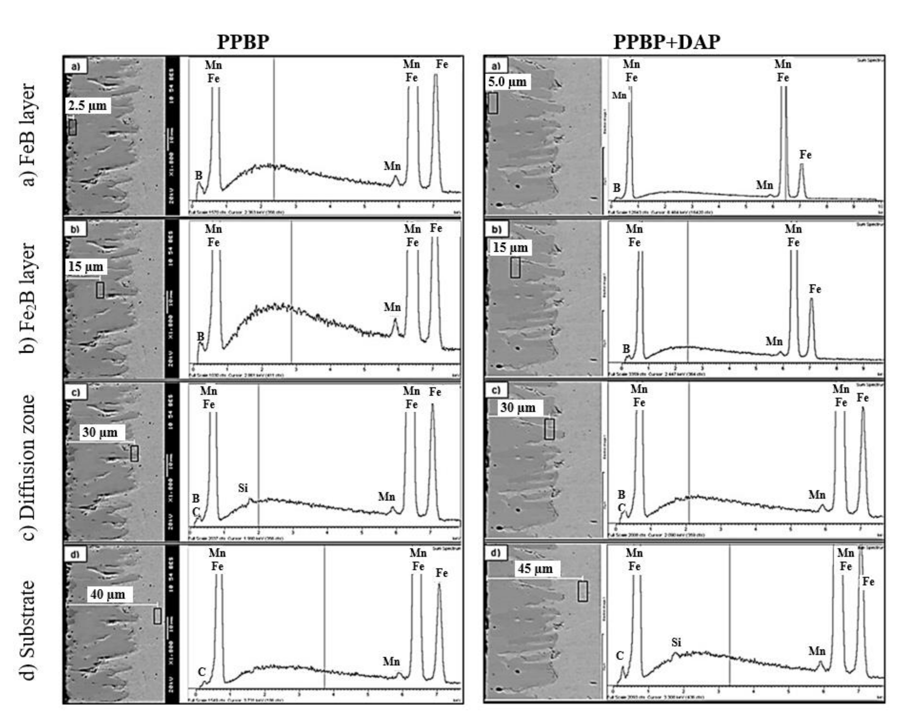


Figure 2. SEM-EDS spectrum in cross-section obtained for PPBP, and PPBP+DAP.

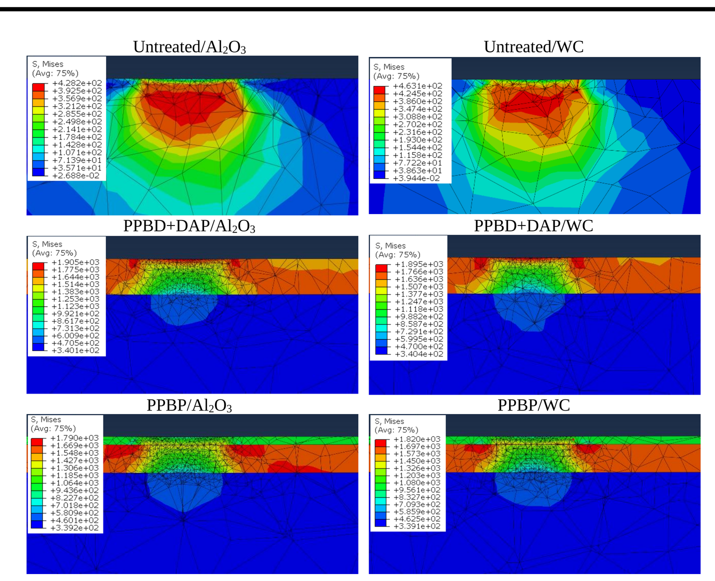


Figure 2. Von Misses stress distribution along the cross-section of the samples with Al2O3 and WC tribo-pairs.

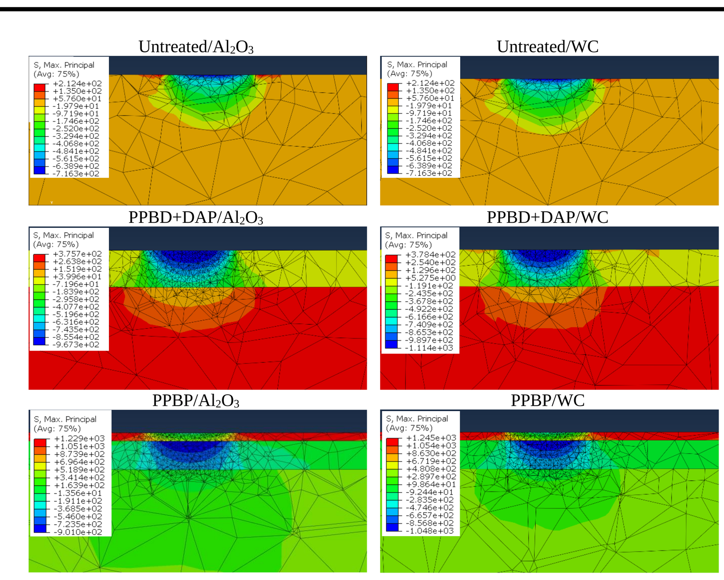


Figure 3. Principal stress distribution along the cross-section of the samples with Al2O3 and WC tribo-pairs.

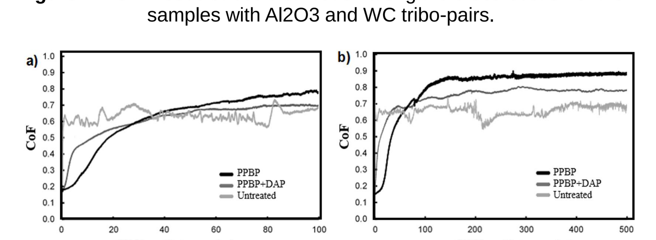


Figure 4. CoF against the relative wear distances with an Al2O3 ball for a) 100 m and b) 500 m.

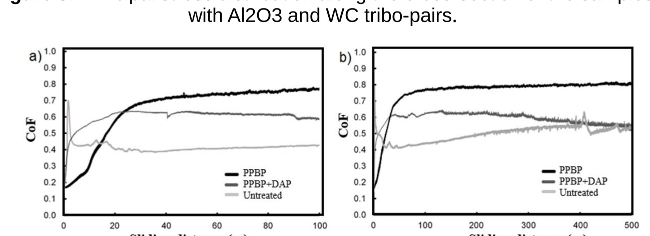


Figure 5. CoF against the relative wear distances with a WC ball for a) 100 m and b) 500 m.

RESULTS

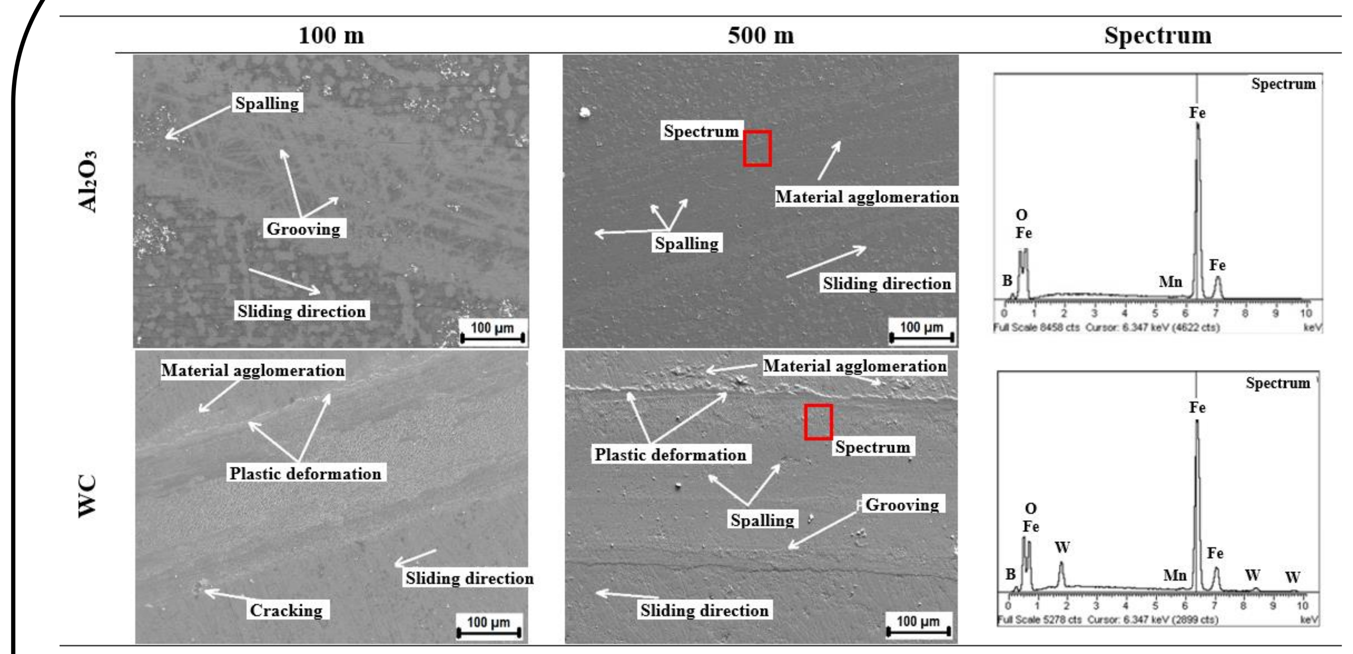


Figure 6. SEM-EDS micrographs of the wear track generated by the Al2O3 and WC ball on PPBP 1018 AISI steel under 5 N of load at a distance of 100 and 500 m at different magnifications.

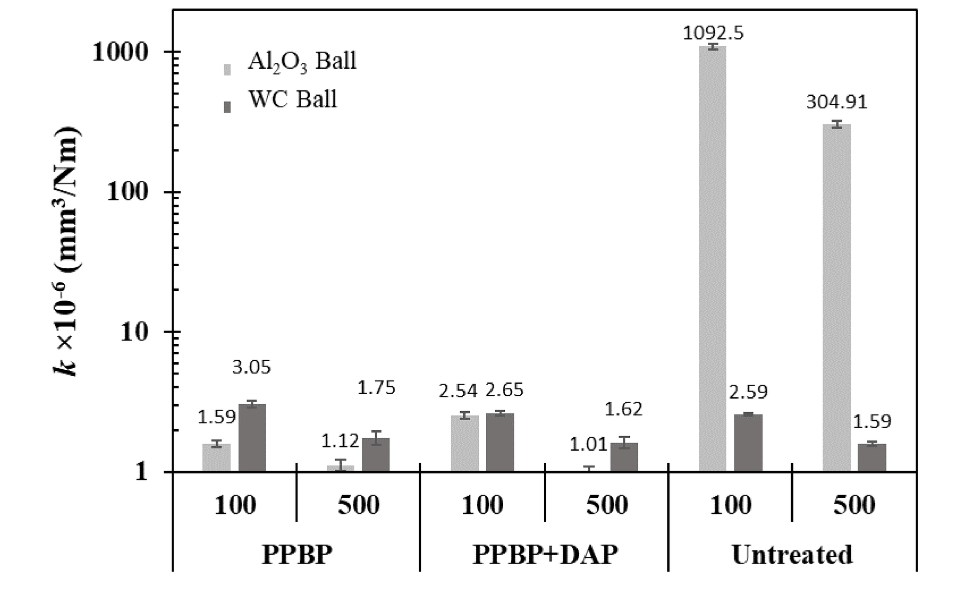


Figure 9. Specific wear rate (k) values for the overall experimental set conditions.

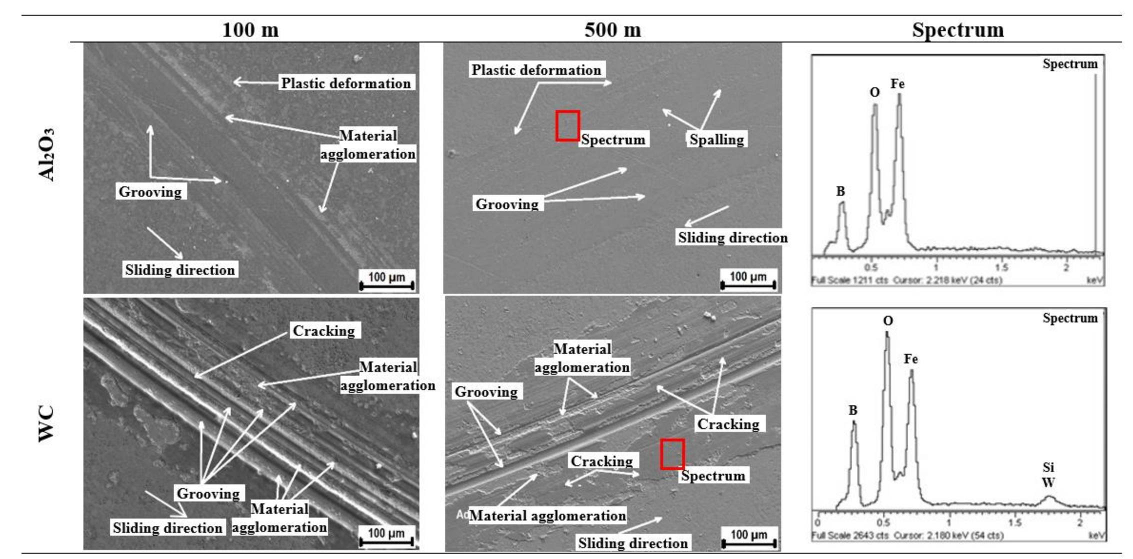


Figure 7. SEM-EDS micrographs of the wear track generated by the Al2O3 ball and WC on PPBP+DAP AISI 1018 steel under 5 N of load at a distance of 100 and 500 m.

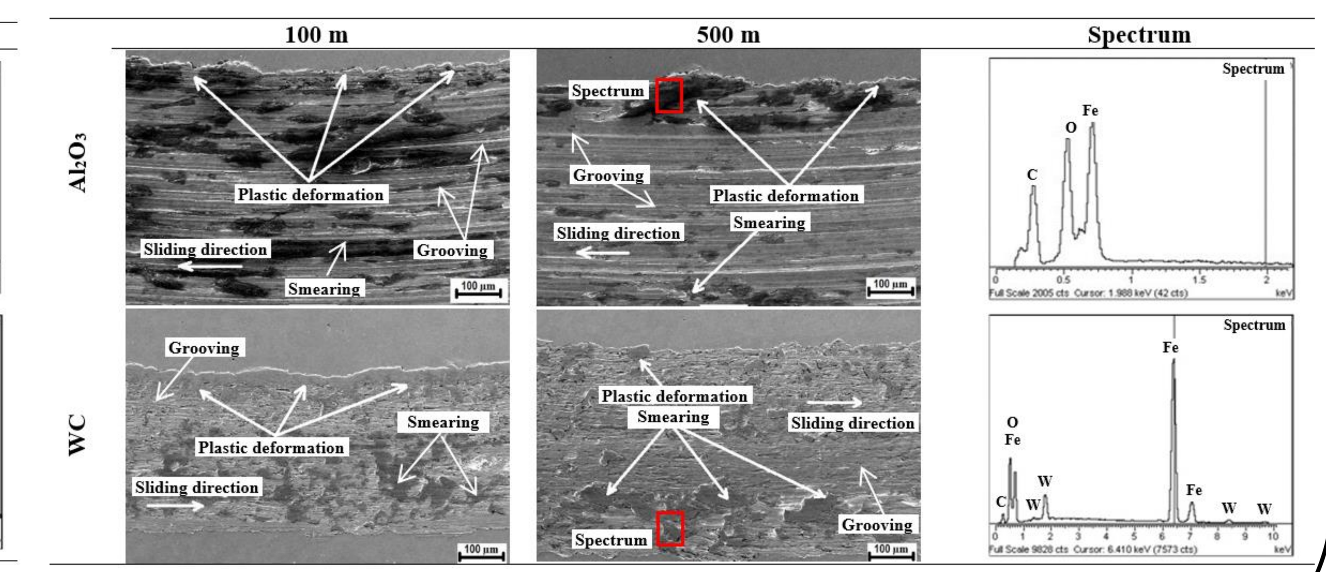


Figure 8. SEM-EDS micrographs of the wear track generated by the Al2O3 and WC on untreated AISI 1018 steel under 5 N of load at a distance of 100 and 500 m at different magnifications.

CONCLUSIONS

a) The average of the surface (Fe2B) hardness is 19.3±0.3 GPa for the PPBP+DAP condition. For the PPBP condition, the average surface hardness (Fe2B) is 18.6±0.3 GPa, and lastly, for the untreated material, there is an average hardness value of ~3.1 GPa. The effect of the DAP on the hardness values evaluated on the surface of the samples was manifested in an approximate increase of 8.3%, compared to the values obtained during the PPBP.

b) The CoF was analyzed in wear tests, whose results show that, for all tests with 5 N, the samples of AISI 1018 steel cleared have a higher CoF value, both for the static torque of Al2O3 ball and the WC ball, while the CoF of PPBP+DAP samples is diminished due to adhesion mechanisms of particles that function as a lubricant reducing CoF, which causes a more stable behavior of its curves.

c) The WC ball used for these tests plays a significant role in the data obtained, being less hard and rigid than the PPBP+DAP an abrasive behavior and a higher specific wear rate to the tribo-pair can be seen, while the Al2O3 ball reduces a more significant amount of roughness in the PPBP and PPBP+DAP, in turn polishing the wear tracks, which causes less damage to them but increases the CoF.

d) Plastic deformation was found in the base material of all numerical simulations and can be an important factor in the presence of the general stresses state on the surface just outside the contact zone. Maximum Von Misses was found in the interface between the base material and the borided layers, optimal for the gearbox applications. Also, due to the reduction of the wear rate, contact pressures, and the cracking as a failure mechanism on the worn surface, the PPBP+DAP provides a major performance for this application. Notice that, the borided samples exhibited a major tribological performance in comparison to the AISI 1018 steel without boron, which increases with the total sliding distances, thus providing higher contact pressures through the layer depth

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REFERENCES

1 K. Holmberg and A. Matthews: Coatings Tribology: Properties, Mechanisms, Techniques and Applications in Surface Engineering, Elsevier., United Kingdom, 2009.
2 P. Gopalakrishnan, P. Shankar, R. V. Subba Rao, M. Sundar, and S.S. Ramakrishnan: Scr. Mater., 2001, vol. 44, pp. 707–12.
3 W. Fichtl: Mater. Des., 1981, vol. 2, pp. 276–86.
4 R.A. García-Léon, J. Martínez-Trinidad, I. Campos-Silva, and W. Wong-Angel: DYNA(Colombia), 2020, vol. 87, pp. 34–41.
5 I.E. Campos-Silva and G.A. Rodríguez-Castro: in Thermochemical Surface Engineering of Steels, Woodhead Publishing, Oxford, 2015, pp. 651–702.
6 M. Kulka: Current Trends in Boriding: Techniques, Switzerland, 2019.
7 M. Keddam and S.M. Chentouf: Appl. Surf. Sci., 2005, vol. 252, pp. 393–9.
8 S. Şahin: J. Mater. Process. Technol., 2009, vol. 209, pp. 1736–41.
9 I. Campos-Silva, M. Flores-Jiménez, D. Bravo-Bárcenas, H. Balmori-Ramírez, J. Andraca-Adame, J. Martínez-Trinidad, and J.A. Meda-Campaña: Surf. Coatings Technol., 2017, vol. 309, pp. 155–63.
10 A.M. Delgado-Brito, D. López-Suero, A. Ruiz-Ríos, R.A. García-León, J. Martínez-Trinidad, J. Oseguera-Peña, and I. Campos-Silva: Ceram. Int., 2019, vol. 45, pp. 7767–77.