24th COBEM - 2017

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

COBEM-2017-0939
TRIBOLOGICAL PROPERTIES OF BORONIZED AISI 4140 STEEL

Steffen Alexandre da Costa Aichholz
Ricardo Diego Torres
Michelle Sostag Meruvia
Paulo César Soares Junior
Andressa Damião de Almeida
Pontifícia Universidade Católica, PUC-PR, Rua Imaculada Conceição, 1155 CEP 80215-901, Curitiba, PR - Brasil
ste.aichholz@hotmail.com
ricardo.torres@pucpr.br
meruvia@fisica.ufpr.br
pa.soares@pucpr.br
andressa-damiao@hotmail.com

Abstract. *In this study, AISI 4140 steel was boronized using solid state thermochemical boriding technique. The process was carried out at 900°C during 45 minutes, producing a monophasic iron boride (Fe_2B) layer with a mean thickness of 49,55 μm. The tribological properties of the boronized samples were examined and compared to electroless nickel plated samples using a pin-on-disk wear test. The wear tracks were evaluated by Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS). Boronized samples reached faster a steady state friction coefficient than the electroless nickel plated samples and the SEM examinations of the wear surface revealed an abrasive wear mechanism on the wear surface of the boronized samples.*

Keywords: *Thermochemical Boriding, AISI 4140, Tribology*

1. INTRODUCTION

One of the challenges posed by the pre-salt exploration is the development of new materials to withstand adverse conditions in ultra-deep waters. The Brazilian basins are among the most aggressive environments in the world for the action of corrosive and abrasive agents in oil and gas production equipment, due to their different temperatures, pressures and depths. In the oil and gas industry, the flanges and valves are made of AISI 4140 steel. To improve the surface properties of AISI 4140 steel, thermal or thermo chemical heat treatments are commonly used. Boriding has been found to be an effective method for significantly increasing the surface hardness and the wear resistance of metals (Whittle and Scott, 1984; Tabur et al., 2009; Ulutan et al., 2010 and Selcuk and Karamus, 2003). Boronizing is a thermochemical surface treatment, in which boron is diffused into, and combines with, the substrate forming a single or double phase iron boride layer at the surface. Typically, boriding is carried out at temperatures varying from 850°C to 1050°C by using solid, gaseous or liquid boron rich atmospheres (Bejar and Moreno, 2006). This study employs a solid boriding technique, which is less expensive and easier to process than other boriding techniques. The objective of this study is to evaluate tribological properties of boronized AISI 4140 steel and compare it to electroless nickel plated specimens.

2. EXPERIMENTAL PROCEDURE

In this study, AISI 4140 steel specimens were used, with the chemical composition shown in Table 1. The samples were cylindrical with a diameter of 25,4 mm and thickness of 10 mm. Specimens were grinded on 600 mesh SiC paper before boronizing. Boriding heat treatment was carried out by using a powder-pack-boriding method with commercial Ekabor®2 powder. All boronized samples were packed in the powder mix and sealed in a stainless steel container. Boronizing heat treatment was performed in an electrical resistance furnace under atmospheric pressure at 900°C for 45 minutes followed by cooling in air.

Table 1. Chemical composition of AISI 4140 steel.

% C	% Mn	% Si	% Cr	% Mo	% P	% S
0,40	0,84	0,23	1,04	0,17	0,018	0,027

The pin-on-disk wear tests were carried out using a Al_3O_2 ball (6 mm diameter) counterpart and by applying a constant normal load of 5 N over the samples. Tracks with 3, 5 and 7 mm radius were made in each sample with a sliding distance of 250 m and linear speed of 3 cm/s. All tests were carried out at room temperature and the relative humidity was kept between 50 and 60%. The wear rates of the samples were estimated after the wear test through the removed material volumes which in turn were approximated using a profilometer.

3. RESULTS AND DISCUSSION

Plots of the Coefficient of Friction (COF) versus sliding distance of the samples are given in Fig. 1. Figure 1a shows that the boronized surface during the running in time the COF increased rapidly and after 20 m decreases to a steady state friction coefficient of 0,6. The stableness of the COF can be associated to the high hardness of the iron boride layer. The nickel plated surface in Fig. 1b. reveals a different behavior, the COF increases until the test reaches 200 m and only then in starts to stabilize, the mean coefficient of friction was 0,4.

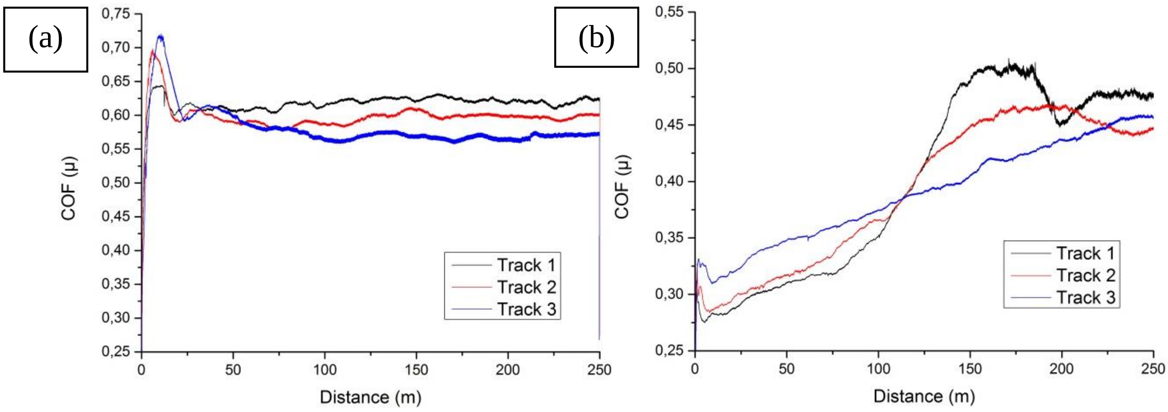

Figure 1. COF vs Sliding Distance. (a) Boronized sample; (b) Electroless nickel plated sample.

The boronized sample wear tracks SEM images are presented in Fig. 2. These longitudinal lines presented along the tracks are found in abrasive wear mechanism.

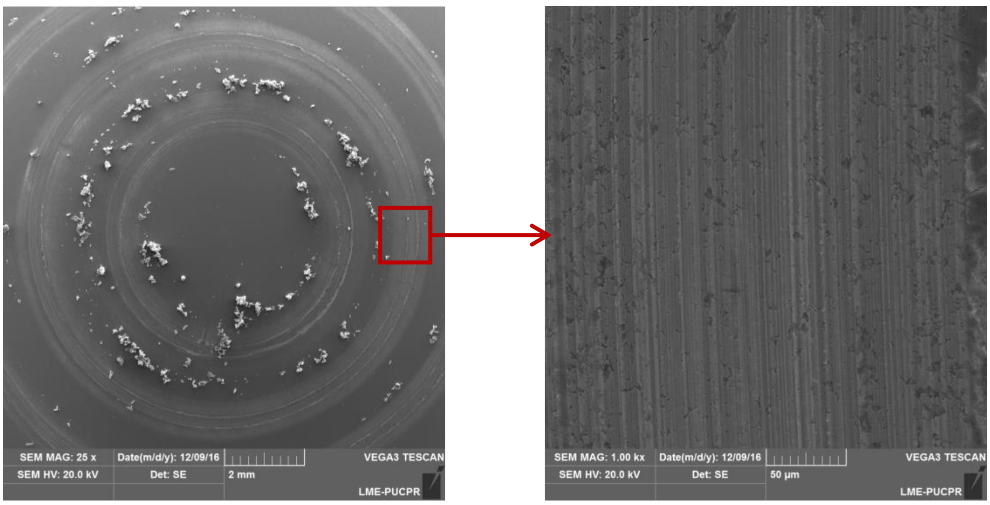

Figure 2. Wear tracks of boronized sample.

It can be seen in Fig. 3, that the wear tracks of the nickel plated surface presented both, adhesive and abrasive wear mechanism. Coatings that form a passivation layer, like the nickel oxide formed in these coating, have a higher tendency to have an adhesive wear mechanism due to their electron-affinity with the ceramic (Al_3O_2) counterpart of the wear test.

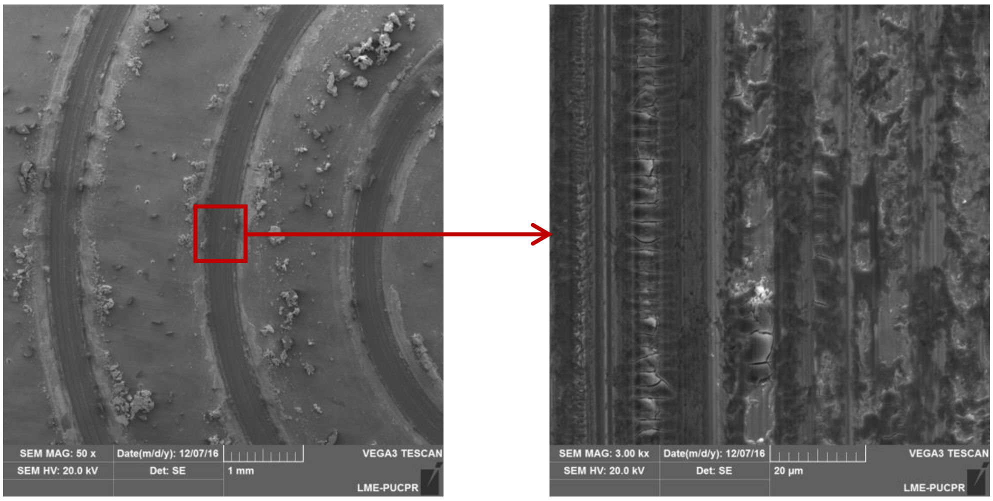

Figure 3. Wear tracks of electroless nickel plated sample.

4. CONCLUSIONS

Experimental wear test results show that the boronized surface has an abrasive wear mechanism, a higher coefficient of friction than the nickel plated surface, however it reaches faster the steady state coefficient of friction. A steady state coefficient of friction is more desirable in industrial applications, because in a long term use it’s easier to predict the behavior of the layer.

5. REFERENCES

Bejar, M. A., and E. Moreno, 2006. "Abrasive wear resistance of boronized carbon and low-alloy steels." *Journal of Materials Processing Technology* , Vol. 173, n. 3, p. 352-358.

Selcuk, B., Ri Ipek, and M. B. Karamış, 2003. "A study on friction and wear behaviour of carburized, carbonitrided and borided AISI 1020 and 5115 steels." *Journal of Materials Processing Technology*, Vol. 141, n. 2, p. 189-196.

Tabur, M., et al, 2009. "Abrasive wear behavior of boronized AISI 8620 steel." *Wear*, Vol. 266, n. 11, p. 1106-1112.

Ulutan, Mustafa, et al, 2010. "Effect of different surface treatment methods on the friction and wear behavior of AISI 4140 steel." Journal of Materials Science & Technology, Vol. 26, n. 3, p. 251-257.

Whittle, R. D. T., and V. D. Scott, 1984. "Sliding-wear evaluation of boronized austenitic alloys." Metals technology, Vol. 11, n. 1, p. 522-529.

6. RESPONSIBILITY NOTICE

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