STUDY OF HUMIDE ABRASION IN STEELS H-13 AND AISI D-2.

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RESUMEN
En el presente trabajo se desarrolla la caracterización tribológica de aceros AISI H13 y D2, sometidos a un proceso de nitruración iónica para determinar la resistencia al desgaste en condición acuosa. Los ensayos de desgaste son realizados con un equipo para medir desgaste por abrasión según la norma ASTM G105-89. La ayuda de esta investigaciones usar un nuevo material a precio más bajo que tenga propiedades excelentes ante la resistencia al desgaste en un medio agresivo con alta abrasión en medio acuoso, como sucede en varios casos como equipos en la industria de la Minería.

ABSTRACT
In the present work, is developed the tribologic characterization of steels AISI H-13 and D-2, submitted to nitruration ionic process to determine wear resistance in aqueous conditions. Wear test are realized with an abrasion wear tool in an aqueous environment, according to the norm ASTM G105-89. The aim of this investigation is to use a new material at lower prize which has an excellent wear resistance properties for high abrasion in aqueous environments, as occurs in several cases as mining industry equipments.

Keywords (4): Abrasion, Steel, Wear, Coatings.

INTRODUCTION
H-13 steel has an appropriate resistance for thermal fatigue. Works made with H-13 can be possible by cooled safety water in hot working conditions. It has excellent properties of thermal, erosion and abrasion wear resistance. But H-13 is depending of hydrogen embrittlement. It is necessary to do a nitried application to obtain more abrasion wear resistance. H-13 steel typical hot work applications are: inserts, cores, ejectors, pins, plungers, sleeves, etc. Other tool and structural applications include punches, shafts, beams, torsion bars and ratchets, etc.

D-2 steel has a high wear resistance at elevated temperatures. Representative applications of D-2 are long-run dies for blanking forming and for cutting laminations, thread rolling, deep drawings, shear and slitter knives, etc...
The plasma nitriding process represents for industrial a precise control of the compound layer quantity and thickness. This technique can be employed for surface hardens most grades of tool steel, stainless steel and titanium alloys.

Nitriding can be leading at important lower temperature with a shorter working time in comparison with the conventional gas nitriding method developed in the 60's. The superficial hardening of nitration steel based by plasma also known as ionic nitration is an efficient method that can be used for many applications [1-2]. The layer developed on the surface reaches to have hardness values higher than the substrate values. To avoid removing this layer by consequence of residual stress due to the excessive micro hardening values, it is necessary to reduce these effects by release mechanicals.

EXPERIMENTAL PROCESS
Experimental equipment for surface nitriding consists of a plasma reactor, a gas supply, a power supply and a vacuum system.

The sample of AISI H-13 and D-2 steels are placed inside a vacuum chamber of plasma reactor where nitriding is optimized. The composition of the mixture employed is nitrogen and hydrogen. The plasma nitriding condition is presented below for two materials.

AISI H13 STEEL
- Nitration Temperature: 500°C.
- Nitration Time: 15 h. Gas mixture: 25% N₂ + 75% H₂.
- Plasma pression: 6.5 HPa.
- Voltage: 700 V.
- Sputtering time before nitriding as cleanning: 2 h.
- Gas mixture during sputtering: 50 % Ar and 50 % H₂.

AISI D2 STEEL:
- Nitration Temperature: 500°C.
- Nitration Time: 15 h.
- Gas mixture: 15% N₂ + 85% H₂.
- Plasma pression: 6.5 HPa.
- Voltage: 700 V.
- Sputtering time before nitriding as cleanning: 2 h.
- Gas mixture during sputtering: 50 % Ar and 50 % H₂.
Abrasion wear resistance carries out by wet abrasion tester, manufactured by ASTM G 105-91 standard, by Tribology group of SEPI, ESIME, IPN, MEXICO. Test specimen has the following dimensions: 24 mm wide by 50 mm long by 12 mm thick. The abrasive slurry employed for tests contained a mixture of water (0.940 Kg) and of rounded quartz grain sand (1.500 Kg) as specify by AF 50/70 test sand. The balance operated to measure the mass loss of metallic specimens has a sensitivity of 0.0001 g

Note: The surface hardness of nitriding metallic specimens is measured by Rockwell and Vickers Hardness testing.

Abrasion Aqueous Test
Abrasion test is realized in a wet condition according to the norm ASTM G105-89 [3]. Test consists of a metallic disc with perpendicular radial agitating paddles in order to keep a homogenous mixture of water and sand. On ledge, there is a neoprene coating with the purpose of wearing a specimen. The wheel and the specimen are submitted to a normal load applied by a lever arm. Scars wear generated on the specimen is due to the abrasion of sand in suspension in water... [4] The picture of this equipment is shown on Figure 1.

Figure 1: Prototype of the aqueous tribometer.

The main components of the tribometer are:
1) Sand deposit with capacity for 1.5 Kg of silica sand.
2) Water tank with capacity of 0.940 Kg.
6) Stainless steel disc with nominal diameter of 177.8 mm and paddles.
7) Neoprene coating with a hardness de A70 ± 20.
8) Stainless steel container for the homogeneous mixture during process.
15) Motor-reducer: with a 1 HP and a speed reducer with a 5:1 ratio.
16) Weight of approximately 117.6 N.
17) Lever arm.
18) Sample dimensions are: 57.2 x 25.4 x 6.4 mm.

The operation parameters are established in Table 1:

<table>
<thead>
<tr>
<th>Table 1: Operation parameters for abrasion test in aqueous condition.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rotation speed</strong></td>
</tr>
<tr>
<td><strong>Amount Sand and water</strong></td>
</tr>
<tr>
<td><strong>Charge applied on the specimen</strong></td>
</tr>
<tr>
<td><strong>Sliding total distance</strong></td>
</tr>
</tbody>
</table>
EXPERIMENTAL RESULTS

STEEL H-13

After an experimental development, wear resistance results are obtained by weight loss. It is determined that for steel H-13, nitriding is five times more resistant than substrate steel H-13. With table 2, we determine that for substrate steel H-13, wear rate is increased to a rate approximated to 0.4gr for 1117m. Figure 2 describes the characteristic curves of substrate steel H-13 that shows a linear wear behavior between loss weight and the sliding distance in meters. It is observed that the nitriding steel H-13 has good properties of wear resistance due to the minimum weight loss.

Table 2: Result comparison for wear test in H-13 steel.

<table>
<thead>
<tr>
<th>Cycles</th>
<th>Distance (m)</th>
<th>Weight loss (g)</th>
<th>Weight loss (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>1117</td>
<td>0.17</td>
<td>0.107</td>
</tr>
<tr>
<td>4000</td>
<td>2234</td>
<td>0.320</td>
<td>0.146</td>
</tr>
<tr>
<td>6000</td>
<td>3351</td>
<td>0.4669</td>
<td>0.182</td>
</tr>
<tr>
<td>8000</td>
<td>4468</td>
<td>0.602</td>
<td>0.228</td>
</tr>
<tr>
<td>10000</td>
<td>5586</td>
<td>0.7354</td>
<td>0.277</td>
</tr>
</tbody>
</table>

Figure 2: Wear resistance behavior for H-13 substrate and H-13 nitriding.
On Figures 3 and 4, it is observed superficial damage caused for two materials. For H-13 substrate steel, we note important scars wear due to the microploughing phenomena. On nitriding H-13 steel we note a superficial damage minimum. This difference shows that nitriding H-13 steel is better until four times to wear resistance in relation to the substrate H13 steel.

STEEL D-2
Results measured in wear tests for substrate D-2 steel and nitrided are showed in Table 3. We note that for both materials, wear has a linear behavior, but the substrate material is 2.7 times more than the nitriding material. It is showed a comparison for both results on Figure 5.

Table 3: Wet abrasion test for substrate D-2 steel and nitriding.

<table>
<thead>
<tr>
<th>Cycles</th>
<th>Distance (m)</th>
<th>Weight loss (g)</th>
<th>Weight loss (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>1117</td>
<td>0.456</td>
<td>0.11</td>
</tr>
<tr>
<td>4000</td>
<td>2234</td>
<td>0.829</td>
<td>0.191</td>
</tr>
<tr>
<td>6000</td>
<td>3351</td>
<td>1.163</td>
<td>0.240</td>
</tr>
<tr>
<td>8000</td>
<td>4469</td>
<td>1.542</td>
<td>0.309</td>
</tr>
<tr>
<td>10000</td>
<td>5586</td>
<td>1.976</td>
<td>0.390</td>
</tr>
</tbody>
</table>

Figure 3: H-13 Steel without treatment.

Figure 4: H-13 Steel with ionic nituration.
Figure 5: Wear tests in substrate D-2 steel and D-2 nitriding.

On Figures 6 and 7, it is observed scars wear occasioned during wet abrasion test for substrate D-2 steel (Fig. 6) and D-2 nitriding (Fig. 7). For both surfaces, we note a similar wear but for the substrate material, we note a great amount of abrasion grooves.
Figure 6: D-2 Steel without treatment.

Figure 7: D-2 Steel with ionic nitruration.

Comparative results and Conclusion.

Wear tests give us very interesting information. Firstly, if it is compared results of the four materials, one can observe that nitrided materials improve wear resistance abrasion properties in wet conditions (Table 4). Secondly, it is noted a difference rate of weight loss between H-13 steel nitriding and D2 nitriding, but not a significant difference for their wear resistance. In attention to the results obtained, we can determine that H-13 steel has a great compatibility with the ionic nitration process, in comparison of D-2 steel. As we can see in table 4, H-13 steel is the steel that increases significantly its aqueous abrasion resistance after an ionic nitration process. It is clearly observed these results on figures 8 and 9.

Table 4: Summary of the aqueous abrasion wears dates.

<table>
<thead>
<tr>
<th>Cycles</th>
<th>Distance (m)</th>
<th>H-13 Subrat</th>
<th>H-13 Nitriding</th>
<th>D-2 Subrat</th>
<th>D-2 Nitriding</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>1117</td>
<td>0.17</td>
<td>0.107</td>
<td>0.4563</td>
<td>0.11</td>
</tr>
<tr>
<td>4000</td>
<td>2234</td>
<td>0.320</td>
<td>0.146</td>
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<td>1.542</td>
<td>0.309</td>
</tr>
<tr>
<td>10000</td>
<td>5586</td>
<td>0.735</td>
<td>0.277</td>
<td>1.976</td>
<td>0.390</td>
</tr>
</tbody>
</table>

Figure 8: Aqueous wear abrasion for H-13&D2 nitriding and their references.
Figure 9: Comparison between wear tests realized for H-13 and D-2 substrate steel and nitriding.

ACKNOWLEDGMENTS
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REFERENCES