DLC COATING OF ROLLING BEARINGS BY TRIBOADHESION AND ITS EFFECT ON THEIR DYNAMIC RESPONSE

José María Rodríguez Lelis, Eduardo Ramírez Flores, Jorge Colín Ocampo
National Center for Research and Technological Development
Interior Internado Palmira s/n, Col. Palmira
Cuernavaca Morelos, A. P. 5-164, C. P. 62490, Mexico
Phone/Fax: (777) 3127613
jmlelis@cenidet.edu.mx, eduraflo@yahoo.com.mx, jcolin@cenidet.edu.mx

ABSTRACT
In this work vibration signals were obtained for ball bearings with and without DLC coating. The coating was carried out by triboadhesion, and only the inner rolling surface of the bearings was coated. Here it was found that the amplitude of the vibration signal is modified by the thin film DLC coating, and that this can be related to the stiffness of the system and finally to wear resistance of the ball bearings.

Keywords: Triboadhesion, bearings, wear, surface.

1. INTRODUCTION
Mechanical elements such as bearings experience metal to metal contact through their life, this contact causes adherence, abrasion and fatigue, i.e., wear [1]. A way of reducing friction and wear in rolling bearings is through surface treatments, in particular, by the use of coatings. The surface properties on the rolling bearings, caused by the coatings, modify their wear resistance, as well as their stiffness and ultimately, their vibration signal. The last, employed for the diagnostic of the bearing’s health.

In this work, are assessed the dynamic signals of ball bearings with and without DLC coating. Here it was found that the amplitude of the vibration signal of the system is higher for coated bearings, and decreases as a function of the film thickness.

2. THE DEPOSITION PROCESS
The coating was carried out by triboadhesion only in the inner rolling surface of the bearing. An schematic diagram for the deposition process is shown in figure 1. This is composed by: 1) Rotating wheel system, 2) Force measurement system, 3) Feeding system and 4) Acquisition data system. The deposition process consists of passing the coating material through the wheel and the substrate to be coated. The wheel rotates at high velocity and exerts pressure on the substrate generating heat through friction.

This technology takes advantage of the heat generate by friction, i.e., voids are formed and disrupted through statistical fluctuations caused by the temperature increment. Thus the steady state population of voids may be expressed by:

\[ N_c = N \exp \left[ - \frac{G^*_r}{K T} \right] \]  \hspace{1cm} (1)

where T refers to the temperature, N and \( N_c \) are the number of atoms and cavities per volume, \( K \) is the Boltzman constant and the free energy \( G^*_r \) can be obtained as shown in [2] by:

\[ G^*_r = -\Delta G \pi k^2 R^3 + \frac{\Delta G \pi k^3 R^3}{3} + \pi H k^2 R^3 + 2 \pi R^2 W_{ab} k \] \hspace{1cm} (2)

Where \( R \) is the radius of a spherical particle, \( W_{ab} \) is the sum of the free energies of the base and feeding materials plus the free energy of the interface, and \( k \) is ratio of penetration depth divide by \( R \).
From the free energy as described in Eq. (2), the cavity radius can be obtained and from Eq. (1) the population of cavities, where is likely to introduce a particle of the coating material. As described in [3] a thin film of mixed material is formed whose depth is a function of the heat generated through the triboadhesión process.

3. VIBRATION SIGNAL ANALYSIS OF ROLLING BEARINGS.

As mentioned by Barkov and Barcoya [4] bearings can exhibit vibration caused by six kinds of dynamic forces. Also, that the random vibration may be caused by friction forces at frequencies around the 30 kHz, exhibiting low amplitude compared to the vibration encountered in the interval from 2-10 kHz. Vibration pulses caused by the sudden contact metal to metal may be found in the interval from 1 to 1 kHz [5].

The dynamic response of ball bearings with and without DLC coating was assessed. All bearings were subjected at the same load and velocity conditions. The bearings evaluated are shown in Table 1.

The vibration spectrum in the interval of 2000 Hz to 7000 Hz of the five type bearings described in Table 1 are shown in figure 2. Here, it is shown a difference in vibration amplitude between the commercial and coated bearings. Coated bearings showed a higher amplitude than those without coating. Here, the bearing labeled as DA shows higher frequency and amplitude behavior mainly between 5000 to 7000 Hz, similar to those exhibited by bearing RE40S.

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bearing with apparent damage in the rolling surface</td>
<td>DA</td>
</tr>
<tr>
<td>2</td>
<td>Commercial Bearing, first set.</td>
<td>COMP1</td>
</tr>
<tr>
<td>3</td>
<td>Commercial bearing, second set.</td>
<td>COMP2</td>
</tr>
<tr>
<td>4</td>
<td>Bearing with DLC coating, deposition time 10 seconds.</td>
<td>RE10S</td>
</tr>
<tr>
<td>5</td>
<td>Bearing with DLC coating, deposition time 40 seconds.</td>
<td>RE40S</td>
</tr>
</tbody>
</table>

The vibration spectrum from the vibration signal for bearings RE40S, COMP2 and RE10S, COMP1 are shown in figures 3 and 4. In these, it is shown that the dynamic response of the four bearings is similar, except in the amplitude of vibration, the highest amplitude of vibration belongs to the bearings RE40S.

The amplitude of vibration increase of the RE40S bearing may be attributed to the surface properties modification. It should be pointed out that the frequency lies within 3500 to 4500, where contact phenomena start to appear. It may also be noted that the amplitude difference between coated and commercial bearings is lower for the RE10S. It was thought based on these results, that the higher the amount of DLC deposited, the higher is the amplitude increase. This is attributed to the stiffness increase caused by the DLC coating. It also shows that there is a limit of thickness coating for which there won’t be significant increase in the amplitude of vibration.

The increment in amplitude can be related to wear resistance. Wear resistance test were carried out for coated and no coated bearings. It was found that the higher the deposition time was
achieved, the higher wear resistance was obtained. Here, wear resistance up to 307% compared to the bearings without coating was obtained, as described in [6].

4. CONCLUSIONS
The dynamic response of ball bearings with and without DLC coating was assessed. An increase of the amplitude of vibration for the bearings RE40S was detected. The increase of the amplitude of vibration in RE40S shown that the properties of stiffness and hardness of the rolling surface of the bearings are modified by the film DLC coating, properties that might be related to the wear resistance.

It may also be stated that there is a limit for which there will be a significant change on the amplitude of vibration spectrum.

5. REFERENCES


