INFLUENCE OF A SHAFT COATED BY TRIBOADHESION WITH DLC ON THE PRESSURE DISTRIBUTION AND DYNAMIC RESPONSE OF A TILTING PAD BEARING

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Abstract: - This work is concerned with the dynamic and pressure response of a hydrodynamic tilting pad bearing caused by a shaft with and without DLC coating. Here it is shown that the maximum pressure it is moved towards the center of symmetry when the DLC coating is applied. This was attributed to the decrement of the shear stress at the surface between the shaft and the fluid. It is also shown that the amplitude of the vibration signal when analyzed through wavelets is lower for the case with coating compared with the no coating.

Keywords: Triboadhesion, bearings, wear, surface, tilting pad

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 bearings is through lubrication and surface treatments, in particular, by the use of coatings.

The surface properties both of the shaft or bearing pad, undoubtedly affect the friction coefficient, and as consequence, the fluid film thickness as described by the Stribeck diagram.

In this work, it is evaluated the influence of shafts coated with DLC by triboadhesion and with out coating, on the lubricant's film pressure distribution exerted on a tilting pad. The dynamic signals of tilting pad bearings with and without DLC coating were analyzed through wavelet analysis. Here it was found that the amplitude of fluid film pressure decreases for the shaft coated with DLC as well as the vibration signal of the system.

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:

$$N_C = N \exp\left[-\frac{G_T^*}{K\,T}\right] \qquad (1)$$

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_T^* can be obtained as shown in [2]. From the free energy can be obtained the cavity radius and from eq.(1) The population of cavities where is likely to introduce a particle of the coating material.

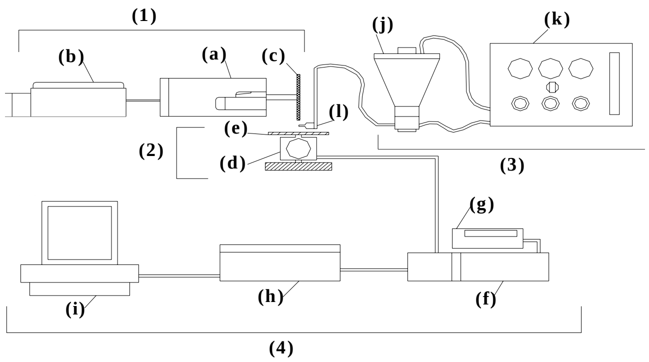

Figure 1. Deposition process: 1) Rotating wheel system: (a) high speed motor, (b) velocity control, (c) mop; 2) Force measurement system: (d) ring type load cell, e) base; 3) Feeding system: (j) particles container, (k) pneumatic control system, (l) nozzle; 4) Acquisition data system: (f) amplifier, (g) volt-meter, (h) signal analyzer, and (i) PC.

3. Experimental Arrangement

To obtain the pressure measurements, eight drilling holes were practiced in one tilting pad as show in fig. 2, and numbered from left to right.

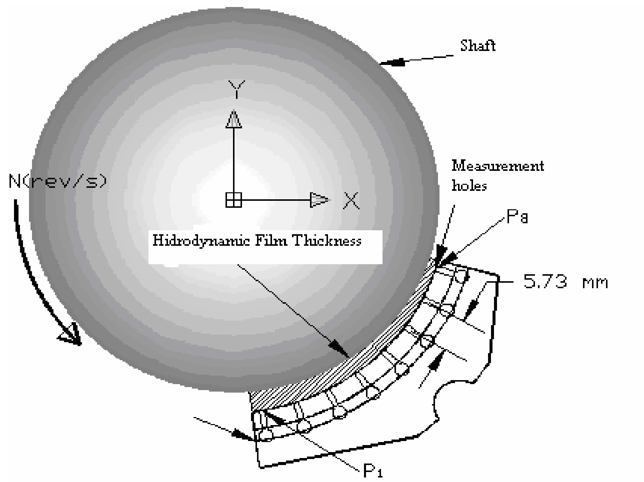

Fig. 2. Tilting pad for pressure measurement

The tilting pad drilling holes were the connected to the pressure transducer, through an oil line, where the pressure signal was transformed to an electrical signal and then recorded by the acquisition system. The tilting pad was the mounted on the experimental rig shown in fig. 3.

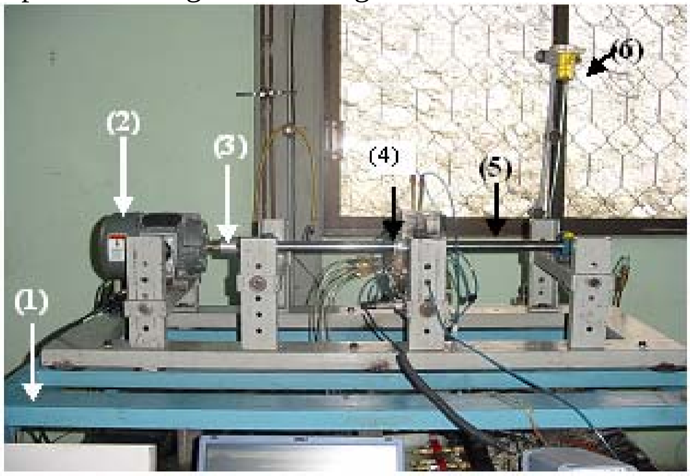

Fig. 3. Experimental arrangement, (1) Main support; (2) A.C. Motor with variable control; (3) Mechanical coupling; (4) Tilting Pad; (5) Shaft and (6) Oil for measurement .

3. Pressure Measurements

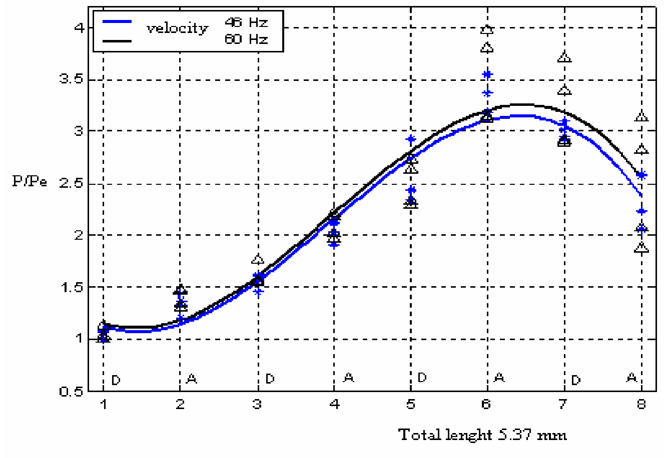

Fig. 4. Pressure measurements for ASIRE at 46 and 60 Hz.

Pressure measurements were taken for different rotational speeds. Here tests without DLC coating are referred as ASIRE and those with DLC coating as ACORE. Tests were carried out at 5, 16, 26, 36, 46 and 60 Hz, and the results for the last two velocities are shown in figures 4 and 5 for coating and no coating. The ratio P/Pe refers to the ratio of the local pressure to the inlet pressure, that in this test was kept constant to 138 kPa.

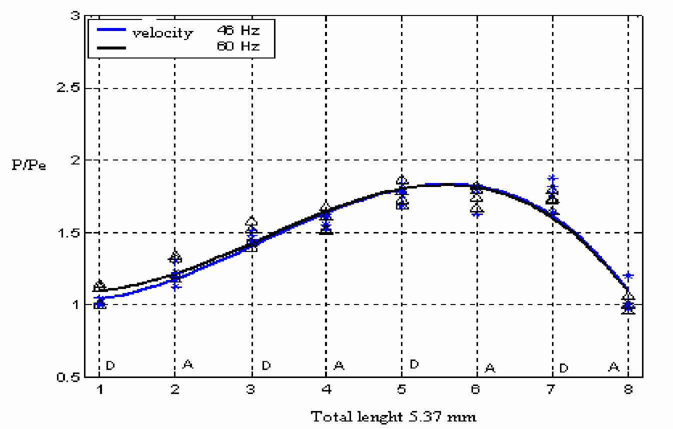

Fig. 5. Pressure measurements for the ACORE at 46 and 60 Hz.

It may be seen that the pressure behavior for the ASIRE and ACORE tests is similar. The maximum pressures reached by the ASIRE test are 340 and 375 kPa; and for the ACORE are 123 and 134 kPa, values that are 119 y 105 percent lower that those obtained for the ASIRE test.

Taken as reference fig, 2, the line of symmetry, that joins the centers of rotation of the tilting pad and shaft, lies between points 5 and 6. It may be noted that the maximum pressure moves towards this line in the case of the coated shaft, and with the no coated towards the right. These results were attributed to the low friction factor of the DLC.

3. Dynamic Measurements

As mentioned by Barkov and Barcova [3] 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 10 kHz [4].

In figures 6 and 7 are shown the 3D plots obtained by applying the Morlet wavelet to the vibration signal. Here three sections are highlighted for low, intermediate and high frequencies. In figure 6 four picks can be distinguished at 11100 Hz: the first at 0.06 s, the second at 0.13 s, the third one at 0.44 s, and the last one at 0.58 s; the highest amplitude was 0.58 e 10^{-5}. In figure 7, three picks can be found at 10250 Hz, and one at 11000 Hz. The three first points are located at 0.23, 0.43 and 0.49 s and the last one at 0.53 s. The maximum amplitude found was 0.36 e 10^{-5} mV.

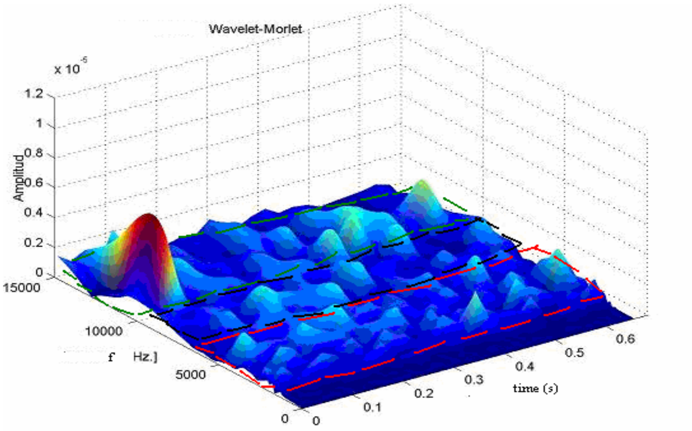

Fig. 6 Wavelet plot for the vibration signal of the ASIRE test at 60 Hz.

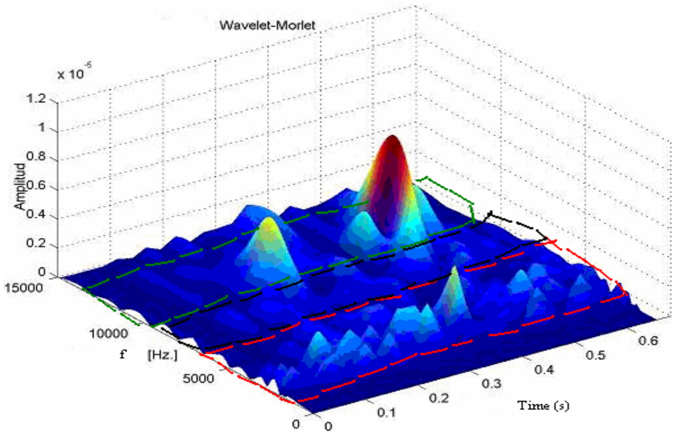

Fig. 7 Wavelet plot for the vibration signal of the ACORE test at 60 Hz.

The differences between both readings can be attributed to the combined effect of the lubrication film and stiffness of the surface shaft caused by the DLC coating. Here was thought that because the rotational speed and clearances were maintained, the pressure required to sustain the load reduces, avoiding the contact between shaft and tilting pad.

4. Conclusions

The influence on the pressure distribution on the hydrodynamic film formed between a rotor shaft and a tilting pad, caused by a rotor shafts with and without DLC coating was evaluated. It was shown that the maximum pressure is lower when the coated shaft was employed and that this maximum lies close to the line of symmetry that joins the centers of rotation of the tilting pad and shaft. A decrement on the maximum pressure close to 100% was found.

Analysis of the dynamic signal showed that a decrement of the amplitude of vibration was detected for the coated shaft . The decrement was attributed the reduction of the shear stresses due to the modification of the friction factor of the shaft when added the DLC.

5. References

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