

Contact Fatigue Wear Evaluation of Thrust Rolling Bearings Lubricated With Greases With Molybdenum Disulfide Or Graphite

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ABSTRACT

The wear of thrust 51100 rolling bearings were investigated and their dissipative responses in a bench test rig were associated to their heating, elastic energy of mechanical vibration and Sound Pressure Level [dB], regarding two greases, both from the same supplier, being one with graphite and the other with Molybdenum Disulfide. The samples were commercially acquired and submitted to a normal load of 450 ± 5 N and 3100 ± 30 CPM, determined after the screening tests. Four variables were measured: temperature [K], electrical power [W], global velocity vibration [mm/s] and Sound Pressure Level [dB]. After 106 cycles, the tracks were analyzed by Optical Microscopy. The bearings lubricated with the grease with graphite showed different responses in relation to the ones lubricated with MoS₂ thrust bearings. The signal of the signatures and the damage morphology are presented and discussed.

INTRODUCTION

In the current industrial context and with an increasing demand for productivity, the use of equipments that can keep up with its needs without stops is necessary. This characteristic of those equipment depends mainly on its mechanical components.

The technological development of new materials with better endurance to the most diverse solicitations is widely evident in several branches of scientific research. The use of metallic alloys, polymeric materials, blends, ceramics, nanotechnologically developed materials, materials developed through plasma, etc, shows us a wide array of

possibilities regarding the selection and development of the most suitable material for a given application. However, some commercially bought materials do not have well defined characteristics, which mean that one cannot be sure of their mechanical properties and their response to severe solicitations that may lead to a premature failure.

The contact fatigue phenomenon reduces the life of the materials and is defined as a damage mechanism due to cyclic loads that act on the Hertz contact tension fields, that, according to Medeiros (2), is evident on the material as the microstructure transformations appear and lead the surface and/or subsurface to damages during the life under cyclic contact.

Superficial interactions control the performance of most mechanical devices, most of them operating under lubricated sliding. In this case, the essential function of the lubricant is the reduction of friction and wear of sliding elements. The presence of the lubricant on the contact interface in layers with even molecular width is capable of changing the tribological response of the system [Maru apud Persson] (3).

Maru (3) noted that in advancing on the understanding of the oil-surface interaction, it's possible to obtain clearer or better fundamented alternatives, in terms of lubricant, materials and alternative solutions for tribological means.

That being said, this paper aims the investigation of the performance of axial bearings lubricated with mineral base grease, with graphite or Molybdenum Disulfide, under different forms of energy dissipation that characterize a

tribological system. The irreversibilities present were monitored, analyzed and associated with possible damages generated by contact fatigue of the system.

EXPERIMENTAL PROCEDURE

On this paper, the results of lubricated tribological tests are presented. The test bodies used were axial bearings 51100, lubricated with greases with different additives: graphite and Molybdenum Disulfide. The parameters taken for evaluation were: electrical energy consumption, energy dissipation as heat, noise level and mass loss. Besides these, the surface roughness and images obtained via Electronic Microscopy were also used in the evaluation of contact surfaces damage.

To intensify the Herzian contact pressure and make accelerated tests, the lower band of the bearing were inverted, so that the spheres were in contact with a plain surface, characterizing a non-conform contact and, thus, generating measurable superficial damages.

The bearings are composed of a component (A) (upper band) with external diameter of $24,0 \pm 0,01$ mm internal diameter of $11,0 \pm 0,01$ mm, a component (B) (cage with balls) composed of $4,76 \pm 0,01$ mm spheres, and component (C) (lower band) with external diameter $24,0 \pm 0,01$ mm and internal diameter $10,0 \pm 0,01$ mm. The rolling bands showed a hardness of 61 ± 1 HRC. On the lower band, analyzed in this paper, the Rockwell C hardness was measured.

In the preparation of the samples, the bearings were washed in propilic alcohol and ultra-sound for 10 min, dried with hot air. Right after, the samples were weighed and measured for their surface roughness in four distinct point in the radial direction of the rolling bands. The results are shown on [table 1](#). The same procedure was adopted after each run so that the electronical microscopy analysis could be performed. For this study, one test and two repetitions were made for each grease, having the parameters changed, the lower bands polished and the time of the run enlarged.

For the lubrication of the system, 2g of a mineral oil / lithium soap grease, NLGI 2 and dropping point $>180^\circ$. One of the samples had graphite as additives and the other molybdenum disulfide.

The experimental equipment used a bench drill adapted with possibility of five velocities and with a motor of 1/3 CV (245 W) of power. The tests were made with a rotation 3100 ± 30 RPM and normal charge of 450 ± 5 N.

Measurement devices were used, together with their respective signal processing systems and a computer for data processing. Through these, the map of irreversibilities was possible, as studied by Medeiros(2). With amperimetric pliers it was possible to collect data of electric energy consumption,

at “W”, with an acquisition rate 0,7 Hz. For the sound energy dissipation registers, a sound level meter was used, in order to measure the level of sound pressure [NPS (dB)]. The signals were collected in data acquisition windows of 4 minutes at 1 Hz, repeated every 30 minutes. The temperatures next to the contact and of the environment were measured using “J” type thermocouples, with 0,5 Hz acquisition ate. The global vibrational velocity was measured with a vibration monitor and an accelerometer, with acquisition of 1 point every 10 minutes. With exception to the vibration velocity, all other sensors were connected to a computer interface. The instrumentation of the test rig can be seen at [figure 2](#).

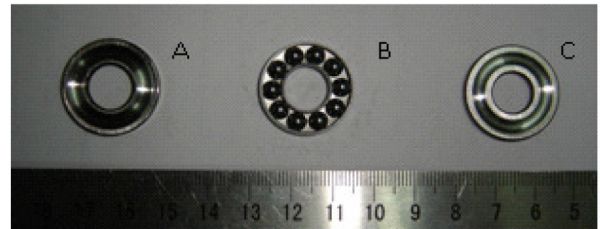


Figure 1. Axle bearing components, (A) Upper band, (B) cage with balls (C) lower band.

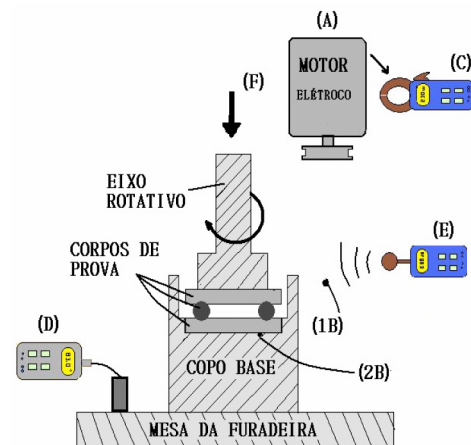


Figure 2. Schematic draw of the rig: (A) Drill, (B) Termocouples, (C) Power Monitor, (D) Vibration Monitor, (E) Decibelimeter, (F) Normal Charge.

RESULTS AND DISCUSSION

The graphics below refer to the data obtained by the equipment that monitored the irreversibilities of the system through the four parameters used in this paper: electrical power, noise level, vibration and heating of the tribological system.

See [Figure 3](#) after last section of paper

[Figure 3](#) above presents the electric power consumed by the engine (A), the thermal energy dissipated by the system

through the difference of temperature next to the contact and of the environment (B), sound pressure level (C) and the global vibration velocity (D). Plots B, C and D provide us with data from the dissipative energy of the system. Through these data, associated with the ones from the electric power consumed by the engine (A), it is possible to monitor and analyze the irreversibilities of the tribological system, confronting it with possible damage generated by contact fatigue of the system described by Medeiros(2).

The red plots refer to the bearings lubricated with Molybdenum Disulfide and the black ones refer to graphite grease. On the plots of [figure 3](#), both in (A) and in (B), before half hour of testing, it becomes evident a trend of the curves to get to their regime, which means that a stabilization of the signal occurs, characterizing the period of “running-in”, ([Hutchings, 1992](#)). However, right after, a new change in this trend can be noticed, more visible on the power graphs. In graphs (C) and (D) this period of “running-in” is only evident on the black curves, the ones that refer to the graphite grease.

On plot (A), it is possible to notice that the curves of the MoS₂ lubricated bearings, in red, show a bigger displacement from themselves, bigger than the one shown by the graphite lubricated bearings, in black. These curves show an electric power consumption response close to each other, which signals an equivalent power consumption among the repetition and a better repeatability of the tests. The curves in red show a difference of 7% among the repetitions. It is noticeable that the grease with graphite as additive has a better performance in the reduction of electric power consumption.

On plots (B) e (C), the curves of both greases show little variation among their repetitions, which shows that, in terms of temperature difference and sound pressure level, the performance of the greases studied is similar. However, as shown in plot (A), the graphite grease has better performance in reducing the thermal energy dissipation. This is confirmed by plot (B). On plot (C), the MoS₂ shows the best performance in the reduction of noise from the friction between the surfaces.

On plot (D), that refers to the global vibration velocity of the system, a great disparity between the tests of the graphite grease lubricated bearings, in black. The average difference between the curves of the two tests is of 14,5%. On the plots of the MoS₂ grease bearings, in red, there is a higher proximity between the curves. Due to the big variation among the curves in black, it's not possible to assert which grease had the better performance in the reduction of the global vibration velocity of the system.

See [Figure 4](#) after last section of paper

[Figure 4](#) shows the graphs of the same parameters measured on the first tests. However, for this run (one for each grease), the rolling band surface was polished and the duration of the test was extended.

All the plots presented on [figure 4](#) show inverse results if compared with the ones obtained with the shorter tests and shown on [Figure 3](#). On plot (A), it can be seen that the electric power consumption of the Molybdenum Disulfide grease is lower than the graphite grease. The temperature difference (plot (B)) is very close for both of them. Plots (C) and (D) also present an agreement with each other: a better performance of the graphite in reducing the global vibration velocity reflects a lower sound pressure level. Nevertheless, these results do not agree with the ones found on the first two runs.

On the graphs of the graphite grease, with exception for the sound pressure level, it is possible to see an oscillation at around 4. Since this oscillation can be seen in the three graphs at the same time, it asserts the relation between the irreversibilities of the system and that they can be monitored by the parameters shown. Though the variations were not large enough to be taken into account as a major change in the system, they can be used to show that, even a minor change in the tribological is reflected on the plots.

See [Table 1](#) after last section of paper

On [table 1](#) the measurements of surface roughness before and after the tests and their respective percentual variation are shown. On every rolling band there was an increase in the average surface roughness (Ra), with highlights for one of the graphite grease lubricated bearing that, besides having the highest surface roughness before the tests, also showed the biggest variation after the test.

According to [Hutchings \(1\)](#) the average surface roughness and the residual stress level are relevant parameters when dealing with metal-metal contacts with relative movements on themselves, lubricated or not, in respect to the generation of superficial damage. That was verified on this paper, since the bearing of test 4, which had the biggest superficial damage, was also the one with the highest initial value of Ra and, therefore, by definition, probably had the biggest variations in the residual stress levels. However, on the bearing of test 1, which also had a high initial value of surface roughness, relevant damage could not be verified. The bearings of tests 2 and 3, which had lower values of initial surface roughness did not show any signs of significant superficial damage.

See [Figure 5](#) after last section of paper

On [figure 5](#) the electronic microscopy images of the rolling bands of the tested bearings are shown with an amplification