EXPERIMENTAL ANALYSIS OF ADDITION OF METAL CONDITIONERS AT GREASE FOR BEARINGS LUBRICATION

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Abstract. *Currently the industries intend to decrease the corrective maintenance costs and to increase the equipment's life, so is increasing investments on predictive and preventive maintenance techniques. However, something unexpected can happen. Equipment may require maintenance that was not programmed/planned, committing the maintenance planning/programming and involving extras costs. Bearings are one of machine's components more analyzed by predictive techniques and were object of study of this paper. The objective of this paper is to compare vibration levels of bearings (with some defect) when is added Metal Conditioners (MC) in semisynthetic grease used for lubrication, from Vibration Analysis (Envelope) and Thermometry Analysis. A tests device with three bearings was designed to verify the vibration and operating temperature behavior when the bearings are lubricated with grease and grease + MC. Later the bearings were completely clean and tested without lubricant. Then, the bearings were substituted by a new group without defects (new and identical). The Experimental tests results show the addition of MC in grease decreased the levels of vibrations and the operating temperature of bearings. The tests without lubrication proved that Metal Conditioner adhere to metallic surfaces, reducing friction. The new bearings' test was essential to compare the severity of defective bearings and to show that tests device did not influence the other tests results previous. Metal Conditioners are efficient and can be considered a good alternative to prolong bearings' life and an interesting option for the planning/programming of maintenance of equipment, ensuring the production.*

Keywords: *Metal Conditioner, Thermometry Analysis, Bearings, Vibration Analysis*

1. INTRODUCTION

Keeping plant equipment in good operating condition to prevent failure and production loss should be a maintenance department's prime objective (Renwick and Babson, 1985). A good maintenances planning and programming is necessary to decrease the unproductive time, and the equipment return to operation quickly. Predictive maintenance can Contribute to Improving plant availability, safety, quality, reduction of maintenance costs, etc (Carnero, 2003). Investments in predictive techniques have been utilized to detect defects early, enabling to program the preventive maintenance to prevent the machine to stop functioning unexpectedly. Unexpected equipment braking generally involves high costs and production time loss (Lago, 2009). *Defect* may be understood how an abnormal operating condition that a machine presents, without interruption of its functioning. When interruption occurs, the machine presents a *Failure* from a kind of defect.

Many industries have its equipments operating during all time. Sometimes a defect is detected and the equipment needs to be stopped for maintenance, but is not possible because exists others maintenances to be realized, according maintenance planning. Stopping a machine for maintenance may not be easy, is an important preparation of all departments involved so that the unproductive time and the maintenance costs can be minimized. For machines that presents some vibration defect, for instance, and is not possible stop it immediately for maintenance, to add Metal Conditioner on the lubricant has been a technical utilized for extend slightly the operating life and delay the maintenance.

In this paper will be studied the efficiency of Metal Conditioner added grease for bearings lubrication, utilizing Vibration Analysis (Envelope) and Thermometry Analysis. Metal Conditioner decreases friction between metallic moving parts and has been utilized in industries for extend machines life.

2. VIBRATIONS ANALYSIS BY ENVELOPE

Bearings present characteristics frequencies according the local where contain defect. The most commons frequencies are: BPFO - *Ball Pass Frequency Outer Race*, BPFI - *Ball Pass Frequency Inner Race*, *BSF - Ball Spin Frequency*, e FTF - *Fundamental Train Frequency* (Dias, *et al*., 2009), that can be evaluated with Eq. 1 to 4, where S is rotation frequency (Hz), P_d is diameter of bearing (mm), N_b is number of balls, ϕ is the contact angle of bearing and B_d is diameter of balls (mm).

$$BPFO = S\left(\frac{N_b}{2}\right)\left(1 - \frac{B_d \cos\emptyset}{P_d}\right) \quad (1)$$

$$BPFI = S\left(\frac{N_b}{2}\right)\left(1 + \frac{B_d \cos\emptyset}{P_d}\right) \quad (2)$$

$$BSF = S\left(\frac{P_d}{2B_d}\right)\left(1 - \frac{{B_d}^2 \cos^2\emptyset}{{P_d}^2}\right) \quad (3)$$

$$FTF = S\left(\frac{1}{2}\right)\left(1 + \frac{B_d \cos\emptyset}{P_d}\right) \quad (4)$$

The Envelope technique consist in a series of procedures applied in time-domain signal (Bezerra, 2004), illustrated in Fig.1.

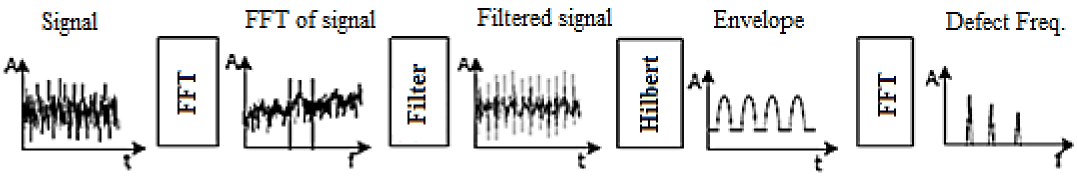

Figure 1: Techniques applied in signal to obtain Envelope. Source: Bezerra, 2004

Fast Fourier Transform (FFT) is applied in a signal on the time-domain to obtain the spectrum of signal. Then, the signal is filtered for maintain resonance frequencies modulated by impact frequencies only. The Hilbert Transform is applied to obtain the demodulated signal and, after FFT, the frequency spectrum is obtained. The function of this technique in bearings is identifying the repetition frequency of pulses caused by successive impacts generated by passage of a rolling element in a defect.

The Global Level of Envelope (Acceleration of Envelope – gE) indicates the general condition of bearings. Enveloped Acceleration Classification that best describes the general size and speed of the bearings being measured should be selected (SKF, 2011), according Table 1. *Class CL1:* bearing bore diameter between 200 and 500 mm, below 500 rpm. *Class CL2* : bearing bore diameter between 200 and 300 mm, shaft speed between 500 and 1800 rpm. *Class CL3:* bearing bore diameter between 20 e 150 mm, shaft speed between 1800 e 3600 rpm.

Table 1: Limits of vibration level (Envelope). Source: SKF

Class	OK	ALERT	DANGER
CL1	0-1 gE	1-2 gE	> 2 gE
CL2	0-2 gE	2-4 gE	> 4 gE
CL3	0-4 gE	4-10 gE	> 10 gE

SKF Machine Condition Advisor was versatile and effective on monitoring of rotating machines both the velocity measurements and the envelope acceleration measurements (Alves, 2011).

3. METAL CONDITIONERS

Metal Conditioner (MC) is a chemical treatment for metals and mechanical components. Is a Liquid with low viscosity that adheres to metallic surfaces reducing friction between mobile parts, must be added to lubricant which carries MC to metallic parts, when heated. After heating of lubricant, the MC displaces to metallic parts by adsorption, maintaining the tolerances originals existent on machine.

Is important detach that the MC is not an additive for lubricant, because physical and chemical properties of lubricant are not modified.

4. METHODOLOGY

A test device was designed to verify the comportment of vibration and operating temperature in bearings with two kinds of lubrication: Grease and Grease+MC. The test device was installed on Dynamics Systems Laboratory (LASID) of Federal University of São João del-Rei (UFSJ) and have the followings components: electric motor 1CV, 1750 rpm, 110/220V **[1]**; flexible mechanical coupling **[2];** one bearing 6206 **[3]**; one bearing 6207 **[4]**; one bearing 6208 **[5]** and mechanical brake system (to simulate load on the system) **[6]**. The tools utilized during the test were: *Amp Clamp* **[7]**; *Microlog GX-75* used to collect data vibration (spectrum) [**8]** and SKF *Machine Condition Advisor* used to collect

Global Level and Temperature **[9].** The internal diameters of bearings 6206, 6207 and 6208 are, 30, 35 and 40mm, respectively. Then, according to Table 1 the correspondent class is *Class 3*.

Figure 2: Tests device on LASID. Source: Author.

The experimental tests were realized at LASID. The test device was started and waited the stabilization of operating temperature of the bearings without load ("Brake off"). Then was initiated the Definitive Tests of Vibration Analysis (Envelope) and Thermometry Analysis on the bearings with load on the system ("Brake on"). The brake was actuated until the electrical motor reach to 7.0 Ampéres, controlled by Amp Clamp.

Definitive Tests were divided in four tests according type of lubrication and condition of bearings. For the Tests 1, 2 and 3 were utilized bearings with some defect, donated by stores of maintenance in electrical motors. The presence of a defect allows visualize easily the changes on the vibration spectrum. On the Test 1 bearings were lubricated with Semi-synthetic Grease (Complex soap, NLGI 1, resistant to water and vibration). On the Test 2, MC was added in grease utilized in the Test 1, according recommended quantity (15% per kilogram of Grease), utilizing a disposable syringe, Fig.3. Test 3 was realized without lubrication (bearings completely clean), all grease utilized on the previous tests was removed. Test 4 was utilized a new group of bearings (identical and without defect). Tests 1 and 2 were realized over 18 (eighteen) hours in two days (9+9), collecting data every half hour.

Figure 3: Metal Conditioner quantity to add on bearing. Source: Author.

5. RESULTS

The following Figures (4 to 15) show Envelope Spectrum of Definitive Tests. All bearings had defects in inner race (BPFI) but in different intensities

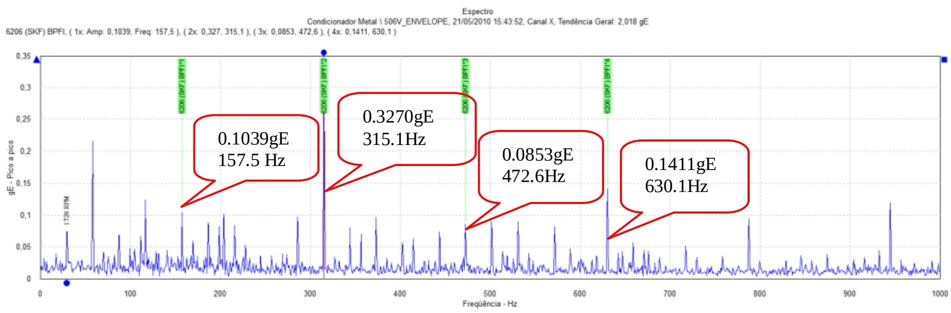

Figure 4: Spectrum bearing 6206, Test 1. Source: Author.

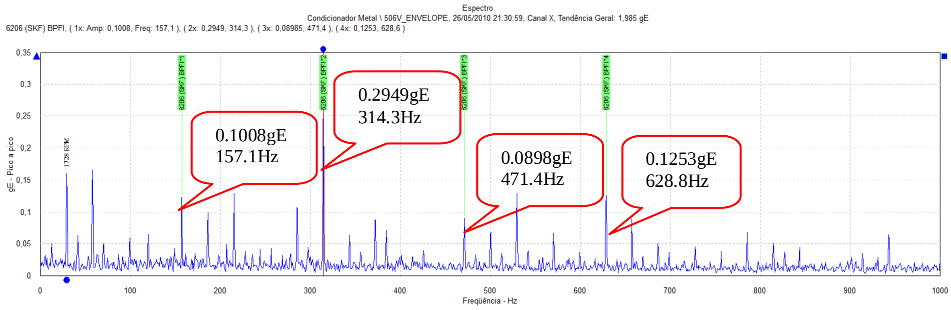

Figure 5: Spectrum bearing 6206, Test 2. Source: Author.

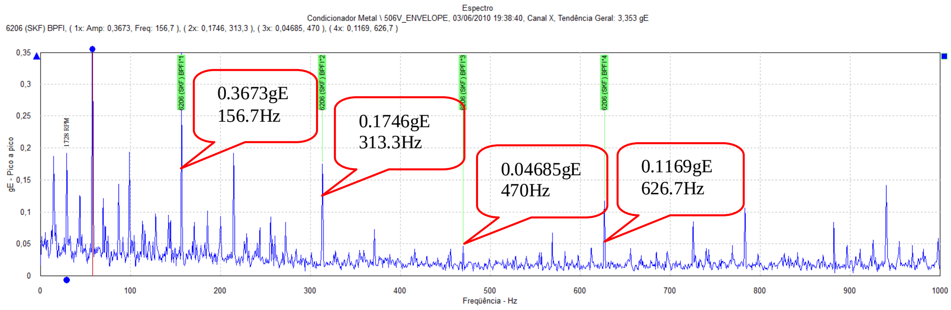

Figure 6: Spectrum bearing 6206, Test 3. Source: Author.

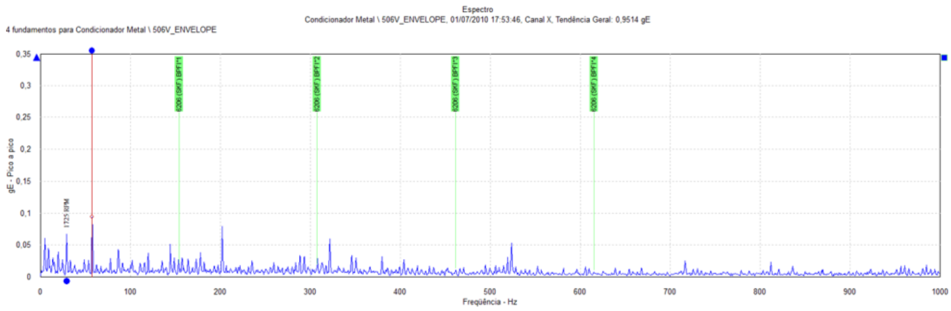

Figure 7: Spectrum bearing 6206, Test 4. Source: Author.

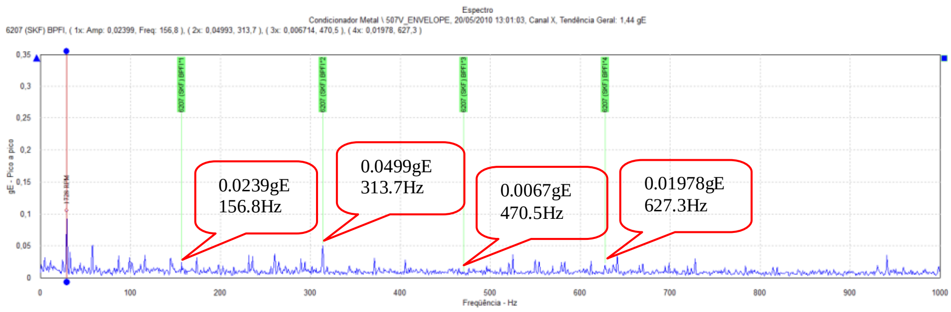

Figure 8: Spectrum bearing 6207, Test 1. Source: Author.

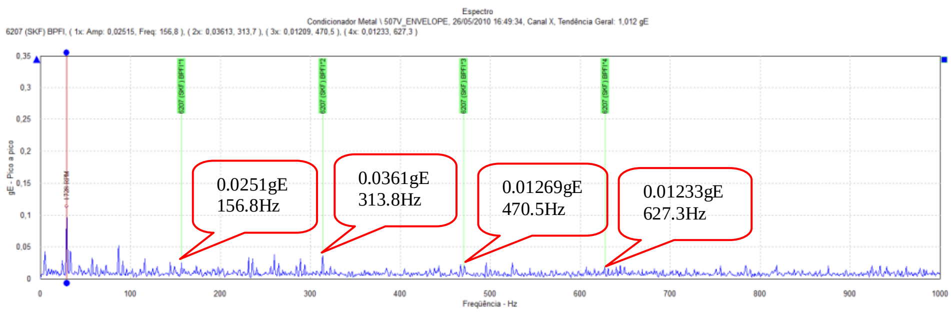

Figure 9: Spectrum bearing 6207, Test 2. Source: Author.

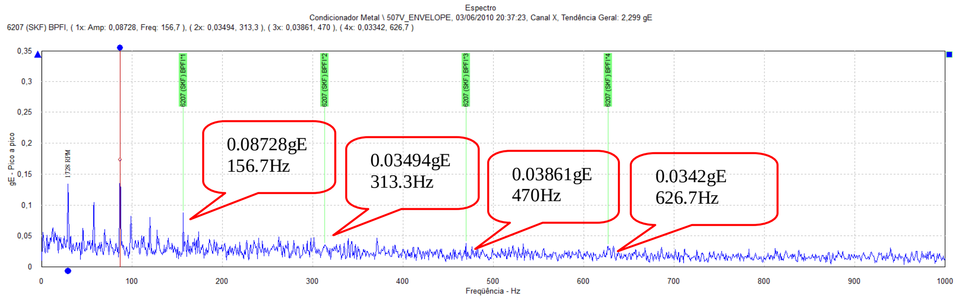

Figure 10: Spectrum bearing 6207, Test 3. Source: Author.

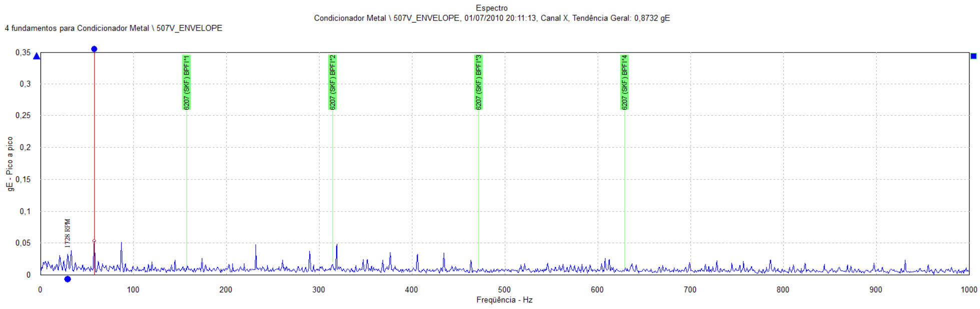

Figure 11: Spectrum bearing 6207, Test 4. Source: Author.

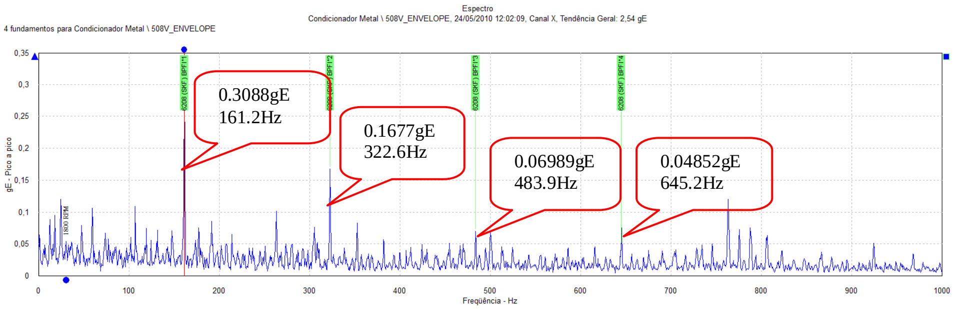

Figure 12: Spectrum bearing 6208, Test 1. Source: Author.

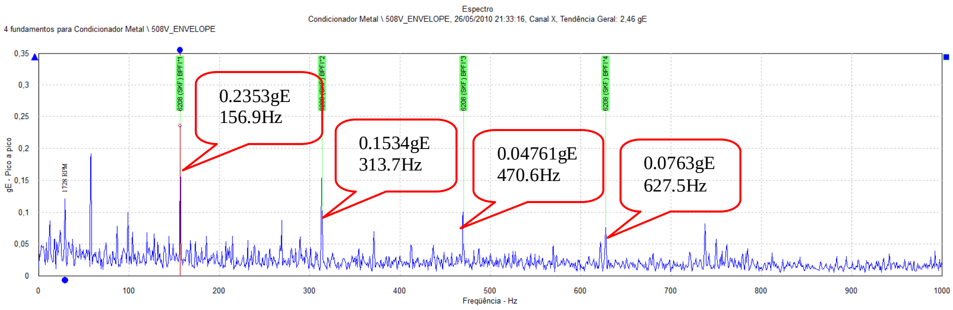

Figure 13: Spectrum bearing 6208, Test 2. Source: Author.

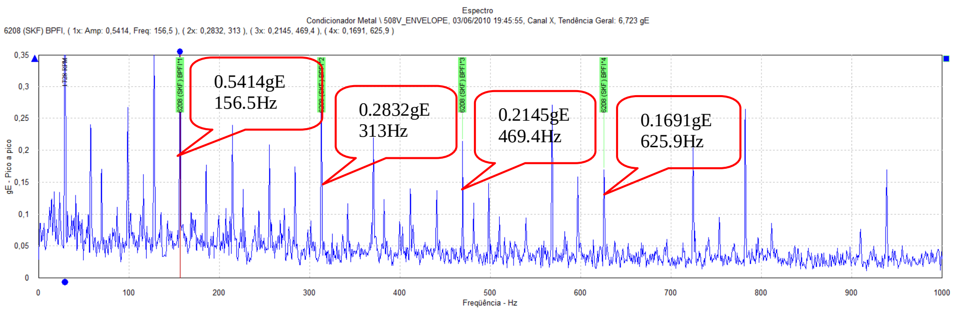

Figure 14: Spectrum bearing 6208, Test 3. Source: Author.

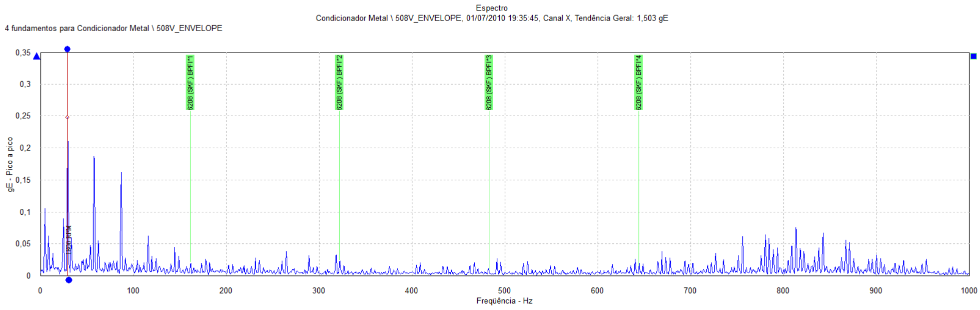

Figure 15: Spectrum bearing 6208, Test 4. Source: Author.

Bearing 6207 presented very low vibration and good conditions of use, verified by comparison between Fig 8 and Fig. 11. The vibration levels presented by defective bearing are very close to levels of the "new" bearing. Bearings 6206 and 6208 had higher vibration compared with 6207, but it still in satisfactory conditions.

Comparing Fig.4 to Fig.5, Fig.8 to Fig.9 and Fig.12 to Fig.13, the vibration decreased when MC was mixed to grease. The Defect Frequency (BPFI) remained and presented low variations on amplitude, this fact was almost expected because the defects on the inner race cannot be recovered. The Global Level (gE) decreased substantially, Table 2 contain the average values obtained during the period of each test.

Table 2: Average Value of Global Level (gE) and Reduction (%)

Bearing	Test	Avg. Global Level	Reduction (%)
6206	Grease	2.293	10.79
	Grease + CM	2.045	
6207	Grease	1.396	21.55
	Grease + CM	1.095	
6208	Grease	2.490	6.20
	Grease + CM	2.335	

Test 3 showed that the metal conditioner adheres to metal surfaces because the vibration level may be considered acceptable. The increased vibration observed in spectra of Test 3 was expected due to damping decrease caused by a lack of lubricant, Figs. 6, 10 and 14. Since with the increase of vibration the Global Level presented values lower than the limit of "danger". The objective of Test 3 was not to prove that MC decrease the vibration like showed on the Test 2, but to show that MC adhere to metal surfaces reducing the friction and allowing that low vibrations were produced. In the Table 3, the values of Global Level relatives to Figs. 6, 7, 10, 11, 14 and 15 are showed (Test 3 and 4).

Spectra of new bearings (Fig. 7, 11 and 15) were important to compare the defect intensities of others bearings and show that test device did not affect the results obtained previously. Figure 16 show the operating temperatures of bearings when lubricated with Grease and Grease+MC. Table 4 contain the values minimum, maximum and average of temperature for each test.

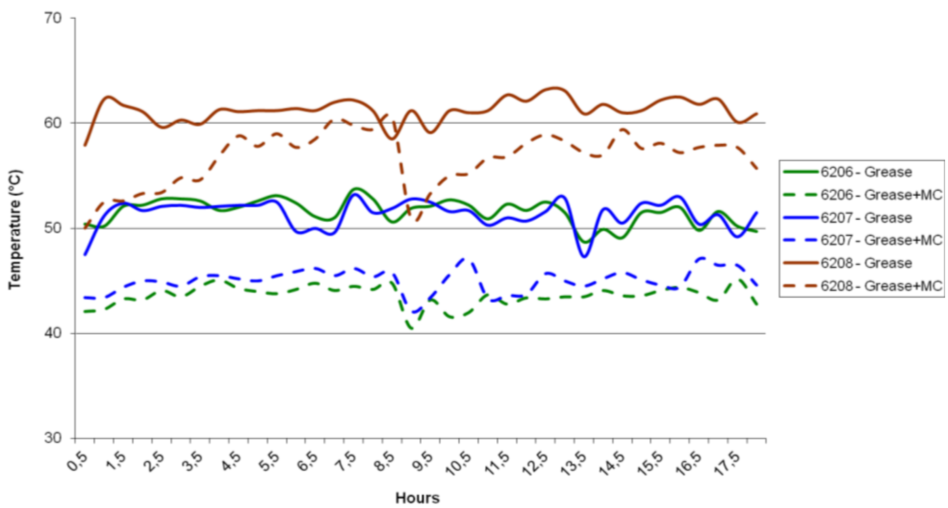

Figure 16: Temperatures (^{0}C) of Test 1 and Test 2 for each bearing. Source: Author.

Table 3: Global Level (gE) of Tests 3 and 4. Source: Author.

Bearing	Test	Global Level (gE)	Condition
6206	Test 3	3.353	OK
	Test 4	0.9514	OK
6207	Test 3	2.299	OK
	Test 4	0.8732	OK
6208	Test 3	6.723	ALERT
	Test 4	1.503	OK

Table 4: Temperature values for each test. Source: Author.

TEST	TYPE	6206	6207	6208
1	**Min**	48.7	47.3	57.9
	Avg	51.5	51.3	61.2
	Max	53.7	53.2	63.2
2	**Min**	40.5	42.1	50
	Avg	43.6	45.0	56.6
	Max	45.2	47.1	60.6
3	**Min**	24.8	25.4	26.5
	Avg	25.35	26.45	30.3
	Max	25.8	27.5	34
4	**Min**	35.5	46	47
	Avg	38.2	47.54	50.62
	Max	40.1	50.2	52.1

The temperature decreased when the bearings were lubricated with Grease+MC (Test 2), because the Metal Conditioner reduces the friction between metallic parts. Test 3 presented lowest temperature, the absence of lubricant combined with presence of MC allowed low friction and low resistance to rolling, but the MC must not be used without lubrication. The resistance to rolling caused by the grease makes increase the temperature due the shear stress on the lubricant film.

The Test 4 presented temperatures lower than Test 1. This was expected because the bearings of Test 4 had no defects.

6. CONCLUSIONS

Bearings must be periodically inspected to prevent mechanical failures and minimize maintenance costs. All bearings utilized on Test 1 and Test 2 of this paper have had low intensity defects in inner race. The average values of Global Level and the temperature were smaller when utilized Metal Conditioner added to grease.

The Global Level and operating Temperature decreased substantially allowing increase the “life” of equipment or delaying the maintenance. In general form, the amplitudes of bearing frequencies reduced but some amplitudes presented slightly increases. These increases are not significant because they are accompanied by a considerable reduction in the Global Level.

Test 3 proved that Metal Conditioner really adhere to metallic surfaces, reducing the friction. Bearings without lubrication operated with low vibrations, but lubricant is indispensable to operating of machines because the Metal Conditioner does not substitute it.

Test 4 was essential to show the spectrum containing low vibration and absence of bearing defects, proving the different defects level of the bearings utilized in the previous tests and the non influence of the test device in the results.

Results of this paper proved the Metal Conditioner is efficient to maintenance planning/programming of machines for increase life equipment or delay yours maintenance.

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