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Vibration Analysis for Predictive Maintenance Application to A Single Row Ball Bearing

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Abstract: *In the aim of a preparation for predictive maintenance, the vibration analysis turns out to be a brilliant tool for some decades for the industry. Its use is intended to provide three levels of analysis: monitoring, diagnosis and monitoring of the state of equipment damage. Practically, the recorded vibration signals are the result of a different sources mixture for components of machine, which makes it difficult to interpret the state of damage of a particular component.*

The propose is to separate the contribution of different vibratory sources generally and directly linked to a fault more or less important of a mechanical component, from many measures taken with an accelerometer. The separation will permit not only the localization of the faults on components, but also the follow up of damage evaluation of each one. The principle is then to improve the diagnosis.

The objective of our work aims the study of load impact and the coupling misalignment of driving system dedicated to vibratory accelerations.

In addition, we will examine the relationship between acceleration and load for average speeds and high speeds, the other part will deal with the coupling alignment.

Keywords- *Maintenance, bearing, vibration analysis, accelerometers, coupling.*

I. Introduction

The industry is continuously on move. It develops, relocates and invents in order to keep or gain a part in the market facing a fierce competition. This competition is amplified with the globalization; the transport is more and more fast, the influence of the shareholder. These reasons made the maintenance among the priorities for the companies. It has a big task not only for increasing availability of equipments, but also the guarantee of the safety of property and people. There are three main types of maintenance: the corrective which is beneficial in the case of the inexpensive and safe equipments, the systematic preventive maintenance: which is based on a schedule defined by the breakdown history and the condition-based maintenance: relays on the continuous monitoring of the running condition via specific indicators.

Generally that's the last type of maintenance which interests industries due to its capacity to grasp the functioning of equipments. Literature works are incorporated within the framework of the condition-based maintenance by using the vibration analysis. It's possible to detect the defective elements and possibly locate them, thanks to the vibration analysis. When a fixed threshold (tallying with the limit vibration level) is reached, it is possible to estimate the residual lifetime of the component under a given running conditions from the knowledge of the damage law [1].The comparison of vibratory measures taken at determined intervals in similar conditions allows the monitoring of the evolution of a fault by using the vibration signal [2]. The excitation signal form spalling representing fault which can appear on the outer ring of the bearing is difficult to be determined. Nevertheless, it is generally admitted that such a signal is a mixture of three signals having a triangular, rectangular and semi-sinusoidal form [3]. Different works [4] proved that, taken separately, the three forms of the excitation signals give a close enough results.The way of using the accelerometer has an essential key role in the measurement, the sensor is placed as near as possible of the potential fault in order to avoid the extern perturbations. Estocq [5] studies the optimum measure points if inaccessible bearing.Two other types of the sensors can be proved interesting in the imminent future: The first sensor, patented by Bolaers, Pottier, Dron [6], is based on the capacitive phenomenon; it is marked out for the fault detection of the rotating machines.

The most frequent damages on the bearings are the spalling fault. In the beginning of the rotation, a set of pulses is generated by these faults, on a defined frequency called "Characteristic frequency" of the bearing fault. This periodic signal is the origin of many bearing fault detection methods.A pretreatment is sometimes required to have a good quality of the recording; it is essentially the noise cancellation and the signal filtering.

The noise cancellation for the signal gives the possibility of keeping just the useful signal. Many techniques exist, among the best known: The spectral subtraction suggested by DRON & BELL [8], [9]. The signal is cut in M blocs, processed by Fourier transform and averaged. This average is then processed by the inverse Fourier transform to remove the noise.Also we find the synchronous averaging suggest by Braun [10], [11]. It is about the acquiring of many signals from a 'Top tour' or a rising edge (while a shock for example) and averaging the set of the signals. And the SANC Method (Self adaptive noise cancelation) [12]. This method is about the determining of an adaptive filter allowing the estimation of the perturbation noise in order to remove it from the signal. The thresholding in wavelets studied by Donoho [13]. This thresholding is used to process the Gaussian stationary noise. This technique can be used to extract the vibratory faults from a heavily noised signal. The source separation method suggested by HASSANI [14], which allows separating two signals statically independent. We can give as an example a speech mixed with a vehicle noise.

II. Experimentation

2.1 EXPERIMENTAL DEVICE

The experimental device is illustrated in the figure 1. It consists of a three-phase motor group with an encoder fixed on a baseplate with an alignement device.The motor controller consists of a frequency converter destinated to adjust progressively the running speed. More over, it has a running speed indicator and an idicator of the power absorbed by the motor.

Figure 1: Expérimental mounting.

In order to simulate vibrations with the device of the base and carry out the test, the following parts are necessary for the mounting: - A device for braking and loading made up from a magnetic powder brake and a controller with a command.- Two new ball bearing complete supports. The support placed beside de motor has an elastic bearing. This allows having enough play for the vibrations generated by the coupling. The other, placed beside the load of this test, is rigid bearing where the sensors are placed.- Two piezoelectric sensors for the acceleration (one horizontal and the other vertical). These latter convert the measured vibrations into signals. They allow recording the signals for the vibration analysis.- A reference sensor witch is a direct reflection cell whose function is the instant record of the rotating speed.- An elastic coupling with tight arm fitted at the end of the shaft.- A rigid flange coupling with radial play whose the shaft bore is offset with δ= 0.2mm.- A measure amplifier permits to supply the acceleration sensors. The signal is digitized in the USB measure device and transferred to the PC. (figure 2)

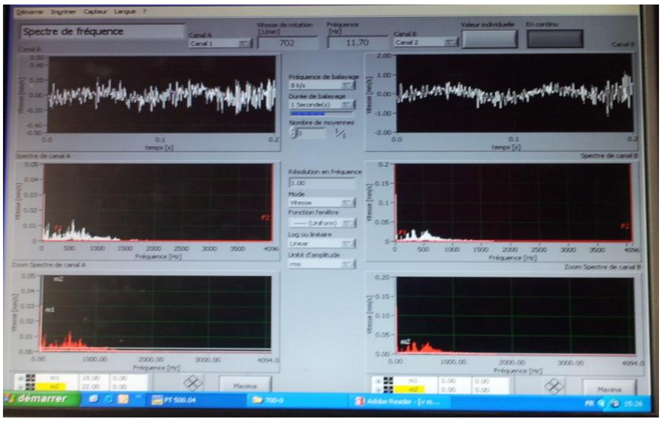

Figure 2: Speed specter recording for the two accelerometers

2.2 THE OPERATING METHOD

The tests were conducted on flat test doubly notched whose dimensions are shown in Figure 1 below. An ideal machine mustn't create vibration because the vibration is always a form of energy waste. Practically, the vibrations are used while the transfer of the forces.First Phase, we made an off-load test with varying the speed (700, 1400, 2100 RPM) and we recorded the signals corresponding to the accelerations.In the second time, we considered the applied load and we made the same last operation, varied the applied torque C (1N.m, 2N.m and 3 N.m).In the third phase, we executed the on-load test with a misalignment.
For this last test, we just changed the coupling with a radial play.

Table 1: Single-row ball bearing characteristics

Bearing type	Category	Inside Diameter	Outside diameter	Thickness	Weight
SKF 6004	Ball bearing	20 mm	42 mm	12 mm	0.072 kg

III. Results and Discussion

3.1 ACCELERATION VARIATION ACCORDING TO THE LOAD WITH A FAULTLESS COUPLING

The figure 3 illustrate the results of the test on a faultless single-row ball bearing, type SKF 6004, after different readings of the acceleration according to the load for three running speeds (700, 1400 and 2100 RPM).

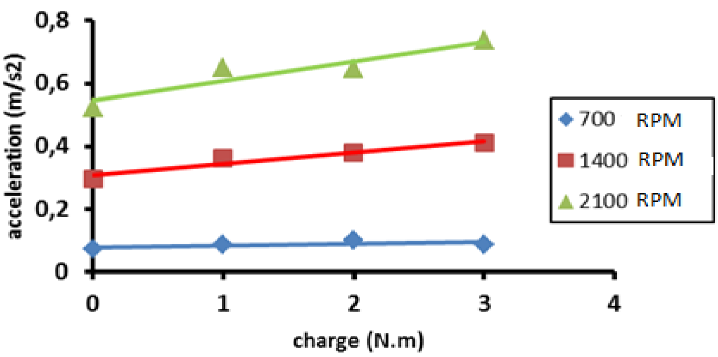

Figure 3: Acceleration variation according to the load for three different speeds

This experiment is based on the idea of getting the three parameters acceleration, speed and load. In a first time, we varied the load for the three rotating speeds of the driving motor in order to determine its impact on the acceleration.We notice that acceleration increases sensibly and linearly for the speeds (1400 and 2100 RPM), however, it remains constant for the speed of 700 RPM because this latter is low, (Fig.3)We observe on the low speeds range, that the load has really an insignificant impact on the acceleration as this latter remained sensibly constant.

III. ACCELERATION VARIATION ACCORDING TO THE LOAD WITH A MISALIGNMENT

The rotating machine is coupled by a coupling. The noncompliant and inappropriate coupling could generate vibrations on the machine. The studied coupling allows simulating different faults and studies the effects on the vibrating behavior. It permits to compare the characteristics of the two different types of the coupling.
The figure 4 illustrates the results of the tests of the single-row ball bearing SKF 6004 with a misalignment. It shows the different variations of the acceleration according to the load for three rotating speeds.

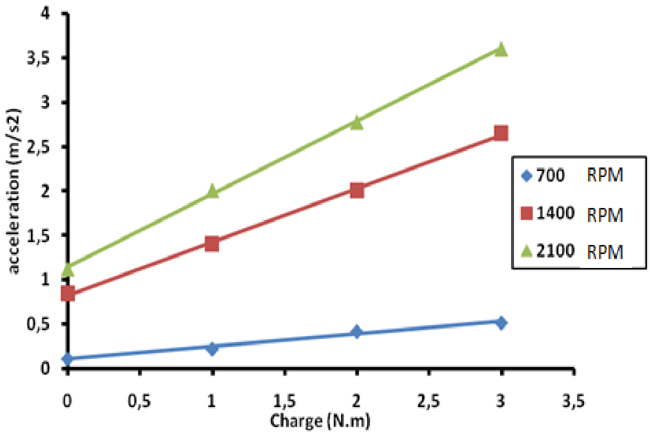

Figure 4: Acceleration variation as function of load for three studied speeds

According the figure 4, we notice that:

a. By increasing the driving speed, the acceleration increases according to load.
b. Whatever the driving speed, the acceleration increases linearly with the load.
c. Between two driving speeds, the difference of the acceleration at each load is increased.
d. The slope of the curve increases with the running speed.
e. For the speed of 700 RPM, The slope is very low because the effect of the load is negligible.
f. By increasing the load, the slope increases considerably with the three speeds.
g. The three curves are linear.

3.2 Comparison Of Results Of The Two Experiments

a. In comparison of the faultless coupling, the vibration acceleration increased.
b. The faulty coupling acceleration increases considerably compared with the faultless coupling.
c. For the speed of 700 rpm, the acceleration remains constant for the first case, while it increases sensibly for the second case due to the misalignment.

IV. CONCLUSION

When the structure is balanced, just the low vibrations are generated. With ageing of the machine, the foundation subsides, the components degrade, and then, the dynamic properties of the machine change.
Our work's objective aimed the study of the impact of the load and the misalignment of the coupling of the driving mechanism on the accelerations. We can conclude in the case of a faultless coupling that:

a. There is no slope with the low driving speeds.
b. By increasing the driving speed the slope increases.
c. For the low speed range, the acceleration remains constant whatever the applied load.
d. The acceleration increases linearly with the load for the medium and high speeds.
e. The effect of the acceleration variation according to the load for the high speeds is due essentially to the inertia effect.

f. In the case of a misalignment, we can conclude that:
g. While increasing the running speed, the acceleration increases as function of load.
h. Whatever the running speed, the acceleration increases linearly with the load.
i. Between two driving speeds, the difference of the acceleration at each load is increased.
j. The slope of the curve increases with the running speed.
k. For the speed of 700 RPM, The slope is very low because the effect of the load is negligible.
l. By increasing the load, the slope increases considerably with the other speeds
m. The three curves of the figure 4 are linear as the used bearing is new.
n. For the faultless bearing, the acceleration of the vibration increases sensibly while it increases considerably for the faulty coupling.
o. For the speed of 700 RPM, the acceleration remains constant for the first case while it rises sensibly for the second case due to the misalignment.

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