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Study of vibration behavior of misalignment and its impacts on the operation of the electric motor and on the energy consumption

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Abstract

Condition monitoring by vibration analysis is effective tool for detecting misalignment defect. The misalignment is a major cause of reduced life of the equipments (couplings, bearings, gears ...); it causes a malfunction to the engine and increases the consumption of electrical energy. To solve this problem, a test bench was developed in our laboratory, will allow us to study the impacts of a misalignment of the engine operation and the electric energy consumption.

Keywords: Conditional Maintenance, Vibration Analysis, Alignment Fault

1. INTRODUCTION

When you submit your paper print it in two-column format, including figures and tables. In addition, designate one author as the “corresponding author”. This is the author to whom proofs of the paper will be sent. Proofs are sent to the corresponding author only.
The misalignment is the relative position deviation of the shaft from the collinear axis of rotation when the machine is running under normal operating conditions.

The Misalignment can affect:

- Two shafts linked by a coupling: the axes of the two rotors may have an angular misalignment at the coupling or a parallel misalignment (lack of concentricity) or a combination of both.
- Two bearings supporting the same axis: the axes of the two bearings of the same machine body are not concentric.

This anomaly can be the cause of a mounting defect, also a bad fitting of the fixing lugs, and a loosening of the fixing lugs of a machine or a deformation of the frame.

- It generates the creation of the efforts that lead the fast deterioration of the coupling system and the deterioration of the bearings.
- In this article the study is divided into two parts:
- The detection of the misalignment by vibratory analysis.
- The impacts of misalignment on the operation of an electric motor and on energy consumption.

2. THEORETICAL STUDY

2.1 Temporal Representation

The temporal representation of a misalignment is a periodic function type complex sinus.

$$X(t) = \sin(2\pi F0t) + 2\sin(2\pi 2F0t)$$

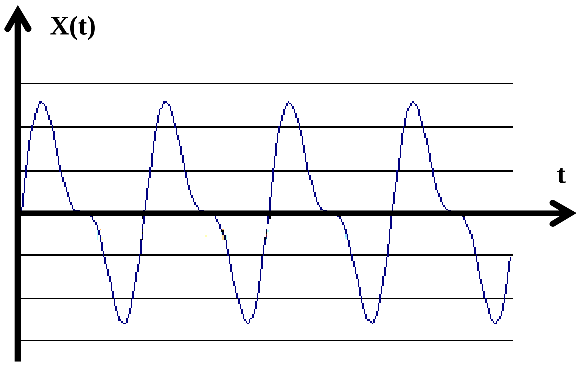

Figure 1 Temporal representation of a complex sinus

2.2 Frequency representation

The frequency representation of a function periodic complex sinus is as follows

$$X(F) = j/2\ [d(F+F0) - d(F-F0)] + j[d(F+2F0) - d(F-2F0)]$$

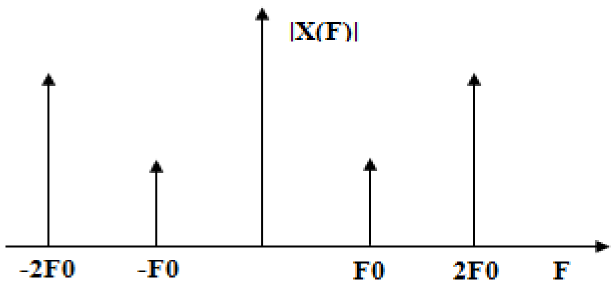

Figure 2 Frequency representation of a complex sinus

3. PRESENTATION OF THE EXPERIMENTAL STUDY

3.1 Introduction

To study the misalignment, we performed a test bench in our laboratory figure (3).

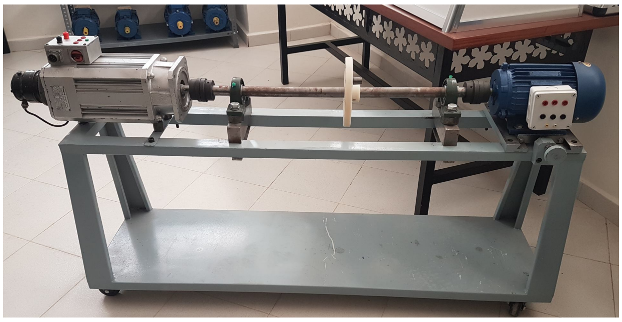

Figure 3 Misalignment Test Bench

The bench consists of:

- Single-phase electric motor 0.5 KW; 1500 RPM.
- Rigid ball bearings 6005-2Z.
- Elastic coupling.

3.1.1 Measurement of global vibrations

➢ **Flawless**

By measuring N.G. we found 0.578 mm/s.

➢ **With misalignment**

By measuring NG we found1,235mm/s.

3.1.2 Measurement of spectral vibrations

Frequency band: the researched fault belongs to the low frequency range, so the maximum frequency FM ≥ 4 x Fr,(4 x Fr Corresponds to a shaft fault). So FM ≥100 Hz.
Number of lines: in order to have a good resolution of the defect peaks, it is necessary to determine the number of lines allowing the distinction between the two nearest peaks. IN this case it is the peak of 0,5 Fr (mechanical gap) and Fr (misalignment).

$$\Delta F = Fr - 0{,}5\ Fr$$

The number of lines is obtained by the relation:

$$NL \geq \frac{FM \times 8}{\Delta F} = 64.$$

We will take NL = 100.
After the parameterization of the device, a measurement was made on the bearing on the coupling side.

➢ **Spectrum without defect**

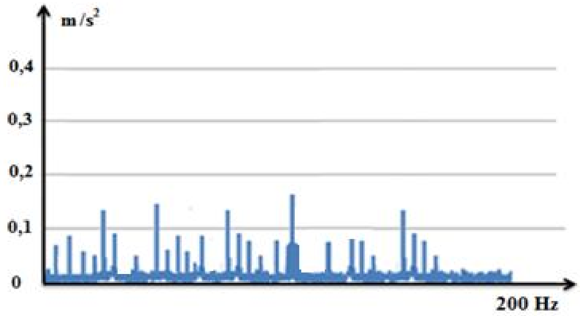

Figure 4 Spectrum recorded

➢ **Spectrum with misalignment**

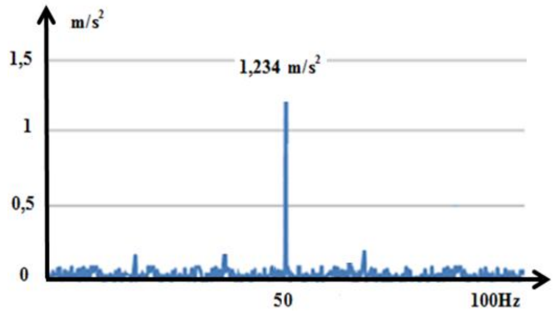

Figure 5 Spectrum recorded

3.1.3 Remark

For a defect of misalignment, we notice:

- The increase of the global level at low frequency compared to the reference state.
- The appearance of the peak twice frequency of rotation (2Fr).

4 THE IMPACTS OF MISALIGNMENT ON THE OPERATION OF AN ELECTRIC MOTOR AND ON ENERGY CONSUMPTION

4.1 Introduction

In this section we will study the impacts of a misalignment on the operation of the electrical motor and on the consumption of electrical energy. For this we used the test bench Figure (3).
We carried out the following tests:

- The motor is started for 10 minutes to read the temperature, the active power P, the reactive power Q and the cosφ in the normal or healthy state.
- The motor is stopped until it returns to the initial temperature.
- We make the first attempt but this time with a misalignment of one degree.
- The motor is stopped until it returns to the initial temperature.
- The first attempt was repeated for the second time but this time with a misalignment of two degrees.

- The motor is stopped until it returns to the initial temperature.
- The first attempt was made for the third time but this time with a misalignment of three degrees.
- The motor is stopped until it returns to the initial temperature.
- The first attempt was repeated for the fourth time but this time with a misalignment of four degrees.
- The temperatures of the various tests are taken by a thermal camera and the values of the powers and cosρ are taken by an analyzer of the electrical network.

The results are presented in the following table:

Table 1: Summary table of thermal and electrical tests

Test	Temperature °C	P(W)	Q (VAR)	Cos ρ
Motor stop	29,2	0	0	0
Motor start without misalignment	33,9	465	84,43	0,98
with a misalignment 1°	37,5	465	84,43	0,98
with a misalignment 2°	40,2	465	84,43	0,98
with a misalignment 3°	42,8	430	136	0 ,92
with a misalignment 4°	45,8	416.7	219,3	0,88

4.2 Graphs

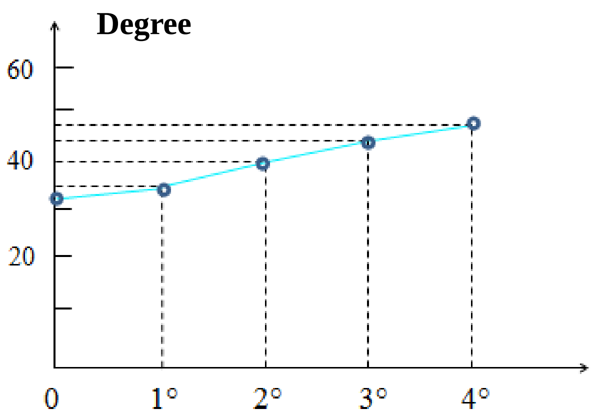

Figure 6 Temperature diagram as a function of misalignment

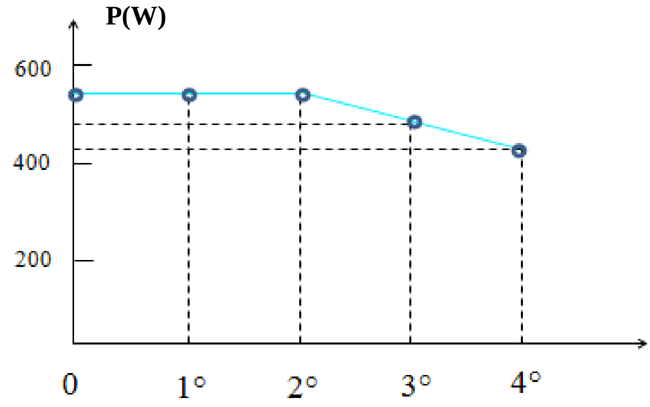

Figure 7 Active power graph as a function of misalignment

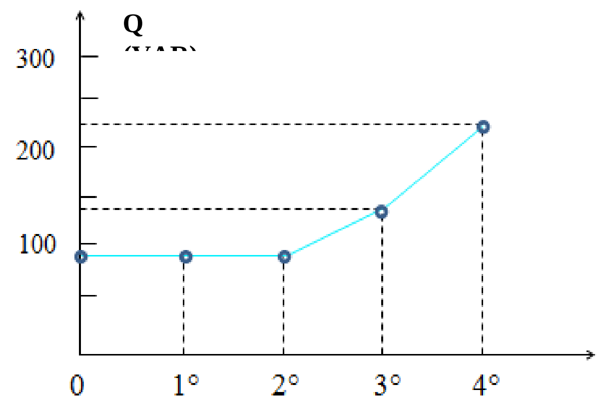

Figure 8 Reactive power graph as a function of misalignment

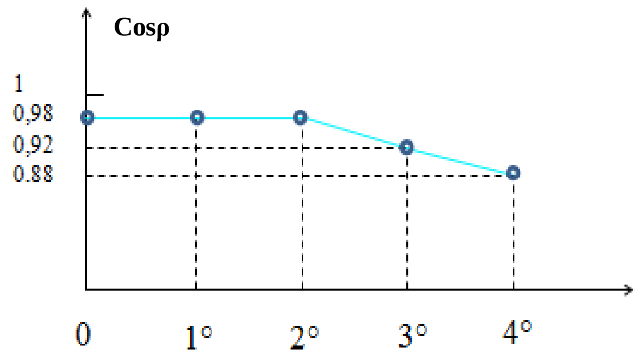

Figure 9 Graph of Cosρ as a function of the misalignment

4.3 Remark

We noticed that when the degree of misalignment is increased:

- -The increase of temperature.
- The increase of reactive power only when the misalignment reaches 2 °.

- The decrease of active power only when the misalignment reaches 2 °.
- And the Cosρ, also decreases only when the misalignment reaches 2 °.

5 CONCLUSION

According to the tests realized, it is observed that the misalignment is manifested by:

- The increase of the global level in low-frequency in relation to the state of reference.
- The appearance of the peak twice frequency of rotation (2Fr) in spectral analysis.

The misalignment causes:

- An increase in the temperature of the electric motor, which can cause damage to the electrical cables at the stator and rotor, thus reducing the service life of the bearings.
- A reduction in the active power which is useful for the conversion of the electrical energy to the mechanical energy, what means a reduction in the torque C and / or speed of rotation ω, provoking thus a malfunction of an industrial installation driven by an electric motor.
- An increase in the reactive power used to supply the magnetic circuits means an increase in losses in the electrical installation.
- A reduction in the power factor Cos ρ, that is to say, the current intensity called is high but the active power is low, thus a loss in energy consumption.

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