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Vibration Monitoring of Industrial Rotating Machines and Development of a Graphical Interface

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***Abstract*— The industrial applications of vibration monitoring for operating equipment are diverse. Vibration analysis techniques allow any industrial operator to constantly assess the health status of their machines, estimate the potential lifespan of various components, and thus prevent premature wear of different parts.**

Excessive vibrations must be avoided and quickly eliminated when detected. The effects of vibrations that cause wear and damage include: Fatigue, Friction and contact wear, Imbalance, Clearance defects, etc.

In this work, we will study two practical cases of industrial rotating machines using vibration analysis. We will diagnose two defective machines with different types of faults. A comparison will be made between experimental and theoretical results. Finally, we will develop a graphical interface to facilitate theoretical calculations.

***Keywords*—condition monitoring; vibrations; rotary machines; Fault detection; predictive maintenance.**

I. Introduction

The abnormal operation of rotating machines is frequently caused by mechanical or electrical faults, which can be detected through vibrational signals. Vibration analysis enables the identification of faults in rotating machinery and offers reliable diagnostic insights. Common faults include looseness, unbalance, eccentricity, blade defects, misalignment, defective bearings, damaged gears, and cracked or twisted shafts [1]. The primary goal of condition monitoring is to identify faults in machinery before they escalate into critical failures [2].

Excessive vibrations are often a result of the operation of rotating machines. The frequency and amplitude of these vibrations cannot be accurately measured by sight or touch alone. If vibrational signals create significant noise or disturbances, this could indicate that the machine has underlying faults that may lead to failure [3]. A study on a Cement Separator machine [4] was conducted to identify potential indicators of condition through vibration measurements and analysis. In this research, various mechanical faults in the cement separator were identified using vibration analysis. Vibration-based condition monitoring has been applied to a variety of mechanical systems and components [5,6,7,8].

Effective maintenance relies on advanced technologies that allow for continuous monitoring of operating conditions and informed decision-making regarding machine or component interventions. Monitoring and predictive maintenance techniques improve productivity, reliability, efficiency, and operational safety [9]. These techniques rely on continuous or periodic measurements of machine performance to detect any changes in signal behaviour. In one study [10], the authors investigated the vibrational behaviour of a recycled plastic perforating machine. Since its installation, the machine has encountered mechanical issues, such as rotor imbalance and bearing failures, resulting in repeated premature shutdowns and disrupting production. The study aims to carry out on-site analyses, including vibration monitoring and spectral analysis, along with theoretical studies and simulations to better understand the machine's vibrational and spectral characteristics.

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II. Industrial Machinery Cases

We study two practical cases involving vibration analysis: An atomizing fan and a cement exhaust fan (*Figures 1and 2)*. Both fans are modelled as follows

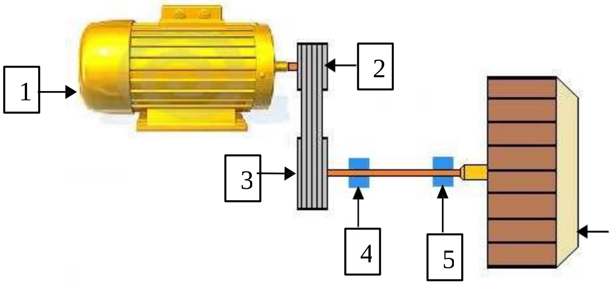

Figure 1: Atomizing fan

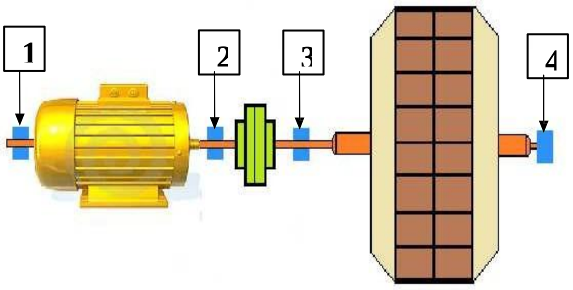

Figure 2: Cement exhaust fan.

The vibration measurement points are taken on the bearings and recorded in three directions: **horizontal radial, vertical radial, and axial**.

Several balancing operations have been performed on the atomizer fan turbine during its operation (**Table 1**). Similarly, the different values for each bearing and in each direction are illustrated in **Table 2** for the exhaust fan in the cement plant.

Table 1: Intervention History Including Atomizer Balancing.

Intervention Dates and Technological Solutions	**Unbalance Level Before Balancing (mm/s)**	**Unbalance Level After Balancing (mm/s)**
July 2015	10.36	02.31
September 2019 Machining of the bearing seat on the electric motor shaft.	12.67 on the motor	01.40
2023	10.53	01.62
October 2024	14.01	03.71

Table 2: Overall Vibration Levels Recorded, June 2024.

Measurement Points	**02**			**03**			**04**	
	Axial direction	Radial horizontal direction	Radial vertical direction	Axial direction	Radial horizontal direction	Radial Vertical direction	Radial horizontal direction	Radial Vertical direction
Level in mm/s	15,08	19,05	10,01	13,38	14,23	10,76	25,26	25,97

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III. EXPERIMENTATIONS ET SOLUTIONS PROPOSEES

CAS 1 : Atomizing fan

The vibrations recorded on this equipment throughout the monitoring process using vibration analysis are due to an imbalance related to a rotational effort known as unbalance. If we divide the six years of vibration monitoring by the number of balancing operations performed on the fan turbine, we find an average of one balancing per year. This indicates that we are facing either a design issue or a failure related to the working conditions to which the equipment is subjected. The last assumption is difficult to consider, as the conditions of temperature, pressure, and dust are normal. This leads us to conclude that there is a design defect related to the wear present on the blades, cone, and disc of the turbine caused by the material being drawn in. Visual inspection of the turbine during the balancing process also confirms this. This unbalance has resulted in bearing defects on both supports of the turbine shaft (No. 03 & 04), as well as play defects observed on the motor flange on the drive pulley side (No. 02 according to the machine's kinematic chain). These two defects have been addressed by replacing the bearings and supports and by loading and machining the bearing surface of the electric motor shaft. Consequently, the balancing operations of the turbine have been successfully completed, following the detection of unbalance on all the supports of the fan.

CAS 2: Cement exhaust fan.

The installation represents a significant strategy in the cement plant's production chain. Therefore, this type of machinery requires periodic monitoring through vibration analysis to prevent unexpected breakdowns and to increase operational availability. It also facilitates the scheduling of maintenance interventions as soon as mechanical defects arise during operation. In our case, we detected an alignment issue at an early stage. We recommended that the maintenance team conduct an alignment check to avoid further mechanical problems. Unfortunately, this misalignment persisted for nearly a year, leading to wear on the bearing surfaces in both free bearings and at the coupling. The vibration levels reached a critical threshold according to international standards VDI 2056, primarily due to significant eccentricity between the rotation axis and the main inertia axis, measuring approximately 0.3 mm on the bearing surface radius of the turbine-side shaft. Due to the delay in intervention for repairs, the degradation extended to the bearings on the shaft and the bearings themselves, making their replacement essential given their condition (0.3 mm of play). As a result, the overall vibration levels improved significantly and became acceptable after these components were replaced. Following our vibration analysis report, which outlined the detected anomalies—including bearing play, misalignment, and rotor imbalance—the following measures were taken to address these issues: - Replacement of the turbine shaft - Replacement of the bearings - Replacement of the rollers - Alignment of the motor shaft with the turbine shaft.

IV. INTERFACE GRAPHIQUE

4.1 STEPS FOR CREATING THE INTERFACE

The necessary steps followed to develop our interface are as follows:

- Development of calculation algorithms for all considered cases.
- Implementation of the calculation algorithms using the MATLAB programming language.
- Comparison and validation of results against experimental data.
- Establishment of the execution flowchart for the interface and its usage.
- Implementation of the interface.

4.2 Interface Utilization

Application Startup Page / On this page, there are three main menus:

- Data: In this menu, the user can choose one of two calculation modes:
  - Parasite Mass.
  - Eccentricity.

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- Display: This section shows the calculated results.

Comparison: This page compares the calculated results with practical results, specifying the desired error margin

4.2.1 Data Menu: Choosing a Calculation Mode The user will select one of the two options:

a. Parasite Mass

On this page, the user will enter and load the data for the studied system, including the parasite mass, and then initiate the calculation.

b. Eccentricity

On this page, the user will perform the same actions as in the previous one, but this time by entering the eccentricity data before starting the calculation.

4.3 Display Menu

After entering the data and starting the calculation, the user will view the calculated results on this page

4.4 Comparison Menu

On this page, the user will input the experimentally obtained values, specify the margin of error, and then initiate the comparison. The program flowchart is as follows (Figure 3):

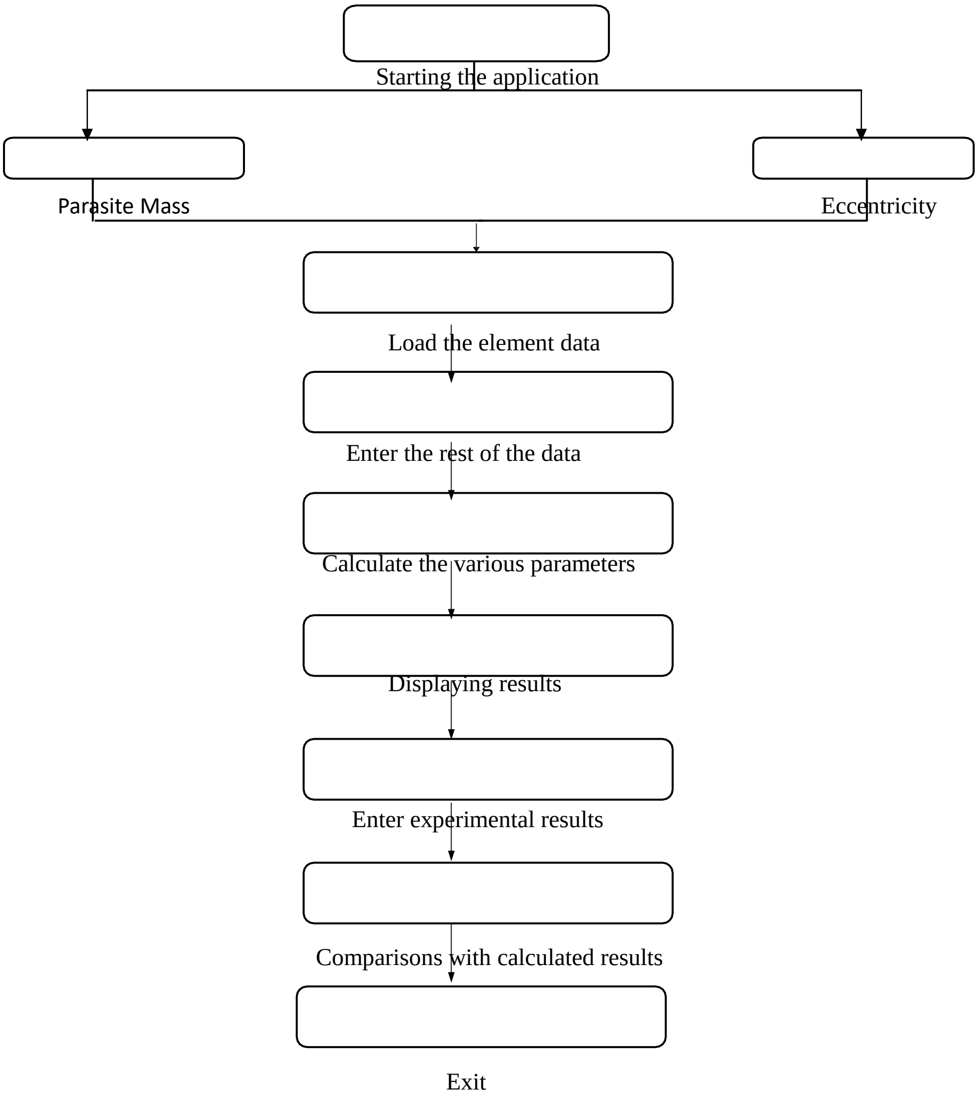

Figure 3: The flowchart of the program

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IV. Conclusion

In this work, we presented practical cases encountered in industrial plants in Algeria, revealing anomalies that produce similar vibration signatures. We focused on two specific cases:
- The ceramic atomizer fan (Atomizing fan).
- The exhaust fan of a cement factory.

The objectives of this study can be divided into two main parts:
- To address malfunctioning machines, diagnose them, and carry out repairs. Additionally, we aimed to study their failures both theoretically and experimentally to validate the results obtained. - To develop a graphical interface using the MATLAB Guide tool.

After performing the necessary repairs on the two mentioned machines, we observed the elimination of defects such as imbalance, misalignment, and play. Consequently, the diagnostics and control operations were justified.
- For the atomizer, we identified the characteristics of the parasitic mass following an on-site balancing, which allowed us to calculate the eccentricity and various other parameters.
- For the exhaust fan, we used eccentricity as a given parameter. All system parameters were determined by first calculating the characteristics of unbalance, including mass, volume, and position.

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