# EVALUATION OF UNCONVENTIONAL TECHNIQUES OF VIBRATION ANALYSIS FOR DETECTION OF MALFUNCTION IN HORIZONTAL ROTATING MACHINES

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PPG-EM Seminars: season **2016**
www.ppg-em.uerj.br

November 10, 2016

**Keywords:** Vibration Analysis, Defect Detection, Unconventional Techniques, Rotating Machines

## Introduction

In popular terms, it has been said that "the machines speak and through sounds and vibration we can hear their complaints and diagnose their diseases". The condition monitoring of rotating machines by measuring and vibration analysis is the process in which a machine is periodically evaluated by measuring and vibration analysis, and their conditions are checked using the vibration signals.

This monitoring can be carried out at three levels: 1- Overall measurement of vibration levels, to know the severity of vibration and compare with preset limits; 2- Frequency spectrum analysis to detect where it comes from vibration and possible defects; 3- Special techniques that can better detail the level, location and type of defect or malfunction. This study aims to evaluate some of these special techniques such as Full Spectrum, SPM spectrum, Orbit, phase analysis / ODS and Envelope. These techniques have been applied on an experimental rig for entering various defects in these mechanisms such as misalignment, imbalance, gear defects, problems in bearings, etc. The results obtained by each technique were evaluated and compared. The final analysis of the results is expressed using the method of digital logic for creating tables of comparative techniques for each type of defect, it is possible to identify which technique is best to diagnose a particular type of defect.

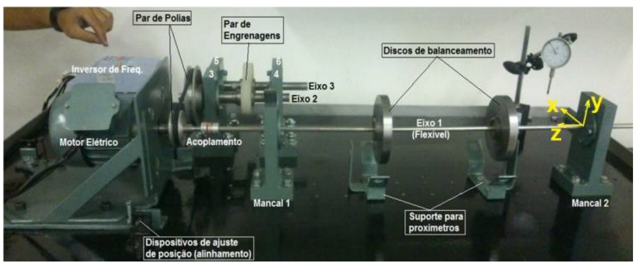


Figure 1: Experimental Rig.

## Method

Experimental method was used to evaluate the following vibration monitoring techniques:

**Conventional:** RMS vibration level (severity) and also frequency and time dominium spectrum.

**Orbit:** The orbit [1] is the trajectory of the shaft center line of the pair of proximity sensors.

**Full spectrum:** The common frequency spectrum resulting from the application of the FFT transform on the time signal. But the full spectrum (Southwick , 1993) it is the spectrum of an orbit. It's derived from the waveforms from the pair of proximity sensors , combined with knowledge of the direction of rotation.

**Shock pulse:** It is a signal processing technique used to measure impact of metals and rolling noise , such as Those found in ball bearings and gears . Unlike common vibration measurement, shock pulse does not measuring movement, but measure the impact that is propagated through the metal ultrasound frequencies.

**Envelope:** The envelope technique, also referred to as " amplitude demodulation " is the technique of extracting the modulation signal from an amplitude modulated signal.

**ODS:** It has been defined as deflection of a structure in a particular frequency. However, an ODS can be defined more generally as any forced movement of two or more points on a structure (Brian, 1999).

**Phase:** It can be regarded as a complement or part of the ODS technique. Certain types of defects generate phase differences known between two or more measurement points, helping to distinguish the specific defect type and the action that should be taken to correct.

### Evaluation Method

The **digital logic method** has been used as a tool for the systematic evaluation of vibration analysis techniques. In this procedure , the reviews are arranged such that only two techniques are considered at a time. To determine the relative importance of each technique for each type of defect, comparative tables and results graphs are built.

## Results

The results presented here are for the application of the mentioned techniques to defects of : Resonance , Unbalance and damaged bearings.

**Resonance:** To determine the natural frequencies, mode shapes, critical speeds and resonance, tests were divided into two different approaches: the first considering the entire assembly as a rigid body, and the second considering only the rotor system (disks, flexible shaft and bearings 1 and 2).

In rigid body approach we used 3 methods: Computer simulation MEF, frequency sweep and impact test. In the second approach we used Rotmef Software is a program that was developed specifically for rotor dynamics and software results for various configurations of discs and bearings positions were confronted with experiments that proved the natural frequency values.

Table 1. Results of resonance test of complete Rig.

| Freq. | Computer Simulation (rpm) | Changing Rotation speed (Rpm) | Impact test (Rpm) | Modes |
|---|---|---|---|---|
| 1 | 112,6 | - | 330 | Linear Z |
| 2 | 333,5 | 310,2 | 300 | Linear X |
| 3 | 367,3 | 387 | 375 | Linear Y |
| 4 | 440,54 | 452 | 450 | Rotation Y |
| 5 | 489,64 | 505 | 495 | Rotation X |
| 6 | 699,24 | 678 | 675 | Rotation Z |

**Unbalance:** The unbalance tests were divided into six stages, two conditions (balanced and unbalanced) for each of the three configurations: Static (B1, B2), dynamic (B3, B4) and balance (B5, B6). For testing of static unbalance was used configuration 1, with only one central disc on the drive shaft 1 between the M1 and M2 bearings spaced at 590mm.

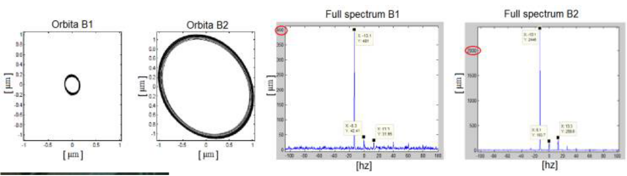


Figure 2: Orbit and Full spectrum for static unbalance test B1 and B2.

**Bearing test:** The defect in the bearing was generated using a small abrasive disc making a tear in the outer race to generate a hole on the inside of the bearing outer race. Rehearsals for bearing were divided into R1 (good bearing) and R2 (defective bearing).

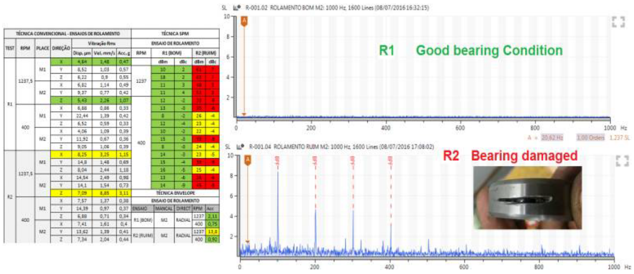


Figure 3: Results of bearing faults tests R1 and R2.

## Conclusions

Through the preliminary analysis were constructed comparative tables of techniques for each type of defect using the method of digital logic. Through the tables it is possible to identify which technique is best applied to diagnose a specific type of defect. Table 2 and Figure 4 shows one of these tables and their respective graphic, which are examples of the final results in the evaluation of techniques for the selected defect unbalance.

| DEFEITO DE DESBALANCEAMENTO | DECISÕES POSITIVAS POSSÍVEIS (N) | | | | | | | | | | | | | | | Decisões Positivas | Coeficiente relativo de ênfase(α) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TÉCNICAS | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | | |
| CONVENCIONAL | 0 | 0 | 1 | 1 | 0 | | | | | | | | | | | 2 | 0,13 |
| FULL SPECTRUM | 1 | | | | | 1 | 1 | 1 | 0 | | | | | | | 4 | 0,27 |
| ORBITA | | 1 | | | | 0 | | | | 1 | 1 | 0 | | | | 3 | 0,20 |
| SPM | | | 0 | | | | 0 | | | 0 | | | 0 | 0 | | 0 | 0,00 |
| ENVELOPE | | | | 0 | | | | 0 | | | 0 | | 1 | | 0 | 1 | 0,07 |
| ANÁLISE DE FASE / ODS | | | | | 1 | | | | 1 | | | 1 | | 1 | 1 | 5 | 0,33 |
| Total de decisões positivas: | | | | | | | | | | | | | | | | 15 | 1,00 |

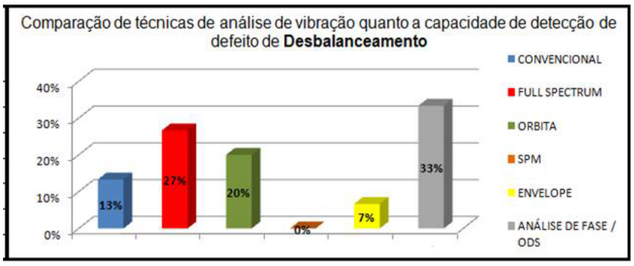


Figure 4: Final Graph of techniques evaluation for unbalance detection.

## Acknowledgments

Acknowledgements to the advisors Renato Rocha and Francisco Soeiro, to the company Naproservice and my mentor Leonard Koornneef.

## References

[1] D. E. Bently. Fundamentals of rotating machinery diagnostics. Technical report, Bently Pressurized Bearing Press, 2002.