COMFAULDA (Composed Fault Dataset)

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Abstract

The measurement and diagnosis of the severity of failures in rotating machines allow the execution of predictive maintenance actions on equipment. These actions make it possible to monitor the operating parameters of the machine and to perform the prediction of failures, thus avoiding production losses, severe damage to the equipment, and safeguarding the integrity of the equipment operators. This paper describes the construction of a dataset composed of vibration signals of a rotating machine. The acquisition has taken into consideration seven distinct operating scenarios, with different speed values. Unlike the few datasets that currently exist, the resulting dataset contains simple and combined faults with several severity levels. The considered operating setups are normal condition, unbalance, horizontal misalignment, vertical misalignment, unbalance combined with horizontal misalignment, unbalance combined with vertical misalignment, and vertical misalignment combined with horizontal misalignment. The dataset described in this paper can be utilized by machine learning researchers that intend to detect faults in rotating machines in an automatic manner. In this context, several related topics might be investigated, such as feature extraction and/or selection, reduction of feature space, data augmentation methods, and prognosis of rotating machines through the analysis of failure severity parameters.

Classifications: Vibration; Unbalance; Misalignment, Combined faults; Diagnosis.

Data Description

The devised dataset presents 2162 vibration signals acquired from seven operating conditions of the rotating machine simulator: normal operation, unbalance, horizontal misalignment, vertical misalignment, unbalance combined with horizontal misalignment, unbalance combined with vertical misalignment, and horizontal misalignment combined with vertical misalignment [1].

The vibration signals were acquired for 5 seconds with a sampling rate f_s = 50 kHz. Therefore, each entry of the dataset contains 250,000 samples. For each of the seven distinct operating conditions, different values of the motor rotation speed (in the interval [12,60] Hz) were employed, with an increment of approximately 1 Hz between each recording. Each measurement presents eight channels, which are described in Table 1. The number of signals of normal scenario is described in Table 2. The number of signals of isolated faults: unbalance, horizontal misalignment, and vertical misalignment is presented in Table 3. For some fault scenarios, it was not possible to record the lowest motor rotation speed (12 Hz) due to bench limitation, thus some scenarios described in Table 3 presents 48 examples.

The number of signals of combined faults: unbalance + horizontal misalignment, unbalance + vertical misalignment and vertical misalignment + horizontal misalignment is presented in Table 4. Due to bench safety limitations for some fault scenarios, it was not possible

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to record signals above 50 Hz speed resulting in 39 signals and above 40 Hz speed resulting in 29 signals. Lastly, Table 5 summarizes the number of signals for each of the 7 scenarios of the dataset.

Table 1. Channels description.

Channels	Description
Channel 1	Time vector
Channel 2	Tachommeter signal
Channel 3	Capacitive accelerometer signal for axial direction (X)
Channel 4	Capacitive accelerometer signal for vertical direction (Z)
Channel 5	Cappacitive accelerometer signal for horizontal direction (Y)
Channel 6	Piezoeletric accelerometer signal for axial direction (X)
Channel 7	Piezoeletric accelerometer signal for vertical direction (Z)
Channel 8	Piezoeletric accelerometer signal for horizontal direction (Y)

Table 2. Normal condition.

Scenarios	Signals Details	
	Quantity	Speed (Hz)
Normal 1	49	[12, 60]
Normal 2	49	[12, 60]
Normal 3	49	[12, 60]
Normal 4	49	[12, 60]
Normal 5	49	[12, 60]

Table 3. Number of simple faults.

Scenarios	Signals Details	
	Quantity	Speed (Hz)
Unbalance (6 grams)	48	[13, 60]
Unbalance (10 grams)	48	[13, 60]
Unbalance (15 grams)	48	[13, 60]
Unbalance (20 grams)	48	[13, 60]
Unbalance (25 grams)	48	[13, 60]
Unbalance (30 grams)	48	[13, 60]
Unbalance (35 grams)	48	[13, 60]
Horizontal misalignment (0.5 mm)	48	[13, 60]
Horizontal misalignment (1.0 mm)	49	[12, 60]
Horizontal misalignment (1.5 mm)	49	[12, 60]
Horizontal misalignment (2.0 mm)	49	[12, 60]
Vertical misalignment (0.51 mm)	49	[12, 60]
Vertical misalignment (1.27 mm)	48	[13, 60]
Vertical misalignment (1.4 mm)	49	[12, 60]
Vertical misalignment (1.78 mm)	48	[13, 60]
Vertical misalignment (1.91 mm)	49	[12, 60]

Experimental Design and Methods

The acquisition of the vibration signals for the dataset was performed using the experimental bench Alignment Balance Vibration Trainer (ABVT), which is manufactured by SpectraQuest company. The recordings were carried out in the Dynamic Testing and Vibration Analysis Laboratory of the Federal University of Rio de Janeiro (LEDAV/COPPE/UFRJ). The main bench features are described in Table 6.

Data acquisition system

The data acquisition system used to acquire the signals from the dataset is composed of the following items: 4 accelerometers, 1 analog tachometer, 2 signal acquisition module and 1 computer as presented in Figure 2.

Accelerometers

In order to allow the identification of faults in rotating machines from vibration signals, it is necessary to measure vibration signals in three directions: axial (X), tangential (Y), and radial (Z). Figure 3 shows the measurement plans for the vibration signals [2, 3].

On the internal bench bearing, one triaxial capacitive accelerometer of the model 4332M1-002-060, manufactured by the company TEconnetivity, was positioned to measure accelerations in X-, Y-, and Z-directions (perpendicular to each other), as depicted in Figure 1.

Table 4. Number of combined faults.

Scenarios	Signals Details	
	Quantity	Speed (Hz)
Unbalance (6 grams)+ Horizontal misalignment (0.5 mm)	49	[12, 60]
Unbalance (6 grams) + Horizontal misalignment (1.0 mm)	49	[12, 60]
Unbalance (6 grams) + Horizontal misalignment (2.0 mm)	49	[12, 60]
Unbalance (20 grams) + Horizontal misalignment (0.5 mm)	39	[12, 50]
Unbalance (20 grams) + Horizontal misalignment (1.0 mm)	39	[12, 50]
Unbalance (20 grams) + Horizontal misalignment 2.0 mm)	39	[12, 50]
Unbalance (30 grams) + Horizontal misalignment (0.5 mm)	29	[12, 40]
Unbalance (30 grams) + Horizontal misalignment (1.0 mm)	29	[12, 40]
Unbalance (30 grams) + Horizontal misalignment (2.0 mm)	29	[12, 40]
Unbalance (6 grams) + Vertical misalignment (0.51 mm)	49	[12, 60]
Unbalance (6 grams) + Vertical misalignment (1.27 mm)	49	[12, 60]
Unbalance (6 grams) + Vertical misalignment (1.91 mm)	49	[12, 60]
Unbalance (20 grams) + Vertical misalignment (0.51 mm)	39	[12, 50]
Unbalance (20 grams) + Vertical misalignment (1.27 mm)	39	[12, 50]
Unbalance (20 grams) + Vertical misalignment (1.91 mm)	39	[12, 50]
Unbalance (30 grams) + Vertical misalignment (0.51 mm)	29	[12, 40]
Unbalance (30 grams) + Vertical misalignment (1.27 mm)	29	[12, 40]
Unbalance (30 grams) + Vertical misalignment (1.91 mm)	29	[12, 40]
Vertical misalignment (0.51 mm) + Horizontal misalignment (0.5 mm)	49	[12, 60]
Vertical misalignment (0.51 mm) + Horizontal misalignment (1.0 mm)	49	[12, 60]
Vertical misalignment (0.51 mm) + Horizontal misalignment (2.0 mm)	49	[12, 60]
Vertical misalignment (1.27 mm) + Horizontal misalignment (0.5 mm)	49	[12, 60]
Vertical misalignment (1.27 mm) + Horizontal misalignment (1.0 mm)	49	[12, 60]
Vertical misalignment (1.27 mm) + Horizontal misalignment (2.0 mm)	49	[12, 60]
Vertical misalignment (1.91 mm) + Horizontal misalignment (0.5 mm)	49	[12, 60]
Vertical misalignment (1.91 mm) + Horizontal misalignment (1.0 mm)	49	[12, 60]
Vertical misalignment (1.91 mm) + Horizontal misalignment (2.0 mm)	49	[12, 60]

Table 5. Complete dataset.

Scenario	Quantity
Normal	245
Unbalance	336
Horizontal misalignment	195
Vertical misalignment	243
Unbalance + horizontal misalignment	351
Unbalance + vertical misalignment	351
Vertical misalignment + horizontal misalignment	441

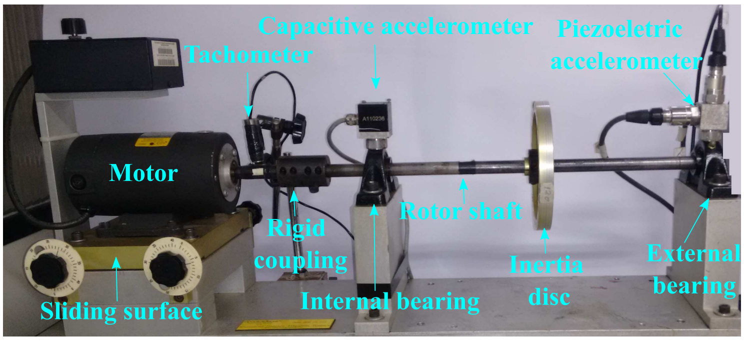

Figure 1. Experimental bench ABVT.

The main features of this sensor are sensitivity 1000 mV/g (±10%) and frequency range $f \in [10, 20000]$ (Hz).

On the external bench bearing, 3 unidirectional piezoelectric accelerometers of the model 601A01 manufactured by the company IMI Sensors were positioned to measure accelerations in X-, Y- and Z-directions (perpendicular to each other), as shown in Figure 1. The main features of this sensor are sensitivity 100 mV/g (±20%), frequency range [0.27, 1000] Hz, and acceleration measurement range [-50, 50] g. In this case g is approximately 9.81 m/s^2.

Tachometer

To measure the rotational speed of the motor, an analog tachometer model MT-190 produced by Monarch instrument was utilized. It can be observed in Figure 1. This sensor measures the angular speed of the motor shaft, providing as an output an alternating voltage signal, which varies according to the change in motor speed.

Table 6. Bench features.

Motor type	Direct current
Motor power	0.25 hp
Speed range	[12 60] Hz
System mass	22 kgrams
Shaft length	520 mm
Shaft diameter	16 mm
Rotor diameter	152.4 mm
Distance between bearings	390 mm

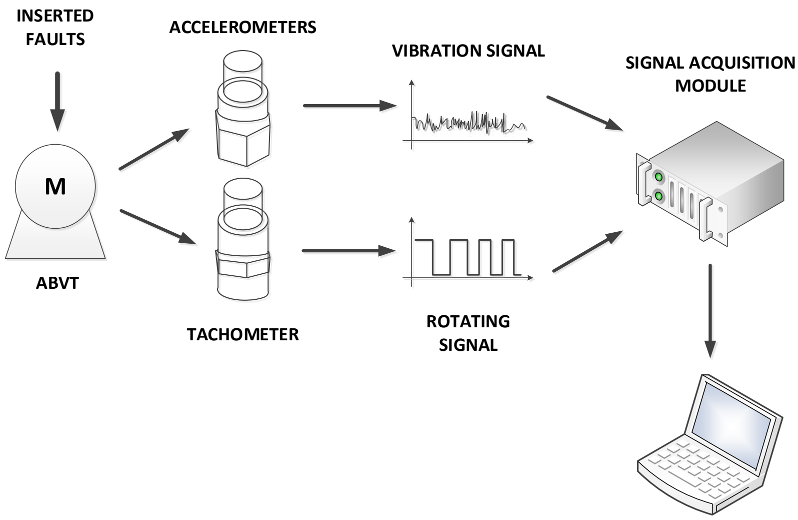

Figure 2. Signal recording scheme.

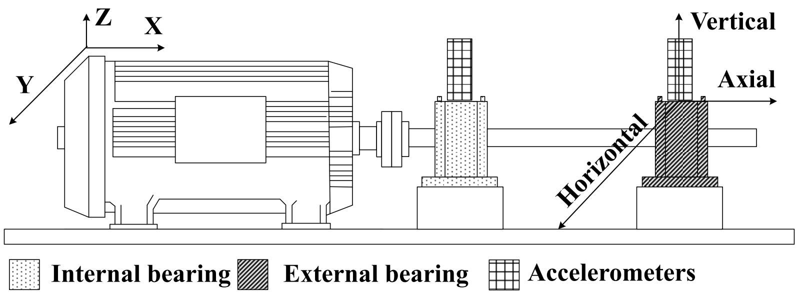

Figure 3. Identification of vibration measurement axes.

Signal acquisition

The module used to record the vibration and tachometer signals was the signal acquisition module (NI 9234), manufactured by National Instruments. This module converts the analog signals from the sensors into digital voltage or current signals. The main features of module sensor are 24 bit resolution, maximum sampling frequency of 51.2 kHz, 102 dB dynamic range, anti-aliasing filter, operating temperature range of [-40, 70] °C and signal conditioning for piezoelectric sensors. The Labview™ software was used to implement the interface between the acquisition module and computer as shown in Figure 4. Through this interface, it is possible to view the signals of each channel during the acquisition step, to avoid recording errors. In this interface, it is also possible to choose the type of file format to which the signals will be exported. In addition, the signals can also be filtered to reduce the presence of noise.

Insertion of faults

The dataset contains 7 different types of scenarios for the rotating machine, namely, normal operating condition, unbalance, horizontal misalignment, vertical misalignment, unbalance associated with horizontal misalignment, unbalance associated with vertical misalignment and horizontal misalignment associated with vertical misalignment.

The unbalance fault is inserted into the ABVT by placing screws with a known mass on the inertia disc at center-hug configuration, as show the Figure 5(a). Seven different masses were used to induce unbalance: {6, 10, 15, 20, 25, 30 and 35} grams.

The horizontal misalignment defect is produced by moving the base of the DC motor in the horizontal direction and measuring its position with a digital caliper as show the Figure 5(b). The chosen parallel horizontal misalignments were 0.5, 1.0, 1.5, and 2.0 (in millimeters).

Vertical misalignment fault is inserted from the addition of known thickness shims at the base of the electric motor as show in Figure

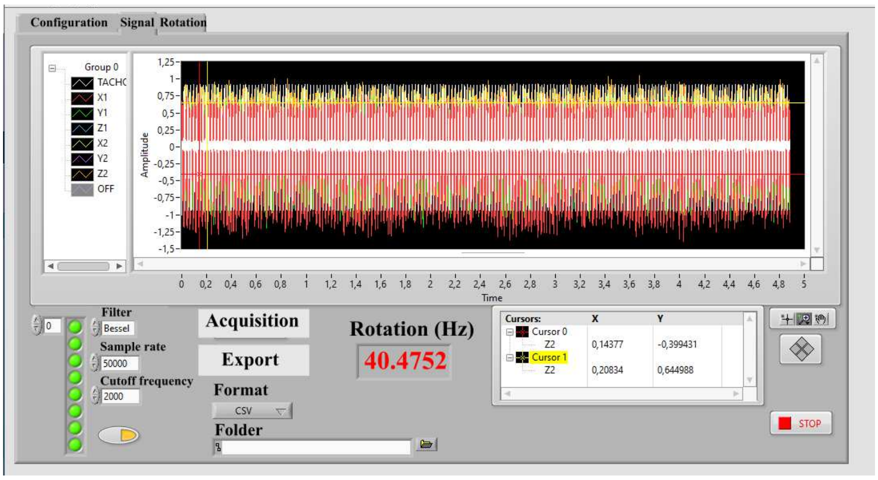

Figure 4. Labview™ screen.

(a) Insertion of unbalance. (b) Insertion of horizontal misalignment. (c) Insertion of vertical misalignment

Figure 5. Faults insertion.

5(c). Six differents values of vertical misalignment were used [0.51, 1.27, 1.4, 1.78, 1.91] millimeters.

References

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