Experiment: Bearing Fault Diagnosis using Signal Processing Techniques

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Objective

The objective of this experiment is to perform fault diagnosis of a rolling element bearing based on acceleration signals, especially in the presence of strong masking signals from other machine components. This will demonstrate how to apply envelope spectrum analysis to diagnose bearing faults.

Introduction

Squirrel Cage Induction Motors (SCIM) are used for electro-mechanical energy conversions in many industries such as rolling mills, power plants, steel industries, locomotives, electric vehicles, etc. Low cost, low maintenance, and moderate efficiency are the three top reasons behind the popularity of SCIMs. Even though SCIMs have robust construction; they may develop faults. The causes of the faults can be attributed mainly due to the hotspot formation and the presence of the uneven magnetic pull. The hotspot formation and the presence of the uneven magnetic pull may result from insulation degradation,non-uniform loading patterns, installation defects, manufacturing defects etc.

Majority of problems in rotating machinery are caused by faulty gears, bearings etc. Failure in bearing is one of the primary causes of breakdown in rotating machines. Such breakdowns can lead to expensive shutdowns, drifts in production and even human casualties

Dataset Description

MFPT Challenge data contains 23 data sets collected from machines under various fault conditions. The first 20 data sets are collected from a bearing test rig, with 3 under good conditions, 3 with outer race faults under constant load, 7 with outer race faults under various loads, and 7 with inner race faults under various loads. The remaining 3 data sets are from real-world machines: an oil pump bearing, an intermediate speed bearing, and a planet bearing. The fault locations are unknown.

Each data set contains an acceleration signal `gs`, sampling rate `sr`, shaft speed `rate`, load weight `load`, and four critical frequencies representing different fault locations: ballpass frequency outer race (BPFO), ballpass frequency inner race (BPFI), fundamental train frequency (FTF), and ball spin frequency (BSF). Here are the formulae for those critical frequencies

Ballpass frequency, outer race (BPFO)

$$\text{BPFO} = nf_r/2\left(1 - \frac{d}{D}\cos\phi\right)$$

Ballpass frequency, inner race (BPFI)

$$\text{BPFI} = nf_r/2\left(1 + \frac{d}{D}\cos\phi\right)$$

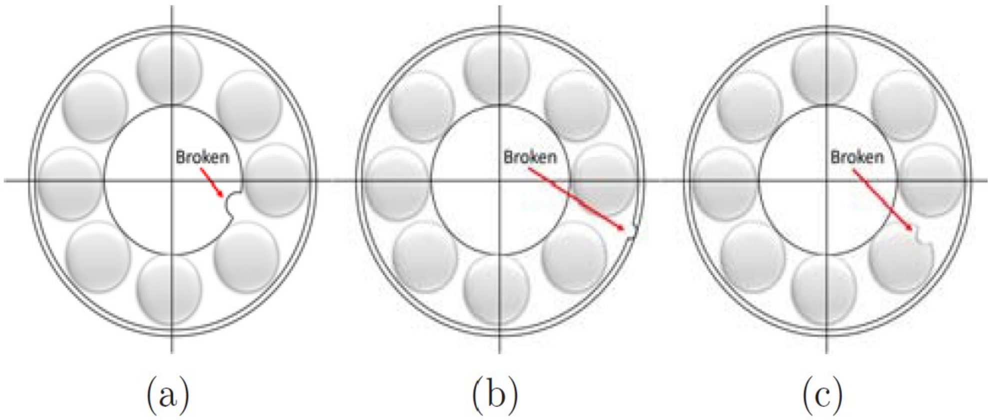

Figure 1: Schematics of various bearing faults. (a) Inner raceway, (b) Outer raceway, and (c) Rolling element
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Fundamental train frequency (FTF), also known as cage speed

$$\text{FTF} = f_r/2\left(1 - \frac{d}{D}\cos\phi\right)$$

Ball (roller) spin frequency (BSF)

$$\text{BSF} = \frac{Df_r}{2d}\left[1 - \left(\frac{d}{D}\cos\phi\right)^2\right]$$

Where d is the ball diameter, D is the pitch diameter. The variable f_r is the shaft speed, n is the number of rolling elements, ϕ is the bearing contact angle.

The dataset can be downloaded from here

Assignments to Solve and Report

Step-by-Step Instructions

Part 1: Detection of Inner Raceway Fault

1. Load the inner raceway fault data from the dataset
2. Plot in Time & Frequency Domain
3. perform FFT & Short Time Fourier Transform (STFT) (from Scratch) of the Signal & plot the result. Write the observations
4. Design a suitable bandpass FIR filter
5. Compute the envelope of the filtered signal Using Hilbert Transform (From Scratch)
6. Compute the One- sided Power spectrum (from Scratch) of the obtained signal
7. Plot the magnitude and compare with given BPFI given in the dataset

Part 2: Detection of Normal condition

1. Repeat the above steps
2. Write your observations

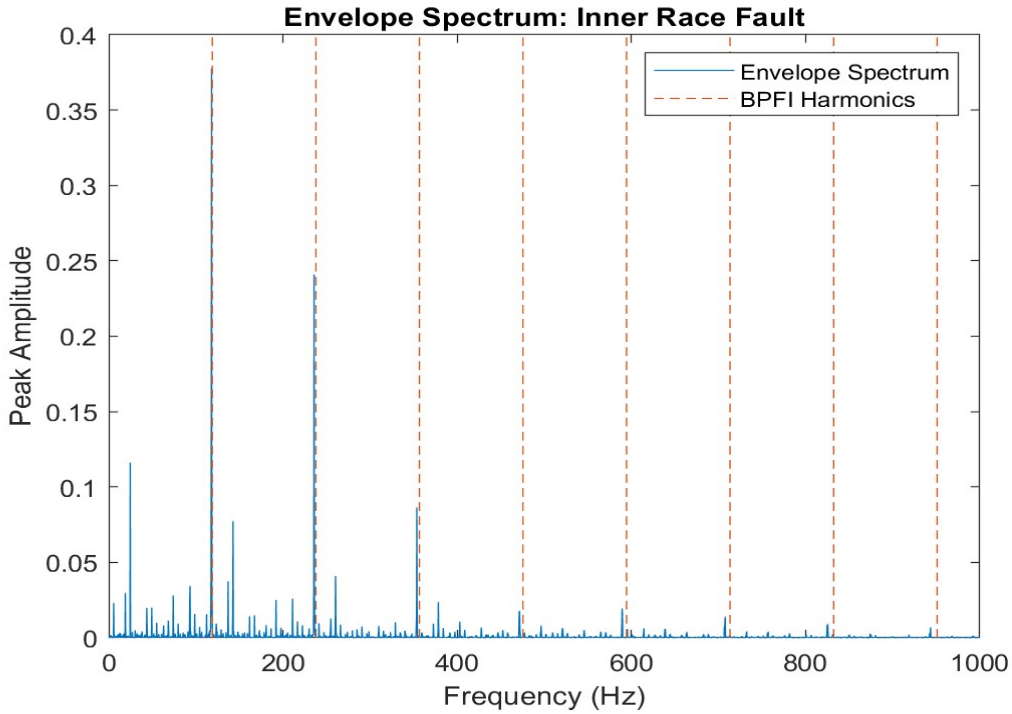

Figure 2: Expected graph for Inner Raceway fault

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Part 3: Detection of outer Raceway condition

1. Repeat the steps same as inner raceway and compare with the given BPFO in the dataset
2. Comment about the obtained Result
3. Compute the Kurtosis value of each signal and compare
4. Design a bandpass filter with fc=2670 & Bandwidth= 763
5. Repeat the same steps as inner raceway fault and compare

References

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4. Bechhoefer, Eric. "Condition Based Maintenance Fault Database for Testing Diagnostics and Prognostic Algorithms." 2013. https://www.mfpt.org/fault-data-sets/