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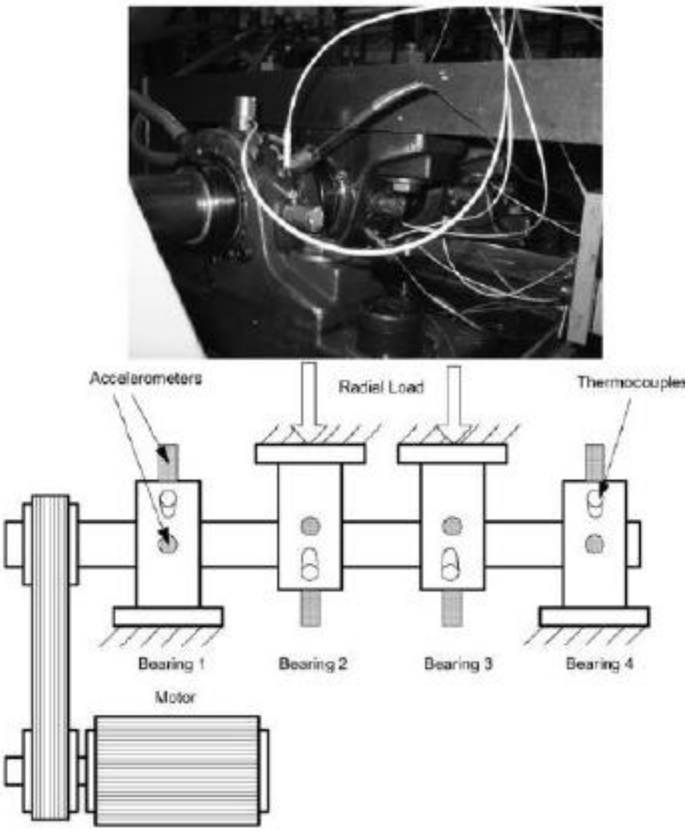
Course: Mechanical signal processing

ESIEE PARIS

Tutorial 1

Test Rig Setup

Four bearings were installed on a shaft. The rotation speed was kept constant at 2000 RPM by an AC motor coupled to the shaft via rub belts. A radial load of 6000 lbs is applied onto the shaft and bearing by a spring mechanism. All bearings are force lubricated. Rexnord ZA-2115 double row bearings were installed on the shaft as shown in Figure 1. PCB 353B33 High Sensitivity Quartz ICP accelerometers were installed on the bearing housing (two accelerometers for each bearing [x- and y-axes] for data set 1, one accelerometer for each bearing for data sets 2 and 3). Sensor placement is also shown in Figure 1. All failures occurred after exceeding designed life time of the bearing which is more than 100 million revolutions.



Set No. 1:
Recording Duration: October 22, 2003 12:06:24 to November 25, 2003 23:39:56
No. of Files: 2,156
No. of Channels: 8
Channel Arrangement: Bearing 1 – Ch 1&2; Bearing 2 – Ch 3&4;
Bearing 3 – Ch 5&6; Bearing 4 – Ch 7&8.
File Recording Interval: Every 10 minutes (except the first 43 files were taken every 5 minutes)
File Format: ASCII

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Description: At the end of the test-to-failure experiment, inner race defect occurred in bearing 3 and roller element defect in bearing 4.

Set No. 2:
Recording Duration: February 12, 2004 10:32:39 to February 19, 2004 06:22:39
No. of Files: 984
No. of Channels: 4
Channel Arrangement: Bearing 1 – Ch 1; Bearing2 – Ch 2; Bearing3 – Ch3; Bearing 4 – Ch 4.
File Recording Interval: Every 10 minutes
File Format: ASCII
Description: At the end of the test-to-failure experiment, outer race failure occurred in bearing 1.

Set No. 3
Recording Duration: March 4, 2004 09:27:46 to April 4, 2004 19:01:57
No. of Files: 4,448
No. of Channels: 4
Channel Arrangement: Bearing1 – Ch 1; Bearing2 – Ch 2; Bearing3 – Ch3; Bearing4 – Ch4;
File Recording Interval: Every 10 minutes
File Format: ASCII
Description: At the end of the test-to-failure experiment, outer race failure occurred in bearing 3.

In this tutorial, we are interested in analyzing the second set of these data. Each signal is a 1s length acquisition sampled with a sampling frequency $F_s = 20480Hz$. This means that each record consists of 20480 samples and the time between two consecutive samples define the sampling period $T_s = 488.28ms$. The data acquisition program consists in acquiring a record each 10min to monitor the health state of the bearings.

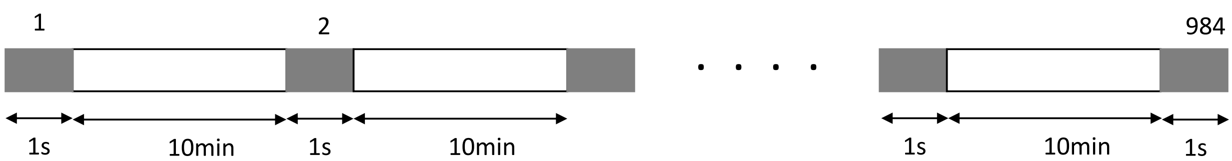

Figure 7: Acquisition program of the run-to-failure test records.

Exercice 1:

The goal of this exercice is to investigate the change in the vibration signal using the time domain signal with no pre-processing. We will use here the vibrations captured by **accelerometer 1**, which is mounted on the bearing 1.

a) Load the data. Note that each file consists of 4 measurements (a 20480-by-4 matrix), each column related to one accelerometer (column 1 for accelerometer 1, and so on). Each measurement (20480-by-1 vector) is a signal or a record, captured over 1 second duration using a single sensor (called accelerometer)

b) Plot the signals of record 100 and record 750 with respect to time. To do so, the students must first define the time-axis using the sampling frequency of the system, then plot the signals with respect to the time axis.
c) Compare these two signals visually. Conclude.
d) Compute the histogram of these two signal and display them in one plot (with different colors). Conclude.
e) For each accelerometer, cascade the 986 signals in the same plot. This will show you the evolution of the vibration signal during the entire test.
    a. How does the vibration signal change?
    b. Conclude.

Exercice 2:

The goal of this exercise is to monitor the evolution of the system health state through some condition indicators applied on vibration data collected by the first accelerometer.

a. Implement five functions that take the vibration signal as an input and compute the five following statistical indicators: peak-to-peak, rms, Kurtosis, crest factor, Skewness. Verify the functions with existing functions in python by comparing both results on an arbitrary signal from the dataset.
b. Gather all the five function in one general function called: **statistical_indicators()** , this function takes as input the vibration signal, and returns five scalars dor the five indicators
c. For each of the 984 record, compute the statistical indicators. Plot these indicators in separate figures with respect to the record time. **Attention: the difference between two records is 10 minutes.**
d. Which of these indicators is sensitive to the fault? Discuss how these indicators evolve with the degradation of the bearing.
e. When the bearing fault starts to appear?

Exercice 3:

In real applications, accelerometers can be mounted far from the faulty component. It is thus interesting to evaluate the ability of this approach to monitor the fault degradation process from other accelerometers. This, the goal of this exercise is to investigate the observability of the fault from the other sensors, which are mounted far from the fault source (bearing 2, 3 and 4). To do so, apply the questions c, d and e in exercise 2 on the three remaining accelerometers. Students must physically interpret the obtained results in terms of detection precocity (when the fault begins?) as well as indicator sensibility to damage.