12th International Workshop on Research and Education in Mechatronics
September 15th – 16th 2011, Kocaeli, Turkey

VIBRATION ANALYSIS BASED LOCALIZED BEARING FAULT DIAGNOSIS UNDER DIFFERENT LOAD CONDITIONS

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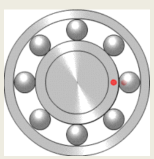
September 16, 2011

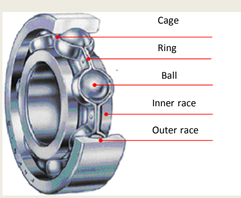
Outline of the presentation

- Bearings
- Motivation
- Predictive maintenance, condition monitoring
- Theoretical information
- Experimental setup
- Experimental results
- Conclusions

Bearing



Bearing allows the motion of the shafts at the desired direction



Bearing basically consist of three parts:
1. Inner race
2. Ball element
3. Outer race

Motivation

- Bearings are used for almost every machine that rotates.
- Rotational forces are very important for motion of machines.
- Bearings reduce the energy losses by providing rolling friction instead of sliding friction at the mechanical and electrical systems.

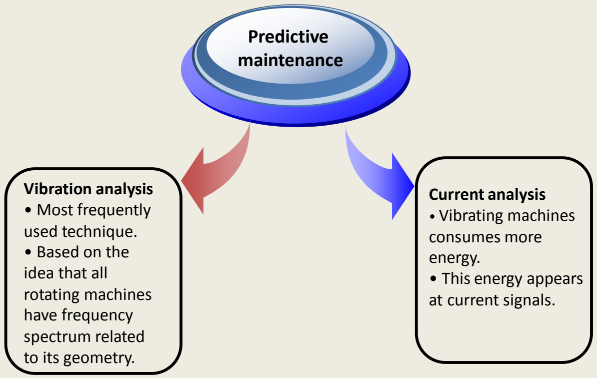
Predictive maintenance

- Predictive maintenance is an important problem for the machining operations having roller bearing elements.
- If the condition of roller element bearing is not monitored and diagnosed in time, the defects occurred on the bearing may lead to
  - catastrophic results on the rotating machining operations, or
  - at least they may cause downtime.

Condition monitoring

- Condition monitoring based on bearing fault diagnosis is necessary to the rotating machinery in automation systems.
- Bearing faults are widely responsible of
  - many loss of production and
  - expense of maintenance in rotational mechanic components.
- The malfunctions are about 40% bearing sourced.

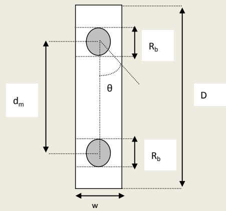
Monitoring techniques



The key points of the study

- For the detection and diagnosis of bearing faults:
  - Frequency analysis
  - Different radial loads
    - 0.4, 0.6, 0.8 bar
  - Shaft-bearing mechanism
    - 2400 rpm
  - Artificially defected bearings:
    - EDM (Electrically Discharge Machining)
    - 0.5 mm (incipient), 1 mm (moderate), 2 mm (severe)
  - Vibration data collected
    - Accelerometer, DAQ card
  - Signal processing with MATLAB
    - Collect, sample, digitize and process on the vibration data
  - High frequency demodulation technique
  - Fault frequency components
    - To determine level of fault and effect of the radial load

Theoretical information



$$BPFO(Hz) = N\frac{f_s}{2}(1-\frac{R_b}{d_m}\cos\theta)$$

$$BPFI(Hz) = N.f_s(1-\frac{1}{2}(1-\frac{R_b}{d_m}\cos\theta))$$

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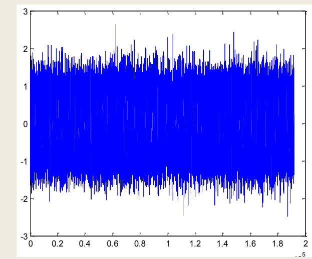
Roller element bearing
D = 52 mm
d_m = 38.95 mm
R_b = 7.895 mm
w = 15 mm
contact angle (θ) = 0º

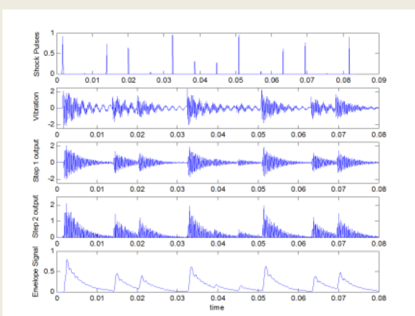
BPFO: Ball Pass Frequency Outer Race
BPFI : Ball Pass Frequency Inner Race
BSF : Ball Spin Frequency
N : number of balls
f_s : revolutions per second of the inner race or the shaft

High Frequency Demodulation

- Demodulation or envelope analysis involves three steps:
  1-) Band Pass Filtering
  2-) Half-wave Rectification
  3-) Low Pass Filtering



Envelope analysis



Shock pulses

Resonance frequency

Band pass filtering

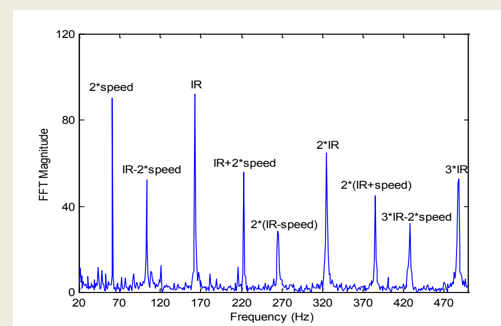
Half wave rectification

Low pass filtering

↓

FFT of the final envelope signal

FFT of the envelope signal

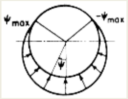


Experimental setup

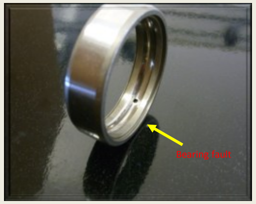
- Bearing shaft mechanism
- AC electric motor
- NI 6211 DAQ card
- Piezotronics accelerometer (PCB 352C65)

Bearing used in the experiments

ORS 6205 polyamide cage groove type radial bearing

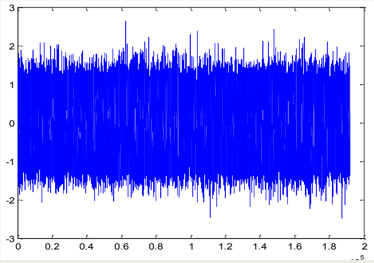


Bearing on the load distribution

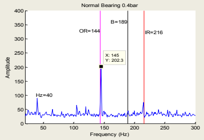


Outer race fault

EXPERIMENTAL RESULTS

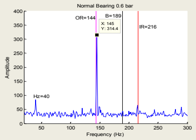


For normal bearing



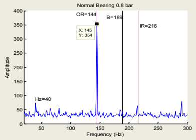
Normal bearing with 0.4 bar radial load

Fault frequency component: 202 Hz



Normal bearing with 0.6 bar radial load

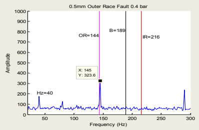
Fault frequency component: 314 Hz



Normal bearing with 0.8 bar radial load

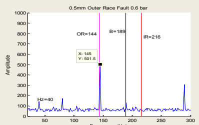
Fault frequency component: 354 Hz

For bearing with 0.5 mm fault (incipient fault)



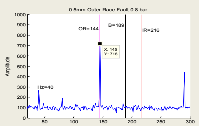
Bearing with 0.5 mm fault under 0.4 bar radial load

Fault frequency component: 324 Hz



Bearing with 0.5 mm fault under 0.6 bar radial load

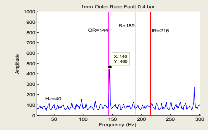
Fault frequency component: 502 Hz



Bearing with 0.5 mm fault under 0.8 bar radial load

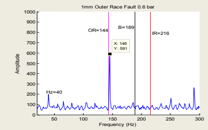
Fault frequency component: 718 Hz

For bearing with 1 mm fault (moderate fault)



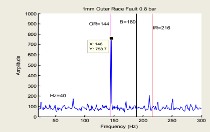
Bearing with 1 mm fault under 0.4 bar radial load

Fault frequency component: 465 Hz



Bearing with 1 mm fault under 0.6 bar radial load

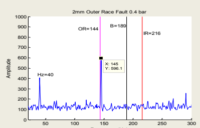
Fault frequency component: 591 Hz



Bearing with 1 mm fault under 0.8 bar radial load

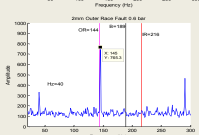
Fault frequency component: 759 Hz

For bearing with 2 mm fault (severe fault)



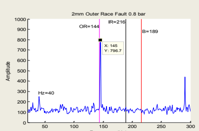
Bearing with 2 mm fault under 0.4 bar radial load

Fault frequency component: 596 Hz



Bearing with 2 mm fault under 0.6 bar radial load

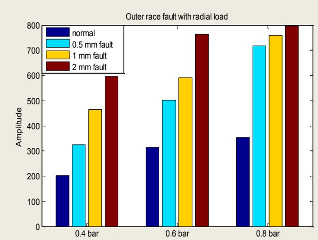
Fault frequency component: 765 Hz



Bearing with 2 mm fault under 0.8 bar radial load

Fault frequency component: 797 Hz

The comparisons of fault frequency amplitudes



Fault frequency components ↑ as the quantity of fault and the radial load ↑

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Conclusions

- As bearing fault size and the radial load increase, the amplitude of the fault frequency components also increases.
- It is possible to determine the level of fault and loading.
- The study presented in this paper can be extended to vibration based condition monitoring of more complex systems.

THANK YOU FOR YOUR ATTENTION