THE UNIVERSITY OF NEW SOUTH WALES
SCHOOL OF MECHANICAL AND MANUFACTURING ENGINEERING

MECH9223 Machine Condition Monitoring

Assignment 2: Diagnostics Project

Due: Wednesday, 18 October 2017, 5pm (Week 12)

1. Rationale

The primary aim of this assignment is to introduce you to machine diagnostic techniques by providing hands-on experience in processing measured vibration signals. The assignment involves the diagnosis of localised rolling element bearing faults using digital envelope analysis.

2. Background Information

The signals to be analysed are time history signals from bearings on a gear test rig. Each student has been allocated a distinct set of data (in the form of MATLAB data files), taken from original measurements made with the three faults, for various speed and load combinations. They are denoted as:

'bg.mat': bearing in good condition (for the particular speed/load situation)

'bf.mat': bearing with a fault (in the outer race, inner race or rolling element) for the same speed/load situation.

The MATLAB files contain two columns for each signal. Column 1 is from an accelerometer near the bearing and column 2 is from a once-per-rev Tacho.

The individual data files will be emailed to the UNSW student email address of each of you, or else provided through Moodle. The harmonic and sideband cursor tools ('harmonics.m' and 'sidebands.m') will be posted on Moodle to allow you to accurately extract the harmonics of the fault frequency and sidebands.

The acceleration signals were scaled in ms^{-2} at the time of downloading. The speed of the shaft in the test rig should be identified by analysing the tacho signal (use the mean time between pulses rather than a frequency spectrum). Note that calculated bearing frequencies may be in error by a few percent because of slip. The sampling frequency of the signals is 48 kHz, and the record length is 100,000 samples for each record. The bearing parameters are as follows:

Ball diameter	d = 7.12 mm
Pitch circle diameter	D = 38.5 mm
No. of rolling elements	n = 12
Contact angle	ϕ = 0°

3. Fault Detection Using Envelope Analysis

The aim of the assignment is to determine the fault in the faulty bearing, for your signal, using the following procedure:

1. First compare the baseband spectrum of the faulty bearing signal to the reference condition. This can be done using the PWELCH command, which forms an average power spectrum from overlapped time records. It is suggested to use a 1024-point transform with a Hamming window and 50% overlap. The comparison can be done on both linear and logarithmic (dB) amplitude scales, to see what difference this makes. It is suggested to make the zero-dB reference equal to 10^{-6}.

2. Demodulate an appropriate band to form the envelope signal for the envelope analysis. This should be a band where a substantial change occurred with respect to the reference spectrum. The demodulation is carried out on the complex spectrum obtained by transforming the whole time record, not on the PSD spectrum, which has reduced resolution and no phase information. You should compare the results from a couple of different bands, and explain your choice of these bands. Note that the valid bandwidth below the anti-aliasing filter is 20 kHz, but it is possible to use the spectra up to about 22 kHz before the filter roll-off becomes too steep. The width of the band to be demodulated should be chosen as at least equal to the required bandwidth of the final envelope spectrum. The latter should contain at least three harmonics of the highest potential bearing fault frequency (i.e., > 3.5 times this spacing). On the other hand, the demodulated band can be broader, but the final envelope spectrum only displayed over a more limited range.
3. The band to be demodulated should be placed in a new buffer with the lowest frequency in the band at zero frequency, and padded with zeros to at least double its size (so that the new sampling frequency is at least double the desired frequency range). Inverse transforming this signal gives a complex (analytic) time signal whose amplitude is the required envelope, and its square the squared envelope. Obtain the amplitude spectrum of this envelope signal and of the squared envelope.
4. Search the envelope spectrum for the suspected bearing fault frequencies (and sideband patterns) using a harmonic/sideband cursor, and make conclusions about the fault. Analyse the envelope signal of the reference signal, for at least one of the frequency bands by way of comparison.

4. Report Content

Your report should identify which of the three fault types corresponds to your data, giving your reasons, and should compare and discuss the results for the envelope and the squared envelope, and for the effect of choice of band, including whether the spectrum comparison should be made on linear or logarithmic amplitude scales.

Following is the suggested report structure:

- *Title / Cover page*
- *Executive summary*: brief summary of project, equipment, diagnostic methodology and major findings and conclusions (max 1 page)
- *Introduction*: project background, relevant literature review, and overall layout of report
- *Experimental setup*: details of equipment being tested, instrumentation and data acquisition
- *Data processing and technical discussion*: use logically organised sub-sections to describe the following. Justify using figures, tables, and plots wherever appropriate.
    - Evaluating bearing fault frequencies
    - Evaluating the speed of the machine
    - Diagnostic methodology used
    - Identifying the frequency range of interest
    - Signal demodulation (minimum two bands)
- *Conclusions and Recommendations*
- *References*
- *Appendix*: attach generated MATLAB code

5. Report Format

All reports must follow the School's standard formatting guidelines (see http://www2.mech.unsw.edu.au/content/userDocs/PresnofAssts.pdf). All reports must be typed on computer only; handwritten reports will not be accepted. The report should be written in 12-point font, with 1.5 line spacing. The report should be a maximum of 25 pages (excluding the cover sheet and Appendix). Any pages exceeding this limit will not be marked. The Appendix should only contain your MATLAB code. All sources must be referenced. Author-Date (Harvard) referencing and Numerical referencing are both acceptable.

6. Report Submission

The report is due on **Wednesday, 18 October 2017 at 5pm (Week 12).** Submission will be accepted up to 11:55pm without incurring a late penalty. Late submissions will incur **a 5 mark penalty per day, accruing at 5pm on each successive day**. **Your report should be submitted electronically as a single Word doc or pdf using the Moodle TurnItIn tool.**

7. Marking Criteria

Your report will be marked out of 30, and will represent 30% of your total grade for the course. This is an individual assignment. Any copied reports will not be marked. The quality of your report writing will determine a significant portion of your grade. Your report writing and format should meet the level of quality expected in industry. You should focus on presenting a moderate amount of information in a clear and concise manner, rather than a large amount of information that is not communicated properly.

The following is a guideline as to how marks will be allocated.

Report/format [10 marks]

- Executive summary
- Introduction
- Brief literature review
- Experimental setup / instrumentation
- Sections and report flow, figure/plot labels, references

Data processing [15 marks]

- Evaluating bearing fault frequencies
- Evaluating the speed of the machine
- Diagnostic procedure
- Spectrum comparison (dB scaled), linear scale
- Signal demodulation - minimum two bands

Correct fault diagnosis, conclusions and recommendations [5 marks]

- Accurate identification of the source of the fault
- Interpreting harmonics and sidebands and linking these to calculated frequencies

Penalties:

- Late submission: 5 marks per day (~17% per day)
- Analysing wrong set of data: 20% (6 marks)

8. Suggested Primary References

Bearing diagnostics lecture notes (Week 6).

Randall, R. B. & Antoni, J. 2011, Rolling element bearing diagnostics--A tutorial, *Mechanical Systems and Signal Processing*, 25, 485-520. (Placed on Moodle)

Phil Howlin
4 September 2017