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Two Stage Helical Gearbox Fault Detection and Diagnosis based on Continuous Wavelet Transformation of Time Synchronous Averaged Vibration Signals

ABSTRACT
- To find reliable symptoms of a fault in a multistage gearbox.
- Explores the use of time synchronous average (TSA) to suppress the noise and Continuous Wavelet Transformation (CWT).
- The results obtained in diagnosis an incipient gear breakage show that fault diagnosis results can be improved by using an appropriate wavelet.

THEORETICAL BACKGROUND
• Continuous Wavelet Transform:
Continuous Wavelet transform is to perform the following equation:

\[ CWT \{ x(t); a, b \} = \int x(t) \psi^*_{a,b}(t) dt \]

Where: \( x(t) \) is the vibration signal, \( a \) is scale (dilation) factor, \( b \) is time location (translation) factor, and \( \psi_{a,b}(t) \) represents the complex conjugate of wavelet function.

• Time Synchronous Averaging:
Assuming a signal \( x(t) \) consists of a periodic signal \( x_r(t) \) and a noisy component \( n(t) \), the period of \( x_r(t) \) is \( T_o \) whose corresponding frequency is \( f_o \). The synchronous average of the signal \( x(t) \) by using TSA can be expressed as:

\[ y(t) = \frac{1}{M} \sum_{i=0}^{M-1} x(t + iT_o) \]

Where \( M \) is the number of average segments and \( y(t) \) is the average signal.

RESULTS
- CWT has been shown to be an effective tool for rotating machinery fault detection and diagnosis.
- TSA allows the noisy components to be removed significantly and hence highlights the fault related impulse components which paves the basis for accurate feature extraction.
- Three types of wavelets: db1, sym2 and coif3 were explored to find the optimal wavelet for separating the small fault.
- The results have shown that wavelet db1 produces the best fault separation whereas the coif3 wavelet fails to do the separation.

FUTURE WORK
- Drive a mathematical model for vibration signal characterisation under healthy and faulty gear condition.
- Validate the modelling results and hence the developed algorithms based upon the experiments data.

TEST FACILITIES AND GEAR FAULTS
- Figure 1 Experimental test rig of gearbox
- Figure 2 Schematic diagram of test rig
- Figure 3 Gear faults: (a) 20% tooth damage (b) 100% tooth damage
- Figure 4 Gear healthy case plot of continuous coefficient map of the test signal
- Figure 5 Gear with one complete tooth removed case plot of continuous coefficient map of the test signal