GEARBOX DAMAGE DIAGNOSIS USING WAVELET TRANSFORM TECHNIQUE

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ABSTRACT: Vibration-based schemes are founded on the assumption that vibration signals from gearboxes measured using accelerometers reflect their condition accurately. This deviant vibration can be attributed to the defects in one or more components of the gearbox. Recently, Wavelet Transform (WT) has been proved to be more suitable for analysis of vibration signals, since most of the time-vibration signals have instantaneous impulse trains and exhibit transient (non-stationary) nature. The aim of this paper is to use an adaptive wavelet filter based on Morlet wavelet applied on the torsional vibration data measured from a single-stage gearbox with artificially induced cracks in the gear. This is done to extract some parameters and check their diagnostic behavior searching for the most potential and appropriate for future health monitoring schemes. The parameters in the Morlet wavelet function are optimized base on the kurtosis maximization principle. The wavelet used is adaptive because the parameters are not fixed. The results demonstrate that the adaptive wavelet filter is found to be very effective in detection of symptoms from vibration signals of a gearbox with early tooth crack. Moreover the influences of crack depth, speed and load on the wavelet entropy are introduced. Multi-hour tests were conducted and recordings were acquired using torsional vibration monitoring. The transitions in the wavelet entropy values with the recording time were highlighted suggesting critical changes in the operation of the gearbox.

EXPERIMENTAL METHDOLOGY

Experimental setup: The test rig setup is consisted of a single-stage gearbox with two helical gears (26 and 64 teeth). A three-phase motor (3 HP, 220 V, 9 A, 50 Hz, 1440 rpm) is the base drive. A short shaft of 20 mm. diameter is attached to the shaft of the motor through a flexible coupling; this is to minimize effects of misalignment and transmission of vibration from motor. The shaft is supported at its ends through two ball bearings and then the motion is transmitted directly to the gearbox. A hydraulic loaded disc brake was used to load the gearbox. The various cracks (defects) are created in the pinion wheels while the mating gear wheel is not disturbed, Two Bruel & Kjaer accelerometers were used for the vibration monitoring both mounted upon the gearbox case, one in each side-axis. The sampling frequency used was 2.00 kHz and signals of 0.50 s duration were recorded. B&K portable and multi-channel PULSE type 3560-B-X05 analyser is used. The B&K PULSE labshop is the measurement software type 7700 is used to analyse the results, while the speed is measured by photo electric probe. Recordings were carried out at constant speed condition and closed windows. The speed range is up to 400 rpm.

RESULTS AND DISCUSSION

Figure 1 shows the signal measured for cracked (faulty) gear in terns of time-domain waveform. No periodic impulses appear on the waveform even though crack may have appeared in the gear already. The periodic impulses of crack was hidden in the signal. **Fig. 2** shows the largest kurtosis's value . which is 7.75 at β =0.5 and the scale value equals to 2.0. To illustrate the sensitivity of the kurtosis as a function of β , the value of scale a was fixed to be 2.0 and plot the kurtosis- β relationship, which follows that the kurtosis is very sensitive to the value of β. The filtering result with the Morlet optimized wavelet filter (β = 0,5 and a = 2) based on equation 14 and is shown in **Fig. 3**. Periodic impulses are obvious in **Fig. 3**. Since the number of samples are 2048 with the time considered is 500 ms, the perriodic is just about 0.150 s. On the other hand, the meshing natural frequency is 426 Hz. To demonstrate the efficiency of the proposed adaptive wavelet fillter, three other values of parameters a and β corresponding to relative large kurtosis are selected to produce three different wavelet filters. The first set of parameters values is a = 8 and β = 0.25 and the corresponding kurtosis value is equal to 5.45. The second set of parameters values is a = 8 and β =0.5 and the corresponding kurtosis value is equal to 5.95. The third set of parameters values is a = 4 and β =0.5 and the corresponding kurtosis value is equal to 4.68. The results with these wavelet filters are shown in **Fig. 3**. There is still heavey noise in the waveforms, while the kurtosis values are changed from set to another and the number of impulses are also changed. This shows that the wavelet filter obtained with the largest kurtosis value provides the best filtering results.

Where the wavelet entropy is calculated based on equations 2 to 5. The results in these figures display that the increase of speed is accomplished by an decrease in wavelet entropy, while the increase in either the load or crack depth is occupied by an increase of wavelet entropy. **Fig. 4** depicts the evaluation **of** wavelet entropy parameter with respect of testing time ranged from 0.0 min to 360 min. To assist the more accurate observation of this parameter evaluation during the range of testing time, a magnification was seen in the **Fig. 4**, where the first transition period is obtained at the end of testing time near 165 min, while the second transition period is observed from 165 to 360 min. These transition periods are important and possess diagnostic value as they can be used to define and characterize critical changes of the gears damage accumulation and evaluation.

CONCLUSIONS

1- In non-stationary vibration waveform feature and in the process of feature extraction. An adaptive Morlet wavelet filter based on the kurtosis maximisation is proposed to detect periodic impulses automatically for recognition of gear tooth crack.

2- the increase of speed is accomplished by an decrease in wavelet entropy, while the increase in either the load or crack depth is occupied by an increase of wavelet entropy. Moreover, these results are important and possess diagnostic value as they can be used to define and characterize critical changes of the gears damage accumulation and evaluation.

3- The transitions in the wavelet entropy values with the recording time were highlighted suggesting critical changes in the operation of the gearbox.

Reference:

1-Wang, D., Miao, Q. and Kang, R." Robust health evaluation of gearbox subject to tooth failure with wavelet decomposition" Journal of Sound and Vibration 324, pp. 1141-1157, 2009.

2-Burrus,C. S., Gopinath, R. A. and Guo, H." Introduction to wavelets and wavelet transforms" A Primer , Prentice Hall, NJ., 1997.

3-Wang, D., Miao, Q. and Kang, R." Robust health evaluation of gearbox subject to tooth failure with wavelet decomposition" Journal of Sound and Vibration 324, pp. 1141-1157, 2009.

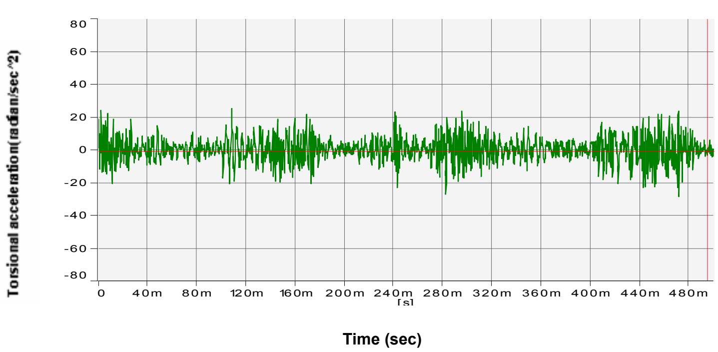

Fig. 1 Time history of torsional vibration

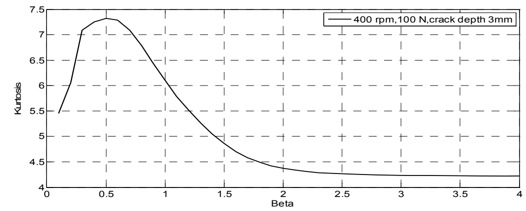

Fig. 2 kurtosis as function of beta (β)

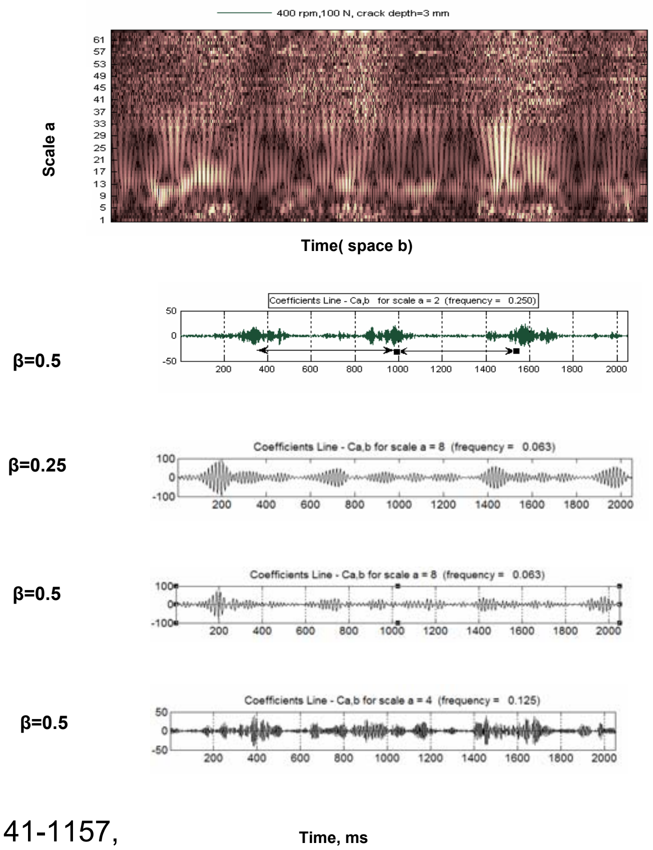

Fig. 3 Wavelet analysis of torsional acceleration for faulty (cracked) gear using optimized wavelet filter

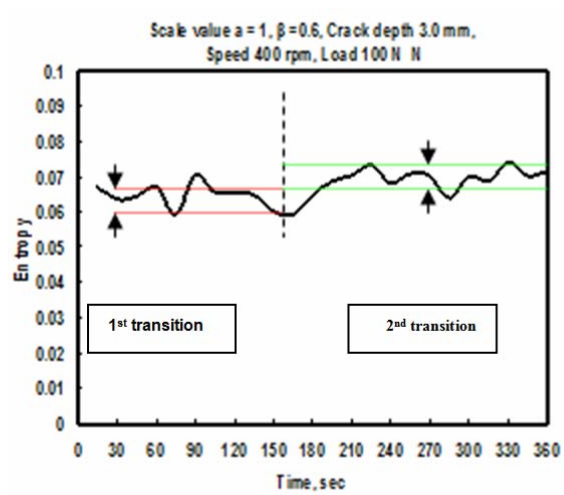

Fig. 4 Relationship between Wavelet entropy and testing time