ON THE NEED OF THE WAVELET ANALYSIS FOR FATIGUE CONDITION MONITORING

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Abstract: Wavelet analysis has attracted attention for its ability to analyse rapidly changing transient signals. Based on that capability, it was then used in this study to detect high amplitude of strain signal of the coil spring. The signals were recorded at two different road profiles that are paved road and unpaved road. Wavelet analysis was then performed in order to obtain wavelet transform representation for each of the road. Fatigue damage assessment will be used to verify this finding. The obtained result shows that the time of peaks occurrence in wavelet transform representation are in line with the time of the high amplitude strain occurrence. It is true for all types of signal. It is also verified with the value of the fatigue damage. It is noticed that the value of the fatigue damage is higher at the similar time frame. The finding indicates that the wavelet analysis can be used as an alternative method for the fatigue condition monitoring cases.

Keywords: Strain signal; high amplitude; wavelet; fatigue damage; condition monitoring

1 INTRODUCTION

Currently, there are many conventional methods for faults identifying and diagnosis. Based on the representation of a signal during its processing, a method can be referred to as time-domain or frequency-domain [1].

Time domain methods are usually sensitive to impulsive oscillations. Characteristics arising from the defects being monitored, also known as features, of the raw time signal can be extracted from a machine. Typical features are the r.m.s. value, peak value, crest factor, kurtosis and the shape, size and orientation of a bearing locus derived from orbital analysis [2]. These features, once established to be related to the defect being monitored, often yield satisfactory results. However, if the signal generation mechanism is complex, time-domain methods are often not refined enough.

Frequency domain methods assume that the signal being analyzed has components that are periodic. Thus, a defect produces a periodic signal at the characteristic defect frequency. Examples of the frequency-domain methods include spectrum analysis, cepstrum analysis, high frequency resonance technique (HFRT) and holospectrum [3]. Among them, spectrum analysis seems to dominate the fault diagnosis scene. The main limitation of spectrum analysis is that although a local transient will contribute towards the overall frequency spectrum, its location on the time axis is lost. There is no way of knowing whether a particular frequency component exists throughout the life of the time signal or during just one or a few selected periods. Unfortunately, many monitoring situations demand knowledge of not just the frequency composition of a transient but also its time of occurrence [4].For instance, the coil spring will generates a transient signal when it is driven over a pithole or bump compared to the smooth surfaces. That situation will be detected in the measured time domain signal.

The continuous wavelet transform (CWT), a joint time- and frequency-domain technique, is proposed in this paper. CWT is capable of indicating abrupt changes in structure or system conditions [5]. In addition, it can give a better representation of the signal than conventional methods, providing fuller information on the machine operating condition. CWT is used here to produce a 3-D image from the measured signal.

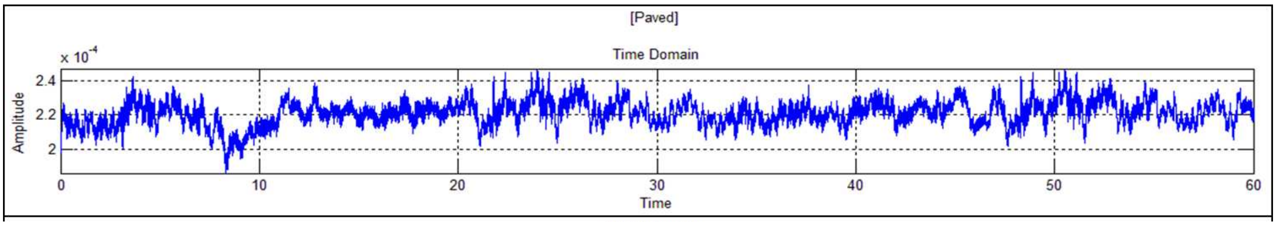
CWT of a time series is defined as [6]

$$F_{\Psi}(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} f(t)\Psi\left(\frac{t-b}{a}\right)dt \tag{1}$$

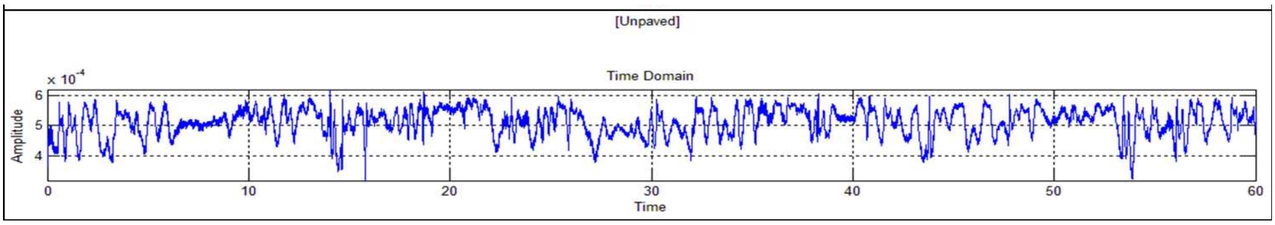
The quantity $\Psi_{a,b}(t)=\frac{1}{\sqrt{a}}\Psi\left(\frac{t-b}{a}\right)$ is referred to as the wavelet function. The position variable *b* shifts the wavelet function along the time axis *t* of *f(t)*while the scale variable *a* expands or compresses the wavelet function $\Psi_{a,b}(t)$. Compared to Fourier transform, the scale variable *a* is equivalent to the inverse of the frequency. The definition also suggests that $F_{\Psi}(a,b)$ is the correlation coefficient between the wavelet function $\Psi_{a,b}(t)$ and the time signal *f(t)* at the scale *a* and position *b* of $\Psi_{a,b}(t)$.

2 METHODOLOGY

The continuous wavelet transform was applied to the strain signals from two different road profiles that are paved and unpaved road. Samples of these signals are shown in Fig. 1a and 1b, respectively. Different types of road profile give different strain amplitude to the coil spring. Compared to unpaved road, paved road have smoother road surfaces. Thus, unpaved road exhibit higher amplitude rather than paved road. It is measured by using 1mm size of strain gauge which is fixed at a coil spring (refer to Fig 2). The strain signal was recorded in 60 seconds length and it was sampled at 500 Hz. Then the analysis was preceded with fatigue damage analysis in order to validate the obtained result from the wavelet analysis. This analysis was used the similar input signal for wavelet analysis.



(a)



(b)

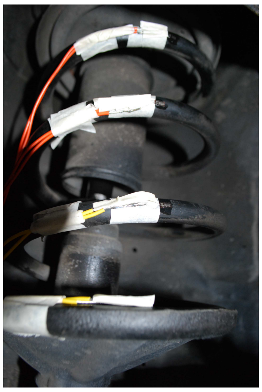


Fig. 2 1 mm size of strain gauge was used to record the strain signal.

3 RESULT AND DISCUSSIONS

The measured strain signals were then analysed using continuous wavelet transform (CWT). The wavelet transform representation for unpaved road can be seen in Fig. 3b. It shows that the transient or high amplitude event of the strain signal can be detected using wavelet analysis. Based on Fig. 3a, the signal contains high amplitude approximately at 14s, 19s, 54s and 56s. These high amplitudes were also detected in the wavelet analysis at the similar time frame occurrence. The values of the frequency for these high amplitudes were also provided. It seems that high amplitudes occur at frequency ranges from 40Hz to

90Hz. This indicates that the wavelet analysis is a good tool to monitor the condition of the structure due to fatigue failure since high amplitude strain will contribute to the fatigue damage.

Fatigue damage assessment has been performed in order to proof the result obtained from the wavelet analysis. The fatigue damage values were plotted against time. Based on Fig. 3c, the fatigue damage values were noticed going higher at the higher amplitude value that is $7.5\text{x}10^{-4}$ at 14s recorded time. The same case goes with 19s, 54s and 56s. They exhibit higher fatigue damage values compared to the other time occurrence. Another example of the analysis can be referred to Fig. 4 for paved road. The time occurrence of the high amplitude also detected in the wavelet transform representation and was proved by the existing of the high value of the fatigue damage.

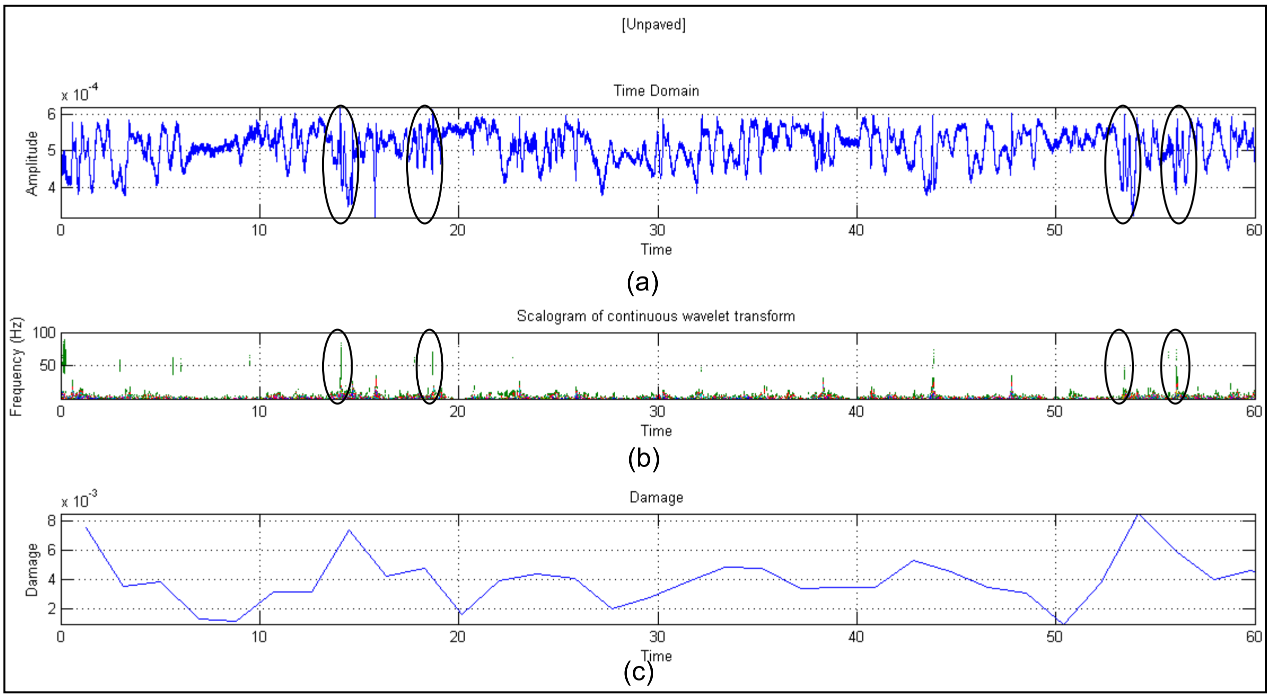


Fig. 3 a) Time domain signal for unpaved road, b) wavelet transform representation and c) fatigue damage value

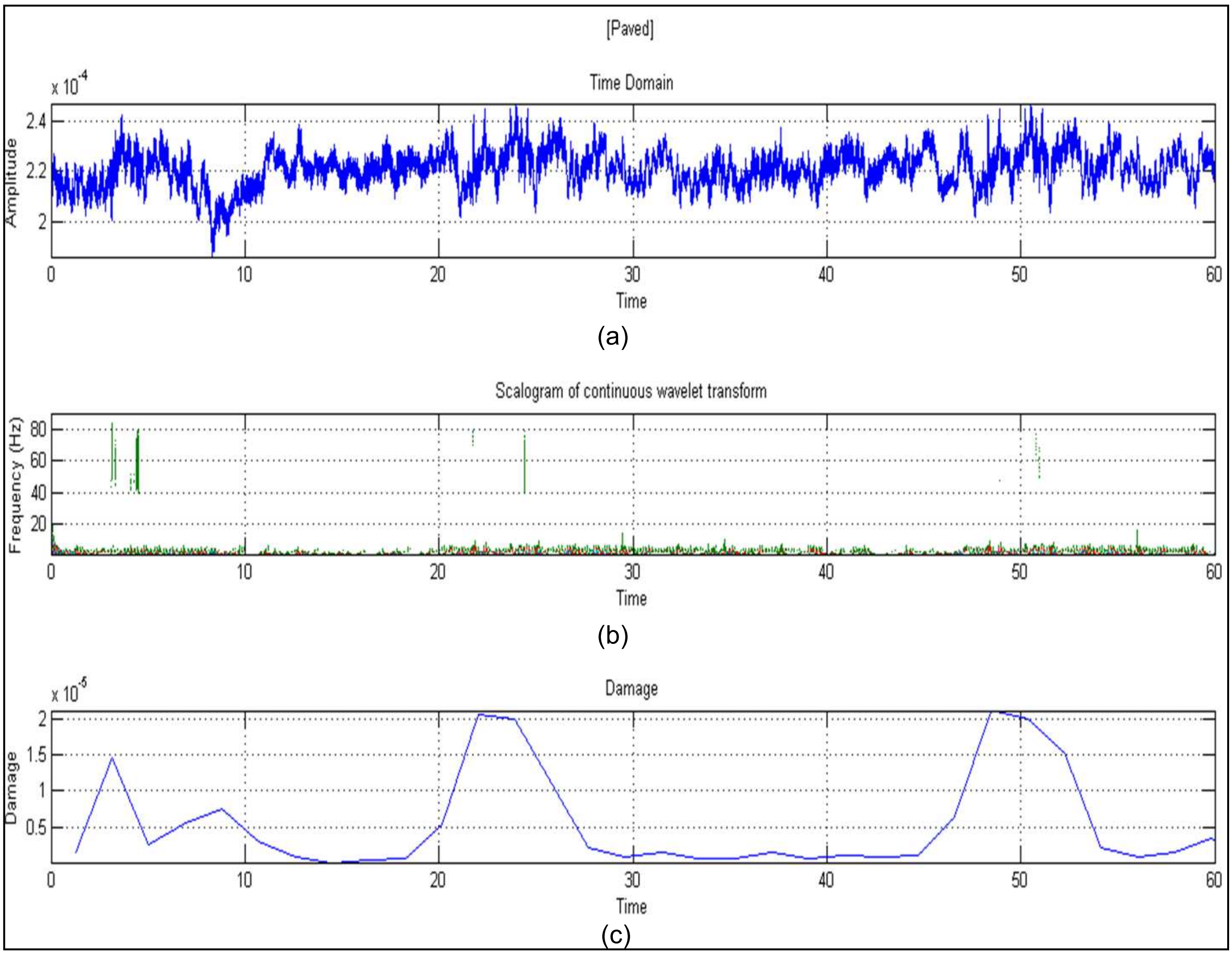


Fig. 4 a) Time domain signal for paved road, b) wavelet transform representation and c) fatigue damage value

4 CONCLUSIONS

Continuous wavelet transform was used to detect high amplitude strain signal. It is really important in monitoring condition due to fact the high amplitude strain will contribute to the fatigue damage. Fatigue damage assessment plays a vital role in supporting the obtained results.

5 ACKNOWLEDGEMENTS

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