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Fatigue Data Extraction Analysis Using Daubechies Wavelet Transform

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ABSTRACT

Daubechies wavelet transform (DWT) is a one of members in wavelet transform family. Wavelet transform (WT) have ability in vibrational analysis in fault detection. In this study, the ability of *Daubechies* wavelet transform in high amplitude events detection and fatigue data extraction based on wavelet coefficients were applied. DWT represents by the form of 4th order *Daubechies* wavelet (Db4) was used in this analysis. The analysis start with coefficients plot using the time-scale representation that associated to energy coefficients plot for the input value in fatigue data extraction. Three extraction levels were used based on cutting limit from L=1 to L= 3. From the results it shows that, when the cutting limit were increase from L=1 to L=3, It create the shorter signal which is L=1, 31.74%, L=2, 51.38% and L3, 52.37% shorter from the original signal.

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INTRODUCTION

In service life of components in automotive industry were experiences with the significant load that lead to the displacement and contribute to the mechanical failure (Abdullah, S., 2007). Both of the strain and vibration signals are vital parameters in order to achieve the higher of vehicle in term of ride comfort and resistant to the high load (Shengyao, J., 2010). The DWT analysis is commonly used for vibrational diagnostic and fault detection and it is new for fatigue data analysis. The WT can give better observation for non-stationary data and it is also known to be effective in the detection of a low frequency signal (Stazewski, W.J., 1998). The ability of WT in this study is initiated by the high amplitude events identification and extraction based on wavelet coefficients and energy.

Oh (2001) previously have been carried out of fatigue data analysis using the wavelet transform (WT) for spike removal, denoising and data editing. Abdullah (Abdullah, S., 2007) used the wavelet bump extraction method in order to extract high amplitude events for producing a mission signal with shorter time length while retaining the damage value as its original. Similarities of these two studies were using the discrete wavelet transform (DWT) by both authors which is the *Daubechies* wavelet (Db).

Thus, those studies indicated that DWT were suitable to use in fatigue data editing in order to shorter the time. It has generated interest to study the fatigue data analysis using WT in order to see the capability of this wavelet in data extraction. The objective of this study is to extract fatigue data based on wavelet energy coefficients using Db4. The total small amplitude cycles that have been removed using the extraction give the shortened signal.

MATERIALS AND METHODS

For the validation purposes of the applicable of using the above approaches, the time history or a strain signal were used for the data collection purposes. The SAESUS fatigue load time history used in this study was collected from a lower suspension arm of automobile. This data was developed by the society of automotive engineers (SAE). This signal exhibits the variable amplitude pattern which was sampled at 204.8 Hz for 25,061 data points and 122.4 s time as shown in Figure 1. The plot of time history signal presented with x-axis represents the time of the signal and the y-axis represents the amplitude of the signal. The obtained strain signals were analyzed with related coefficients plot using the time-scale representation that associated to energy coefficients plot for the input values in fatigue data extraction.

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The extraction process for producing a shorter signal involved the value of energy coefficients plots for Db4. The limit for each extraction is based on the maximum and the minimum values of energy coefficients. The cutting limit (*cl*) for the extraction procedure is given by

$$cl = \left(\frac{\max E - \min E}{100} \right) L + \min E$$

where E is energy coefficients value, L variable value, L = 1, 2, 3,… In this analysis, the *cl* value is calculated for L=1 to L = 3.

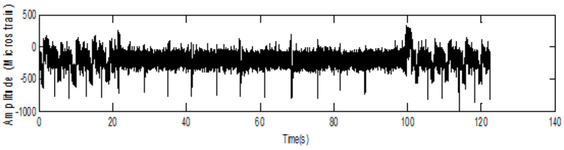

Fig. 1: The time history plot of SAESUS.

RESULT AND DISCUSSION

A wavelet based editing signal used in this study starts with analysing the signal into discrete wavelet environment using Matlab software. A wavelet analysis started with the calculation of the wavelet coefficients, as shown in Figure 2(a), presenting the scalogram plots using the Db4 wavelet. The intensity of colors spectrum is proportional to the absolute wavelet coefficients values as it provides the energy distribution display with respect to the time and frequency.

From the scalogram, a lower scale at higher frequency and small amplitude means that the cycles of the signal had a lower energy and gave the small or no fatigue damage potential. A large scale was indicative of low frequency and higher amplitude indicates that the cycles had a higher energy which means can causing the fatigue damage. Figure 2(b) shows the energy-based distribution plots using Db4 wavelet and it was observed that high amplitude features detected from the related coefficients. Obviously, the lower frequency indicates a higher magnitude distribution and the lower magnitude distribution presents a higher frequency events.

Figure 3 shows, the plot of the edited signal produced from this wavelet based fatigue data editing. The extraction at L = 1 for the Db4 wavelet shorter the signal 31.74% from the original signal. The extraction at L = 2 for the Db4 wavelet give the signal shorter 51.38% from the original signal. The last is L=3 give the signal shorter 52.37% from the original signal. The total a small amplitude cycles that have been removed using the extraction of L = 3 is higher than L= 2 and L= 1.

With respect to this approach, the applicability of fatigue data editing using Db4 wavelet method was proven for the situation to shorten the signal length. The energy spectrum showed relatively adequate of high amplitude events in the fatigue signal and was a very useful tool for damage detection in the fatigue signal. The extraction of fatigue high amplitude events successfully remove the lower energy cycles in the time history and created a new edited signal.

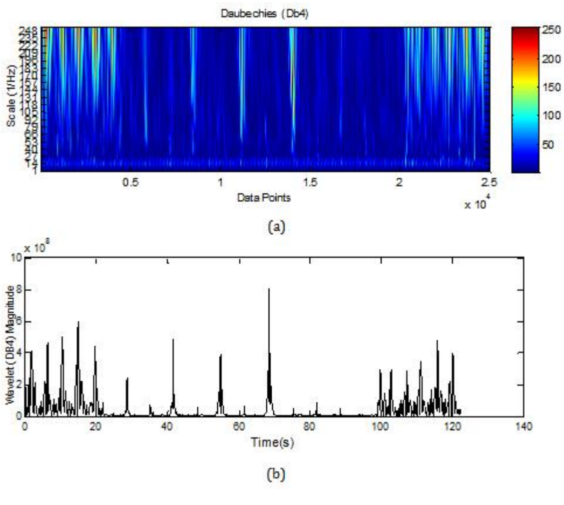

Fig. 2: (a) The Db4 scalogram plots, (b) the Db4 energy coefficients plots.

Conclusion:

This paper discussed on the fatigue data analysis using of DWT wavelet. The DWT is represented by the 4th order *Daubechies* wavelet (Db4) family. The analysis were conducted in the discrete wavelet environment and using the extraction algorithm. The obtained results indicated that Db4 has an ability to extract the fatigue

Australian Journal of Basic and Applied Sciences, 8(19) Special 2014, Pages: 38-40

data in order to shorten the signal. From the results it shows that when the cutting limit were increase from L=1 to L=3, create the shorter signal which is L=1, 31.74%, L=2, 51.38% and L3, 52.37% shorter from the original signal. It can be concluded that Db4 can be used for fatigue data extraction since it's the ability to remove low amplitude cycles from original signal.

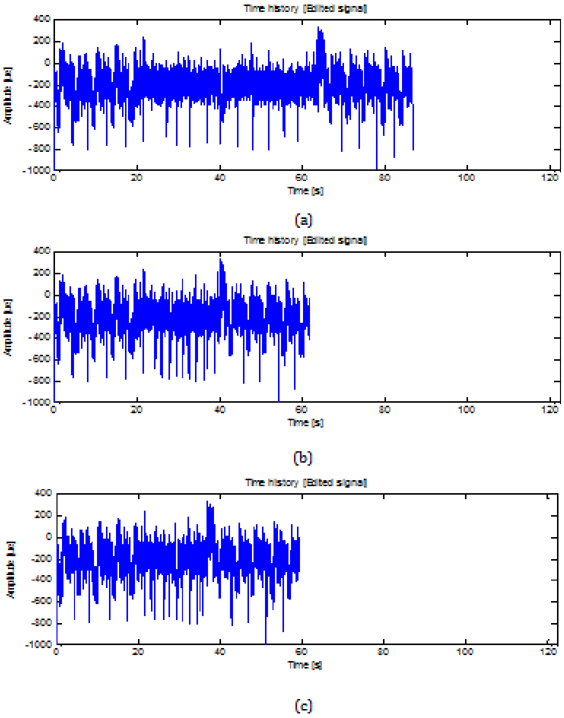

Fig. 3: The edited signal using The Db4 wavelet (a) L= 1, (b) L= 2 and (c) L= 3.

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