VIBRATION SIGNAL ANALYSIS OF A MOTORCYCLE

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ABSTRACT: Nowadays, the motorcycle is becoming widely popular because of their swiftness and conveniences in crowded cities. It is considered the most popular choice in various aspects of transportation in the urban area. When starting and accelerating the engine, it has been found that there was a vibration throughout all parts of the motorcycle. If the driver perceives more vibration, he will feel more uncomfortable. Consequently, the researcher conducted a study of the vibration signal sent through four core points which are the contacts between driver or rider and the motorcycle body including motorcycle left hand, seat, left front footrest, and left rear footrest. The specimen motorcycle is Honda Wave 100s model. The comparison results have been performed by using two parameters of averaged peak and averaged energy of the vibrational signal. The results reveal that the left front footrest has the highest vibration level in both parameters, while the seat has the lowest vibration level. Last but not least, it can be concluded that the mechanical structure of the motorcycle must be developed by considering the engine's vibration sent through all parts especially the position of front footrest which has the highest impact in order to increase the driver's comfort at the highest satisfaction.

Keywords: Engine vibration, Vibration signal, Motorcycle, Averaged peak of the vibration signal, Averaged energy of vibration signal

1. INTRODUCTION

In the present days, motorcycles play an important role in transportation in modern and crowded towns, especially in the capital cities. Their swiftness and economical cost make a number of people turn to use them more and more. One of the reasons to choose a motorcycle of motorcyclist and stackers is its convenience. The feelings of users to the motorcycle seat, hands, and footrests are significant factors that are inevitably considered [1, 2]. These interface positions are affected by the vibrations of its engine and adjacent environments.

The vibration of a motorcycle occurs mainly when the engine starts. The acceleration of the engine reinforces the additional vibration to the motorcycle body. The analysis of the vibration signal has been developed for years in many fields of studies. Distinguishing signal components and its major attributions can be accurately accomplished [3, 4]. Consequently, the concept of signal analysis technique is applied to analyze the vibration of the motorcycle at the important positions in this study.

The experimental procedure has been designed and the HONDA WAVE 100s model has been selected as an instance because of its popularity in Thailand. The positions of the left hand, seat cushion, left front footrest, and left rear footrest, are the four targets to measure the vibration transmitted from its engine. The engine is set to run at five different speeds of 2,000 rpm, 2,500 rpm, 3,000 rpm, 3,500 rpm, and 4,000 rpm. The measurement of vibration signals has been using an accelerometer passing through its corresponding base station. Subsequently, the measured signals are analyzed using some selected signal processing techniques. A couple of main parameters of averaged peak and averaged energy of the vibrational signal are calculated and discussed afterward. The comparative analysis is therefore performed, and the conclusions are finally summarized accordingly.

2. MATERIAL AND METHODS

The introduction of some basic related information of engine vibration and corresponding proposed parameters which are applied to indicate the condition of the machine has been conducted as follows.

2.1 Engine Vibration

Basically, vibration is the phenomenon of back and forth motion of an object under a mechanical force. The engine vibrations are an integral sum of every mechanically moving component on the motorcycle body [5-7]. These vibrations in motorcycle engines are a result of periodic and aperiodic oscillations caused about an equilibrium point. These things are not wanted; however, it has inevitably happened. Therefore, the appropriate thing to do is to limit the size of these vibrations.
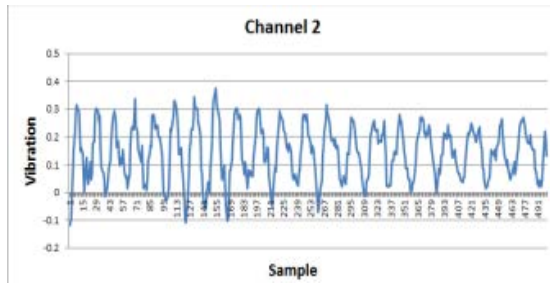
Fig. 1 An example of motorcycle engine vibration signal with a semi-periodic waveform

The core amplitudes and frequencies of the vibration signals should be adequately and properly analyzed. This related information will benefit the mechanical designer to reduce these effects.

2.2 Averaged Power of Vibration Signal

The averaged value of the power of the vibration signal is calculated from the database. This signal attribute has been performed by adopting from the conventional speech processing. Preliminarily, a number of powerful techniques of speech signal processing have been adopted to analyze the engine vibration [8,9]. The state-of-the-art discrete Fourier transform technique which used to extract the spectrum of speech has been exploited. Another technique of quefrency domain conversion has been reviewed. In other words, the cepstrum analysis which used to decompose the speech ingredients has been investigated. Moreover, the autocorrelation technique has been applied to extract the fundamental frequency of the signal. The formant frequencies have also been studied earlier. The zero-crossing rate of the speech waveform has also been explored and adopted. However, there is no significant success from using these mentioned approaches [10-14]. Consequently, one explicit basic technique of power calculation that is successful in the analysis of engine vibration has been selected in this study [15-16].

The power of signal calculated for engine vibration is essentially applied in this study due to its simplicity and fast implementation. The signal power is an amount of energy consumed per unit of time. This quantity is very useful to describe the signal which its energy goes to infinity where this engine vibration can be assumed to be not-squarely-summable as long as the engine does not stop running. Basically, the signal attribute is very meaningful to present the energy of the signal in a period of time. The energy of the engine-running vibration signal often goes to infinity in accordance with the previous constraint. The calculation of the power of the signal is defined by using the sum of
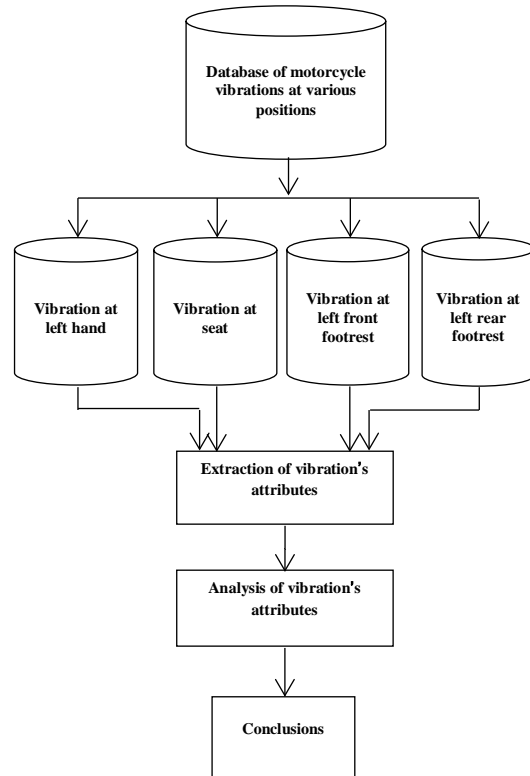

Fig. 2 Experimental Procedure

Fig. 3 Experimental allocation of accelerometers over the specimen motorcycle; (1) left hand, (2) seat, (3) left front footrest, and (4) left rear footrest.

the square of the signal samples [17-19]. Mathematically, the averaged power of an aperiodic sequence x[n] is defined as the following equation.

$$Px = \lim_{K \to \infty} \frac{1}{2K+1} \sum_{n=-K}^{K} |x[n]|^2 \qquad (1)$$

where K is the sequence half-length which extends its limit of the number of samples to infinity. However, in the practical experiment, the extension has been limited to the physical length of the corresponding signal.

2.3 Averaged Peak of Vibration Signal

The averaged value of peaks of the vibration signal is calculated from the database in addition to the power of the engine vibration signal described in the previous section. The averaged peak of the signal is defined as the averaging amount calculated from a number of peak values of periodic or semi-periodic signals existing in a unit of time [20]. Since the engine vibration is characterized as a semi-periodic signal as depicted in Fig.1, the averaged peak of the signal is selected in this study. This attribute is calculated to compare with the power of engine vibration signal for all experimental conditions as explained in the next section.

3. EXPERIMENTAL DESIGNS

To achieve the objective of this study, the experimental procedure has been conducted as depicted in Fig. 2. The database of motorcycle vibrations at various positions is implemented. Subsequently, the distinction of motorcycle vibrations at all four points is conducted. Thereafter, the extraction of vibration's attributes of averaged power of vibration signal and averaged a peak of the vibration signal as mentioned in the previous section has been performed. An analysis of these vibration's attributes has been done comparatively. At the end of the procedure, the conclusions have been summarized accordingly.

In the experiment, the widely well-known motorcycle of Honda Wave 100s model is selected as a specimen. The accelerometers are attached at four core points which are the contact points between driver or rider and the motorcycle body including motorcycle left hand, seat, left front footrest, and left rear footrest as depicted in Fig. 3. These engine vibration signals are measured in the form of acceleration by these accelerometers and recorded by the G-link microstrain serial base station through a host computer. The vibration signal is in the form of an approximate periodic sequence which is assumed to be a power signal with a finite average power [15-16]. The equation (1) has been adapted with a specific length of a sample recorded in 10 iterations. The duration of 10 seconds for each sample at the sampling rate of 2,048 Hz is recorded for all five various levels of engine speeds of 2,000, 2,500, 3,000, 3,500, and 4,000 rpm, respectively.

The root sum square of the accelerations of all three x-y-z directions is calculated from the measured values of vibration signals. The equally-divided sections of the root sum square values are therefore provided for all experiments.
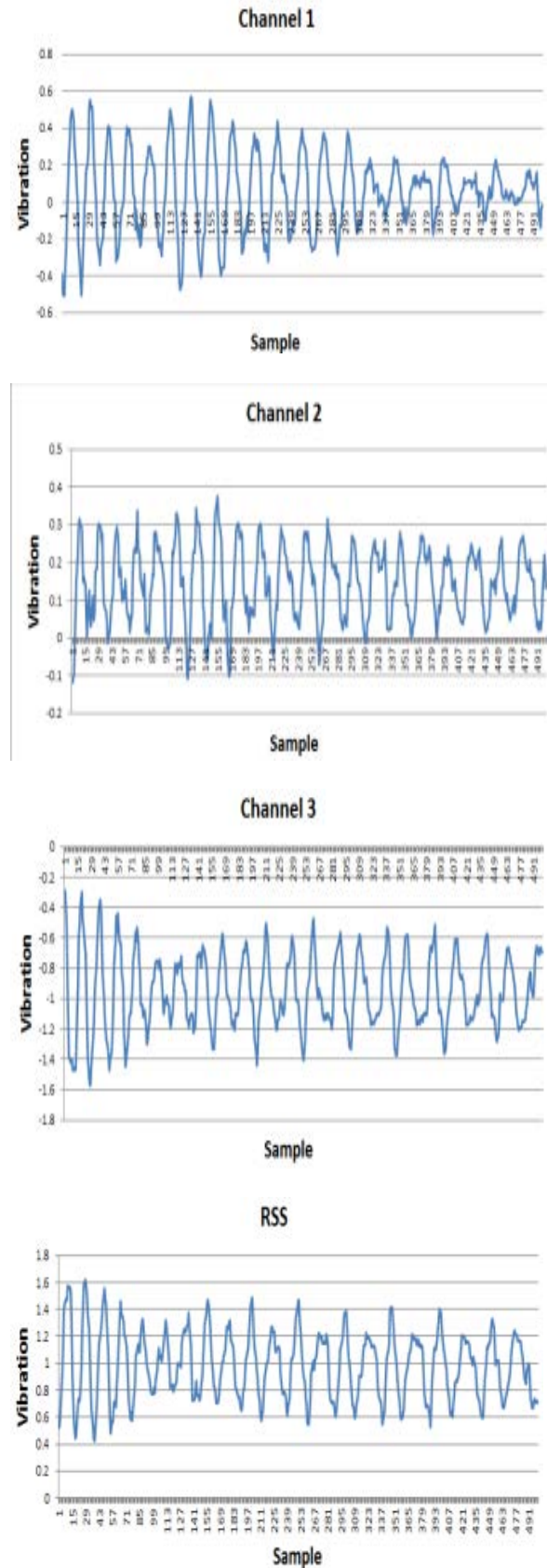

Fig. 4 Some examples of motorcycle engine vibration signals at left hand with the engine speed of 2,000 rpm.
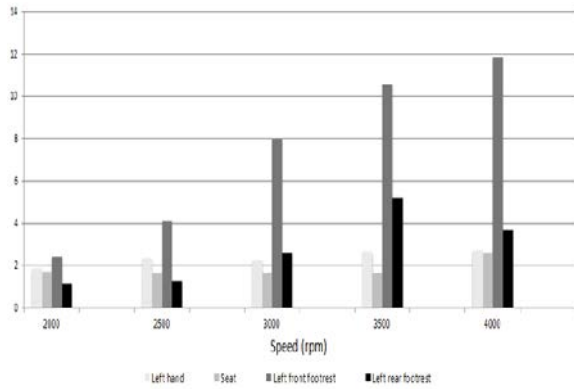
Fig. 5   Comparison of the averaged peak of the vibration signal for four core contacting points including motorcycle left hand, seat, left front footrest and left rear footrest at five different engine speeds from 2000-4000 rpm.
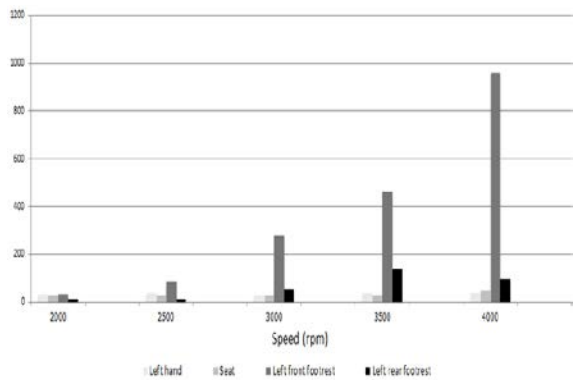

Fig. 6   Comparison of the averaged power of the vibration signal for four core contacting points including motorcycle left hand, seat, left front footrest and left rear footrest at five different engine speeds from 2000-4000 rpm.

Subsequently, the extraction of vibration's attributes of averaged power of the vibration signal as mentioned in the previous section has been conducted [18-19]. Moreover, the averaged peak of the vibration signal is also extracted with the same conditions [20].

4. EXPERIMENTAL RESULTS

Preliminarily, the experimental results of the values of vibration signals are obtained from the accelerometer measurement. A number of portions of motorcycle engine vibration signals at its left hand with the engine speed of 2,000 rpm are presented in Fig. 4. By observing the physical shapes and trends of all database vibration signals, most of the experimental graphs insist the semi-periodicity which reflects from the working periodic cycle of ignition inside the engine and the

corresponding effects of surrounding environments. This concrete evidence reinforces the two proposed parameters which are appropriate for the signal waveforms with periodicity property.

In the second stage, the vibration's attributes of averaged power of vibration signal and averaged peak of the vibration signal are extracted and plotted in a comparative way with different engine speeds as depicted in Figs. 5 and 6 by using the values of vibration signals from the database as mentioned earlier. It can be explicitly noticed from Figs. 5 and 6 that when the engine speed is increased, the averaged power of vibration signal and averaged peak of the vibration signal are in upward trends for nearly most of the positions of the accelerometers. When comparing among the positions of the sensors, both of the vibration's attributes of the seat are mostly lowest, meanwhile, those of the left front footrest are at the highest levels. Moreover, at the high engine speeds from 3000-4000 rpm, it can be observed that the second and third highest levels are those of the left rear footrest and the left hand, respectively.

From the observation of Figs. 5 and 6, at the lower engine speeds from 2000-2500 rpm, the lowest is of that of the left rear footrest, then the second lowest is of that of the seat. It was obviously observed that both of the attributes of left front foot are at the highest levels. The concrete reason is that this position is closest to the motorcycle engine. The vibration is sent directly through the body structure of the motorcycle with the shortest distance. On the other hand, the attributes of the seat position are mostly minimal. A concrete reason is that it is in furthest distance from the engine. Moreover, a supporting reason is that the sponge stuffed within the seat serves as a vibration absorber.

5. CONCLUSIONS

The vibration of a motorcycle at four different positions of its body where the driver or rider perceives from the motorcycle has been studied in this study. The vibration has been transferred from the working engine and all surrounding environments. In this experiment, a study of the vibration signal sent through four core points has been performed. These points are the contacts between driver or rider and the body of the specimen motorcycle body including motorcycle left hand, seat, left front footrest, and left rear footrest. The selected motorcycle which is used in this experiment is the Honda Wave 100s model. Calculation of two parameters of averaged peak and averaged energy of the vibrational signal has been conducted in a comparative way. The experimental

results showed that when the engine speed is increased, the averaged power of vibration signal and averaged peak of the vibration signal are in upward trends for nearly most of the positions of the accelerometers. By comparing among all positions, both of the attributes of the seat are mostly in the lowest levels, meanwhile, those of the left front footrest are at the highest levels. From the experimental findings, it is obviously summarized that the mechanical structure of the motorcycle body should be developed by considering the engine's vibration sent through all parts in order to improve the comfortable perception of the motorcycle users.

6. ACKNOWLEDGMENTS

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