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Vibration Analysis of Electronic Baby Hammock

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ABSTRACT.
Babies love being rocked to sleep in the baby hammock. The natural link between rocking and sleep is related to the frequency and amplitude. A clinical study has shown the optimum best rock to put a baby to sleep has an amplitude of 60mm and frequency of 0.55Hz. However, there is no depth study concerning on this topic. This paper covers the vibration analysis in terms of frequency and amplitude on the commercial electronic baby hammock. Vibration analysis of the weight from 3kg to 16kg is conducted. For each measurement, four conditions are considered: manual rocking, auto rocking with low, medium and high speed. From vibration analysis, the results indicated the auto rocking and manual rocking produce the dominant frequency from 1.1Hz to 1.4 Hz which is beyond 0.55Hz. These frequencies are not recommended since it might affect the babies' brain development and growth. In the other hand, the results show that the corresponding amplitude of the respective dominant frequency is below 60mm. None of the measurements meet the optimum level of frequency and amplitude. Hence, further actions and improvements on the evaluation of safety (in terms of vibration) on electronic baby hammock are needed.

Introduction

The Malaysian and Singaporean's baby cradle is very similar to the hammock and it is well known as '*buaian*' or '*sarung*'. It is a cloth hammock fashioned from traditional batik or cotton fabrics which is attached to a spring and strung up on the ceiling beams or rack. The soft fabric that is suspended around the baby will naturally mound to the baby shape, making them fit snug and comfortable. By employing a gentle horizontal rocking motion, the babies fall asleep easily. Pederson (1969) has shown that the horizontal rocking is more effective as a soother than vertical rocking. Even today, many Malaysian babies and toddlers are still being rocked to sleep using this traditional hammock.

Studies have been carried on the effect of rocking on a baby and concluded that baby sleeps better while being rocked or swung lightly (Pederson, 1969; Bayer *et al.*, 2011). This is because the rhythmic movement mimics the gentle rocking they felt while in the mother's womb (Barnard, 1972). The gentle rocking makes babies feel safe and comfortable thus ensuring that they sleep better. Neal (1968) found that babies who were rocked by a cradle or hammock exhibit significant improvements in terms of weight gain, motor maturation, auditory and visual responses and muscle tension responses compared with babies that did not receive such stimulation. Barnard (1973) also stated that babies that are stimulated by the rocking motion from the baby cradle develops distinct sleep patterns earlier, show significant increases in the amount and length of quiet sleep and scoring higher on a general measure of motor maturation.

The clinical studies have shown that the babies fall asleep easily with gently rocking around 0.25-1 Hz with small amplitude. On the other side, the high amplitude generated by electronic baby cradle might affect the baby's brain development (Lu *et al.*, 1997; Bang & Lam, 2011). Suima (2009) concluded that the best rock to put a baby to sleep has an amplitude of 60mm and frequency of 1.8 seconds (0.55Hz) which equals the mother's heart rate of 67 bpm.

Modern baby cradle or hammock is designed to incorporate an electric motor to provide continuous rocking motion without manual input. The electronic baby hammock has replaced the traditional rocking performed manually by parents. Many of the studies conducted on the design a baby cradle consisting of a cry analyzing system which detects baby cry with different approaches (Blea & Harper, 1973; Wong, 1976; Chau & Chiung, 1997). Bang & Lam (2011) designed automatic baby rocker having a noise sensor to detect baby cry and equipped with few colourful lights made up of LED which are used to entertain the baby while being rocked. Kadu et al. (2014) presented a new approach in designing an automatic swinging cradle system which inbuilt wet sensor which will alarm if the baby is wet. Lu et al. (1997) designed an automatic swinging instrument which can control the swinging angle at 0.36° to 3.6° and set the frequency from 0.4 Hz to 1.0 Hz. These ranges are set since they fall into the interest range that can make babies sleep easily.

Up to date, there are more researches and studies on cradle modification and technologies while leaving no objective and depth research on the vibration analysis (which related to the clinical studies) of the commercial electronic baby hammock. The frequency and amplitude of the vibration caused by the electric motor is vital in the design of an electronic baby hammock to ensure that the baby's neonatal development is not inhibited or affected. Hence, the objectives of this paper have three: (1) To analyze the vibration level of the electronic baby hammock; (2) To compare the vibration level that generated by electronic baby hammock with the manual rocking; (3) To determine if manual rocking and auto rocking of a baby hammock meets the optimum level of rocking.

Methodology

Electronics Baby Hammock

An electronic baby hammock which can be found easily in the market was chosen as a representative example in the present study. The chosen model comes with a motor unit with timer and speed controller, an adapter, a hanger and one set of springs (7 pieces). Figure 1 shows the electronic baby hammock is attached to the rack. Different weight of the babies requires different numbers of springs as listed in the Table 1 which proposed by the manufacturer. The bottles that filled with water are used to simulate the weight of the baby from 3kg to 16kg.

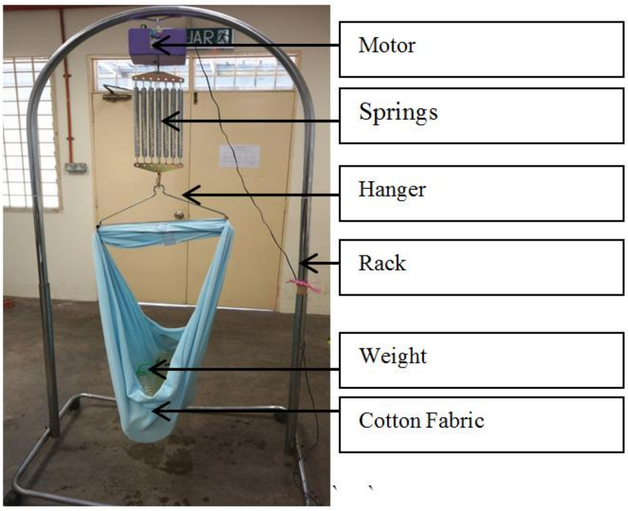

Figure 1. An electronic baby hammock

Table 1. The required number of springs with different weight and ages of babies

Age (month)	Weight (kg)	No. of Spring
0	1.0 - 3.0	2
1 - 2	4.0 - 5.0	3
3 - 4	6.0 - 7.0	4
4 - 6	8.0 - 9.0	5
7 - 12	10.0 - 11.0	6
13 - 36	12.0 - 16.0	7

Vibration Analysis

Frequency analysis of vibration of the baby hammock was carried out to determine the dominant frequency and its corresponding amplitude based on the Fast Fourier Transform (FFT). Figure 2 shows the instruments used in this measurement. This includes a single axis accelerometer (B&K, Type 4507), the FFT analyzer (B&K, LAN-XI Type 3052) and post-processing software (B&K PULSE LabShop).

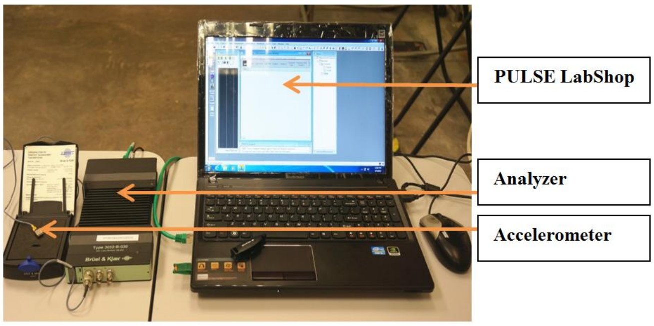

Figure 2. Measurement setup for frequency analysis

The accelerometer was then mounted on the bottles to measure the accelerations. Experiments were conducted based on two modes of rocking: Manual and Auto. The manual rocking was done by gently rocking with one’s hand. Since the variation of speed may affect the frequency analysis, hence the auto rocking was conducted with low, medium and high speed. The low, medium and high speed are set by adjusting the speed controller. The experiments were carried out from 3kg to 16kg with the number of springs as stated in Table 1. The data from the accelerometer was then stored and analyzed using B&K PULSE LabShop. Frequency analysis in the range of 0Hz to 200 Hz was evaluated.

Result and discussion

By analyzing the electrical signals from accelerometer through B&K PULSE LabShop, the nature of the vibration can be observed. Vibration analysis is generally divided into two domains: time and frequency response. Each domain provides a different view and insight into the nature of the vibration. From this vibration analysis, only the time and frequency response for 5kg with 3 springs is shown in the paper since it generally represented the trend for other measurement parameters.

Figure 3 shows the time response for 5 kg with 3 springs for manual rocking and auto rocking with different speeds. Since the baby hammock is subjected to up and down rocking motion, the vibrations generated are sinusoidal or single tone. The amplitudes vary with different measurement parameters. The auto rocking with high speed generates highest amplitude with 4.239 m/s^2; follow by 3.775 m/s^2 for auto rocking with medium speed, manual rocking with 3.328 m/s^2, and 1.689 m/s^2 for auto rocking with low speed. Higher speeds will produce higher amplitude. Obviously, for the auto rocking with different speeds, it does not vibrate in smooth sinusoidal motion as compared with the manual rocking.

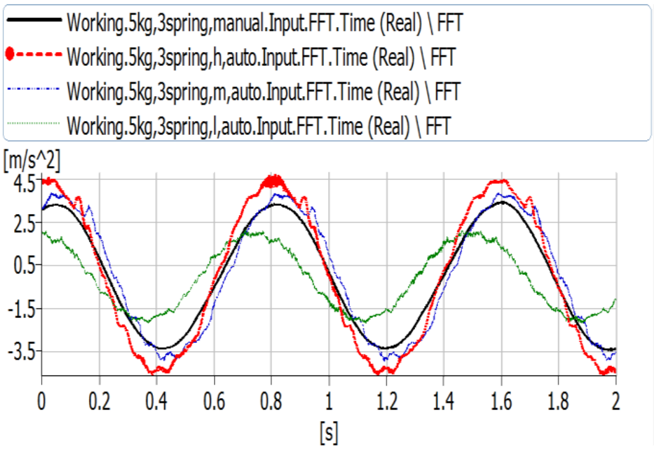

Figure 3. Time response for 5kg weight and 3 springs (h-high speed; m-medium speed; l-low speed)

Figure 4(a) shows the frequency responses for 5kg weight with three springs. The graph consists of four frequency functions which are manual rocking and auto rocking with low, medium and high speeds. The frequency of each tone is represented by the location of each peak in the frequency coordinate in the horizontal axis. The amplitude of each tone is represented by the height of each peak on the vertical axis. In order to have a direct comparison with the optimal rocking frequency and amplitude addressed by Suima (2009), the amplitude is converted from acceleration to displacement. It is clear from the graph that all the peak amplitudes for four different functions occur at 1.25 Hz with 71.653mm for the auto rocking with high speed; 59.296mm for the auto rocking with medium speed, 52.257mm for manual rocking and 28.664mm for the auto rocking with low speed. In Figure 4(a), it is also shown that there are not the pure tones with a single frequency.

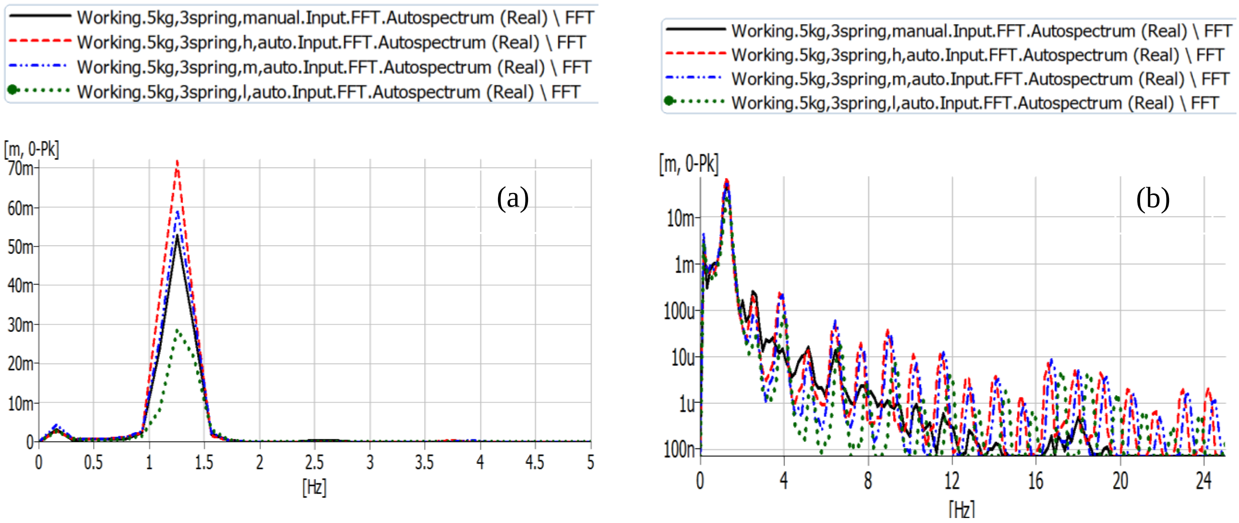

Figure 4. (a) Frequency response for 5kg weight and 3 springs, (b) Log-linear of (a) (h-high speed; m-medium speed; l-low speed)

Figure 4(b) is the frequency response (Figure 4(a)) plotted in logarithmic linear scale. As illustrated in Figure 4(b), besides from the dominant frequency at 1.25Hz, auto rocking with different speeds appears many peaks at higher frequencies which may harmful to babies and need further attention. This is due to when vibration transmitted to the body, it may attenuate or amplify. Different body parts have different resonance frequencies, for example, people complaining about pains in the chest and abdomen at 4-10 Hz, backaches at 8-12 Hz, while headaches, eyestrain and irritations in the intestines and bladder occur at 10- 20 Hz (Sanders & McCormick, 1992).

Figure 5 illustrates the comparison of dominant frequency produced by manual rocking and auto rocking mode with low, medium and high speed for weight 3kg to 16kg. The majority of the dominant frequency occurs at 1.25 Hz, except 1.406 Hz for the auto rocking methods on weight of 4 kg; auto rocking methods with low and medium speed on 6 kg and auto rocking methods with high speed on a weight of 8 kg. On the other hand, the dominant frequency for both manual and auto rocking for weight 16kg occur at 1.094Hz. It is clear that all the rocking frequencies are higher that frequency suggested by Suima, 2009.

Figure 6 demonstrates the comparison of peak amplitude at dominant frequencies for the baby hammock with weight from 3kg-16kg. From Figure 6, for a weight of 3 kg, there is a huge difference of the amplitude of manual rocking with auto rocking methods. For the manual rocking methods, the amplitude is 72.427 mm. For auto rocking method with low speed, the amplitude is the lowest among the weight of 3 kg which is 27.931 mm. While using auto rocking with medium speed, the amplitude is 67.516 mm. The amplitude is highest for auto rocking with high speed which is 92.496 mm. For the weight of 4kg, the amplitude is the highest (74.251 mm) for manual rocking methods. This is probably due to larger force is applied during the manual rocking. For auto rocking method with low speed, the amplitude is the lowest which is 27.931 mm. While using auto rocking with medium and high speed are 67.516 mm and 92.496 mm respectively. With a weight of 5 kg, the amplitude of manual rocking is 52.527 mm. While the amplitudes for auto rocking with low, medium and high speeds are 28.664 mm, 59.596 mm and 71.653 mm respectively.

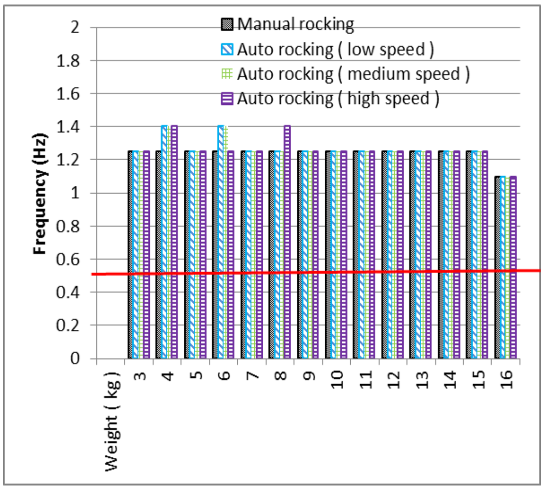

Figure 5. Comparison of dominant frequencies for the baby hammock with weight from 3kg-16kg

For the weight of 6kg, the amplitude of manual rocking is 43.159 mm. The amplitude of auto rocking method with low speed is 23.023 mm. While using auto rocking with medium and high speed is 37.635 mm and 44.158 mm. However, for the weight of 7 kg, the amplitude for manual rocking and auto rocking with low, medium, high speeds for 7kg are 46.291 mm, 26.683 mm, 50.088 mm and 59.196 mm respectively. For baby weight of 8 kg, the manual rocking methods amplitude is 50.642 mm. For auto rocking method with low speed, the amplitude is 21.733 mm. While using auto rocking with medium and high speed, the amplitude is 37.250 mm and 46.125 mm. For 9kg weight, the amplitude of manual rocking is 46.493 mm. The amplitude of auto rocking method with low speed is 25.073 mm. While using auto rocking with medium and high speed are 46.837 mm and 54.228 mm respectively. Move to the weight of 10 kg, the amplitude of manual rocking is 33.706 mm. The amplitude of auto rocking method with low speed is 21.365 mm. While using auto rocking with medium and high speed, the amplitude is the lowest in the particular rocking methods which are 26.515 mm and 29.066 mm. Moreover, the overall amplitude in 10 kg weight is the lowest compared with others. With the baby weight of 11 kg, the amplitude of manual rocking is 47.717 mm. The amplitude for auto rocking method with low speed is 23.512 mm. While using auto rocking with medium and high speed are 42.317 mm and 48.887 mm respectively. With the weight of 12 kg, the manual rocking amplitude is 35.673 mm. The amplitude is the lowest in auto rocking method with low speed, which is 18.860 mm. For auto rocking method with medium and high speed is 34.956 mm and 41.744 mm. For the manual rocking methods with the weight of 13kg, the amplitude of manual rocking is 42.352 mm. The amplitude of auto rocking method with low speed is 23.181 mm. While using auto rocking with medium and high speed is 39.621 mm and 43.897 mm. With the baby weight of 14 kg, the amplitude of manual rocking is 46.316 mm. The amplitude is the highest in auto rocking method with low speed, which is 24.409 mm. While using auto rocking with medium and high speed is 41.355 mm and 44.358 mm. For a weight of 15 kg, the manual rocking methods amplitude is 44.210 mm. For auto rocking method with low speed, the amplitude is 32.201 mm. While using auto rocking with medium and high speed, the amplitude is 38.484 mm and 45.163 mm. For the weight of 16 kg, the manual rocking method has the lowest amplitude (28.920 mm) as compared to other weight. For auto rocking method with low, medium and high speed, the amplitudes are 23.979 mm, 42.711 mm and 50.151 mm respectively.

The optimum amplitude of rocking is determined to be at 60mm (Suima, 2009). Based on Figure 6, the amplitudes obtained for electronic baby hammock using low speed is all lower than the optimum amplitude. In other words, the baby hammock at low speed is suitable for baby as it does not adversely affect the growth or the general well being of the baby. However, the low speed rocking might not be sufficient to calm the baby to sleep or rest as the amplitude is too low. The amplitude for rocking with medium speed mostly falls below 60mm except for case with 2 springs and 3kg weight. This shows that medium speed swinging of the baby hammock is also relatively safe and suitable for a baby's development. The same goes for high speed automatic rocking, with only 2 springs and 3 kg weights exceed the optimum amplitude of 60mm. For manual rocking, two cases exceed the optimum amplitude. The cases are 2 springs with 3kg weights and 3 springs with 4kg weights.

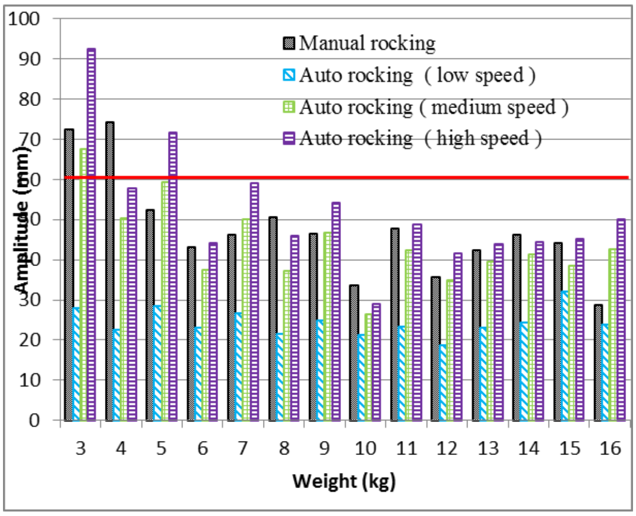

Figure 6. Comparison of peak amplitude at dominant frequencies for the baby hammock with weight from 3kg-16kg

Conclusions

Generally, the vibration analysis of different weights and different speeds shows the peak frequency occur at 1.1 to 1.4 Hz, this is higher than the optimum frequency of 0.5 Hz. The corresponding peak amplitudes are generally lower than the optimum amplitude of 60mm. However, there are some measurements are higher. For example: weight of 3 kg, the amplitude manual rocking and auto rocking methods with high speed. From the time response, it can be shown that the manual rocking provides more 'smooth' vibration than the auto rocking. The auto rocking produces several unwanted amplitudes at higher frequencies which required further attention. Generally the auto rocking and manual rocking produces the peak frequency at 1.1Hz to 1.4 Hz and corresponding peak amplitude below 60mm. None of them meet the optimum level as suggested by Suima (2009) which is 0.55Hz and 60mm.

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