

Transmission of Vibration from Motorcycle Handlebar to the Hand

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Abstract – Vibration transmitted to the hand from motorcycle handlebar can cause discomfort and health issues to the motorcycle rider. The objective of this paper was to investigate the severity of vibration transmitted to the hand from motorcycle handlebar. The engine capacity of the motorcycle was 100cc. Vibration was recorded at the motorcycle handlebar at two engine speeds representing the speed of 10km/h and 20km/h. The total magnitudes of vibrations (weighted W_h) transmitted to the hand from motorcycle handlebar were between 2 and 6.42m/s². Increasing the speed of the motorcycle engine decreased the vibration magnitude transmitted to the hand. The level of vibration exposure can be greater than the Daily Action Limit Value set by the European Directive 2002/44/EC if the motorcycle is used for more than 4.15 hours per day at the speed of 10km/h.

Keywords: Human vibration, hand-arm vibration, motorcycle, handlebar, hands

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1.0 INTRODUCTION

Motorcycle has been used by many people of different background especially in Malaysia. It is affordable, easy to handle, and does not consume a lot of petrol compared to other types of vehicles. Motorcycle has two wheels and only one passenger at a time can be sitting at the back seat. The operation of motorcycle will always accompany by vibration, which will give unpleasant effect to the rider and its passenger (Jeyapaal, 2014).

Vibration from motorcycles might come from the engine, inertial imbalance and external factors such as road profiles. Vibration from motorcycle transmitted through the body tissues will cause various effects on the structures of the body before it is dampened and dissipated. This can be categorized as whole-body vibration and hand-arm vibration. The vibration will affect the riders' and the passengers' health and at the same time will give discomfort feeling. Among health issues associated with hand-arm vibration are vascular disorders, muscle disorders, neurological disorders, and bone and joint disorders (Griffin, 1990).

Previous study has shown that more than 50% of respondents (both female and male respondents) reported discomfort at the hands and the arm (Karmegam et al., 2009). More than 50% of non-occupational motorcyclist respondents reported discomfort experienced at low back, neck, shoulders, elbows, and upper back (Mohd Hafzi et al., 2011). The prevalence of discomfort among occupational motorcyclist is greater than non-occupational motorcyclist but this may due to the longer daily riding time (Mohd Hafzi et al., 2011).

Vibration that is transmitted from the motorcycle handlebar can be greater than the limit value set by the European Directive (European Directive 2002/44/EC). The European Directive 2002/44/EC requires employer to seek methods to reduce vibration if the vibration exposure is greater than the action limit value of 2.5m/s^2 . The Directive also requires that the vibration exposure to be less than 5.0m/s^2 . The International Standard ISO 5349 suggests that a person who is exposed to vibration at the vibration exposure limit value and vibration action limit value will have a 10% chance of getting finger blanching after 5.8 years and 12 years of vibration exposure, respectively. The prevalence of finger blanching is found to be at 4.2% among police traffic motorcyclists (Mirbod et al., 1997), indicating that the vibration that is transmitted to the hand can be severe. Vibration on the motorcycle handle is in the range of 2.2 to 4.9 m/s^2 (Mirbod et al., 1997) and 3.82 to 9.77 m/s^2 (Roseiro et al., 2016). However, there is no vibration exposure standard has been set forth by the authorities in Malaysia.

This study concerned on the severity of the vibration transmitted to the hand from the handle of motorcycle that has low engine capacity. It was expected that the vibration magnitude (weighted W_h) increased as the speed of the engine increased.

2.0 METHODOLOGY

2.1 Measurement of the Vibration Transmission to the Hand from the Handlebar

A motorcycle with engine capacity of 100cc was employed in this study. A tri-axial accelerometer was installed on an aluminium palm adapter placed between the hand and the handle of the motorcycle to measure vibration at the hand of the rider. The weight of the palm adapter and the accelerometer was 25 grams. Vibration was recorded at the rider's hand in static condition. The gear of the motorcycles was not engaged throughout the experiment. Vibration was recorded and analysed by using LabView and Matlab softwares.

Subjects were asked to sit on motorcycle and hold the motorcycle handle together with the palm adapter. The speed of the engine was increased by twisting the handle. Two engine speeds marked by guide ticks on the handles were employed in the experiment that represent motorcycle speed of 10 and 20km/h.

Ten subjects (7 male students and 3 female students) with age between 18 and 30 years old have participated in the study. Subjects were students of Universiti Putra Malaysia (UPM) with median age, weight and height of 23 years old, 58kg, and 170cm, respectively. This study has been approved by UPM Ethics Committee.

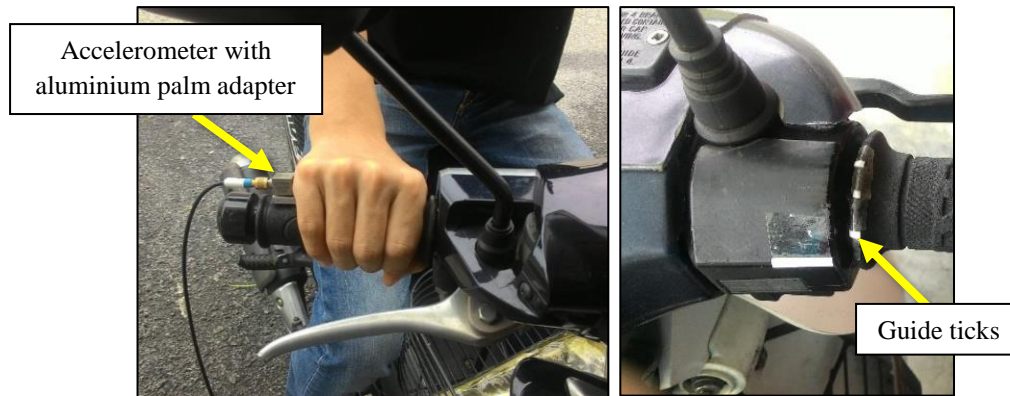


Figure 1: The guide ticks and palm adapter with accelerometer at the motorcycle handle

This study was conducted in static condition; thus, it may not represent actual condition. The vibration due to the road profile and the vibration emitted by engine at different motorcycle speeds were not considered as in actual condition. The engine speeds for motorcycle speed of 10km/h and 20km/h were selected in this study to ensure that the subjects were not being exposed to high noise level due to the speed of the engine during the experiment.

2.2 Analysis and Calculation

Total magnitude of vibration in orthogonal coordinates, a_{hv} was calculated using:

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2} \quad (1)$$

where a_{hwx} , a_{hwy} and a_{hwz} are the frequency-weighted r.m.s. acceleration (weighted W_h according to International Standard ISO 5349) in the direction of x, y and z.

The level of vibration exposure was calculated to an 8-hour reference period of vibration, $A(8)$:

$$A(8) = a_{hw(eq,8h)} = a_{hv} \sqrt{t/T_{(R)}} \quad (2)$$

where t is the daily duration of vibration exposure experienced by subjects and T is the 8 hours' reference time which equal to 480 minutes or 28,800 seconds.

The number of years of exposure, D for an individual to have 10% probability to develop vibration white finger was given by

$$D = 31.8(A(8))^{-1.06} \quad (3)$$

The European Directive 2002/44/EC requires that the Daily Exposure Action Value to be 2.5m/s^2 and if exceeded, an action to reduce vibration is to be taken. The Directive also requires that the Daily Exposure Limit Value to be 5.0m/s^2 and this value cannot be exceeded.

Daily riding time for non-occupational motorcyclist was 1.7 hours with standard deviation of 1.1 hours and for occupational motorcyclist was 6 hours with standard deviation of 2.7 hours (Mohd Hafzi et al., 2011). In this study, the level of vibration exposure experienced

by subjects was calculated for exposure of two hours (i.e., indication of vibration exposure for non-occupational motorcyclist) and eight hours per day (i.e., indication of vibration exposure for occupational motorcyclist working at standard 8 working hours per day).

3.0 RESULTS

Figure 2 shows the total magnitude of vibration a_{hv} for each of the subjects. The magnitude of vibration varied between 2.01 and 6.42 m/s^2 . The highest vibration was recorded on Subject 5 at 20km/h. Motorcycle at 10km/h had greater median total vibration magnitude than 20km/h at 3.47 and 3.32 m/s^2 , respectively.

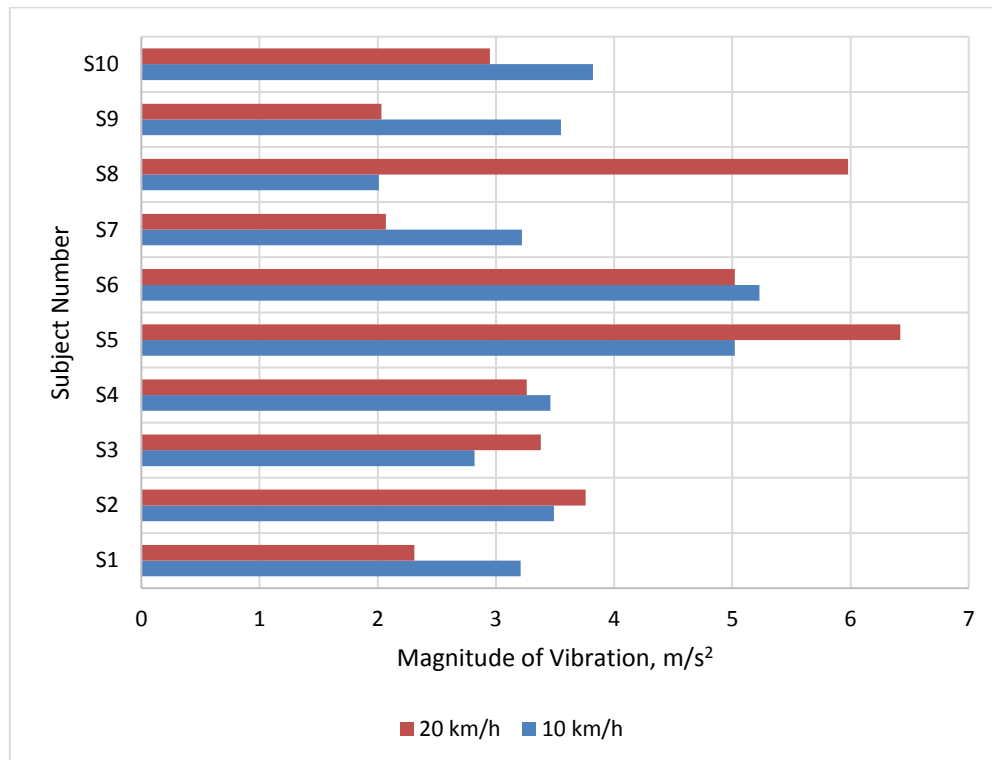


Figure 2: Total magnitude of vibration for each subject

Table 1 shows the level of vibration exposure for both speeds calculated using median value of total magnitude of vibration. The vibration exposures for both speeds were less than the vibration exposure limit value stated in the European Directive 2002/44/EC. Riders who are using the motorcycle for more than 8 hours per day will have daily vibration exposure greater than the daily action limit value.

Table 1: Total 8-h energy equivalent of vibration exposure for each speed in this study

Speed	Range of Daily Time Use (hour)	Median Total Vibration Magnitude for 10 Subjects (m/s^2)	A(8) (m/s^2)
Speed 1: 10 km/h	2 to 8	3.47	1.74 to 3.47
Speed 2: 20 km/h	2 to 8	3.32	1.66 to 3.32

With the magnitude of vibration acquired from the measurement of vibration previously conducted, the time of exposure before it reached limit value can be predicted using Equation

2. For the speed of 10km/h, the time is calculated to be 4.15 hours of motorcycle usage before it reached the vibration exposure action limit value. For the speed of 20km/h, it requires 4.54 hours of motorcycle usage before reaching vibration exposure action limit value.

Figure 3 shows the number of years, D of vibration exposure before getting 10% probability of developing finger blanching. Riding the motorcycle for two hours per day at the speed of 20km/h will have 10% probability of developing finger blanching after 18.58 years. Increasing the hours of riding the motorcycle will further decrease the number of years of vibration exposure, D .

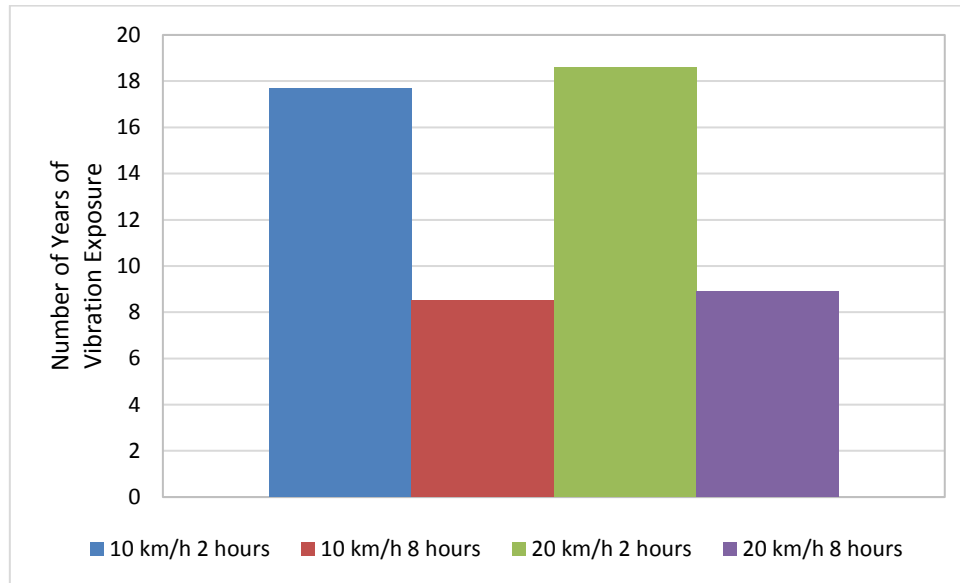


Figure 3: Number of years of vibration exposure before 10% probability of getting finger blanching

4.0 DISCUSSION

4.1 Level of Vibration Exposure when Using the Motorcycle

This study suggests that using the motorcycle for less than 2 hours per day for about 18 years will have a risk of about 10% to develop finger blanching.

The number of years, D , was however, greater than previous study (Roseiro *et al.*, 2016). This is expected because the study was conducted statically. Vibration due to the road profile was not considered in the experiment and in the calculation of $A(8)$.

Furthermore, the level of vibration exposure was also calculated based on median total magnitude of vibration. The median value of vibration magnitude was lower than some of the subjects' total vibration magnitude (e.g., Subject 5 and 8).

4.2 Gripping the Handle and the Effects of Palm Adapter

Previous studies have suggested that increasing the grip of the handle can affect the way hands response to vibration (Mann & Griffin, 1996; Marcotte *et al.*, 2005). In this study, the grip force subjected to the handle were not controlled and is expected to be different among the subjects. Increasing the grip force will affect the vibration magnitude exposed to the hand and thus the

level of vibration exposure. In addition, the study was conducted statically, thus encouraged subjects to require less grip on the handle.

The palm adapter and the accelerometer have a mass of 25 grams. The weight of the palm adapter and the accelerometer can affect the vibration transmitted to the hand.

4.3 Effects of Motorcycle Speed and Seating Position

Two speeds of the motorcycle were employed, 10km/h and 20km/h, achieved when gear is set at Gear 1 (the speed may be higher at Gear 2 or 3 for the same engine speed). Increasing the speed of the motorcycle may increase or decrease the magnitude of vibration, thus increasing or decreasing the level of vibration exposure.

The seating position of the subjects was also uncontrolled and may be different than the actual condition. This may affect the way the subjects gripping the handle and the posture of the hand. The vibration that is transmitted to the hand and the arm can be affected by the grip force and the posture of the hand (Mann & Griffin, 1996; Marcotte et al., 2005, Burström, 1997; Besa et al., 2007).

4.4 General Discussion

The level of vibration exposure can be greater than the action limit value if the motorcycle is operated at the speed of 20km/h for more than 4.54 hours. Similar severity of vibration may be expected at any speed of the motorcycle with similar engine speed as in this study (e.g., similar engine speed at Gear 2 and Gear 3 will produce higher motorcycle speed than in this study).

It has been shown in a previous study that increasing the area of contact increases the apparent mass of the hand (Rezali & Griffin, 2016). The surface of the hand in contact with the handle increases with increasing area of contact and may contribute to the way structure of the handle vibrates. In this study however, the effect of contact area was considered and could contribute to the different vibration magnitude recorded during the study (i.e., the size of the hand of each subject may be significantly different).

This study indicates that a person who is using motorcycle for more than four hours per day (e.g., postman and policeman), could have a risk of getting hand arm vibration syndromes. Vibration from the handlebar of the motorcycle can be reduced by using gloves but it may not be effective to use glove on the finger compared to the palm (Rezali & Griffin, 2016).

5.0 CONCLUSION

This study has found that the vibration magnitude transmitted to the hand decreases with increasing engine speed. Prolonged use of motorcycle could give some adverse effects to the motorcycle riders as the level of vibration exposure can be greater than the action limit value set by the European Directive. The level of vibration exposure is however, expected to be less than the action limit value if the motorcycle is used for less than two hours per day. The vibration that is transmitted to the hand should be monitored especially on riders who are using for more than two hours per day. Attenuation of vibration transmitted to the hand from the motorcycle handlebar may be achieved by redesigning the structure of the handle.

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