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Original Article:

Study of vibration and its effect on health of the motorcycle rider

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Abstract:
The motorcycle riders are subjected to extreme vibrations due to the vibrations of its engine, improper structural design of the motorcycle and the bad road conditions. The literature review reveals that the vibrations are most hazardous to the health if it exceeds the limit. The experiments were conducted to measure the magnitude of the vibrations acting on the rider during motorcycle riding under various road conditions. Experimental values of accelerations and frequencies which are beyond permissible limits according to the literature confirm that vibration certainly affects health of the motorcycle rider.
Key Words: Health, Motorcycle rider, Vibration

Introduction:

The majority population in India is depends on motorcycles for their transportation due to economic reasons. The vibration is common in most of the machine tools and it is more in the motorcycle because of its dynamic nature. Vibration energy waves transferred into the body of the rider are transmitted through the body tissues, organs and systems of the individual causing various effects on the structures within the body before it is dampened and dissipated.

On the other hand, the health problems are also increasing and the rate of patient population is growing at 14% per year.(1) In this context, it is essential to identify whether there is any relation between the health problems of the people and vibration of the motorcycles they are riding.

Hence, the objectives of this paper are to study the:

- Vibration and its effect on health.
- Effect of vibration on driver/rider
- Measurement of magnitudes of vibration in motorcycles while riding

Vibration and its effect on health:

Vibration is defined as the oscillation of a body about a reference position and can be described in terms of amplitude and frequency. The factors such as ergonomic design, damping and attenuation, resonance and many more have a great influence on the exposure characteristics and intensity levels of vibration exposure experienced by machine operators. The human body can tolerate certain levels of vibrational energy but starts to deteriorate & cause long-term damage and disruption of the natural processes of the body.(2) The frequency of vibration and its affects on the human body are depicted in the Table 1.[3,4]

Table 1: Frequency of vibration and its affects on the human body

Frequency of vibration	Types of effect
Below 1 Hz	Motion sickness
3.5 to 6 Hz	Alerting effect
4 to 10 Hz	Chest and abdomen pain
Around 5 Hz	Degrades manual actions
7 to 20 Hz	Communication Problems
8 to 10 Hz	Back ache
10 to 20 Hz	Intestine and Bladder pain
10 to 30 Hz	Degrades manual and visual controls
10 to 90 Hz	Degrades visual actions

According to the Health guidance zones specified by ISO 2631-1, 1997 the impact of the vibration on the health of a worker depends on weighted rms acceleration and exposure duration/ day.(5)

Three important factors which decide effects on the health in respect of exposure to vibration are (6):

1. Threshold value or the amount of vibration exposure that results in no adverse health effects
2. Dose-response relationship i.e., the relationship between severity of the ill-health effects and the amount of exposure
3. The latent period i.e. the time gap between first exposure and appearance of symptoms

Vibration can be classified based on the target on which it effects as hand arm vibration and whole body vibration.

Hand arm vibration and its effects

Hand arm vibration (HAV) is vibration transmitted from hand-held equipment such as jackhammers and steering wheel/ handle bar into the hands and arms of workers. It leads to vibration induced white finger (VWF). If detected early, this disease is curable. If not, it can cause permanent disability in the use of the hands.(4)

Whole body vibration and its effects

Whole body vibration (WBV) occurs when workers sit or stand on vibrating seats or foot pedals. Prolonged exposure to high levels of WBV causes motion sickness, fatigue and headaches. WBV is one of the strongest risk factors for low back disorders.(7) Vibrations with Less than 0.315m/s^2 are found to be comfortable between 0.315m/s2 and 2.5m/s2 are found to be uncomfortable greater than 2.5m/s2 are found to be extremely uncomfortable.(5)

Effect of vibrations on health during driving/riding

The drivers of automobiles are subjected to different magnitude of the vibrations while driving. The magnitude of the vibration also depends on the type of the automobile, engine size, body weight, age of the automobile, type of seating, type of suspension and road surface factors etc.(7) These vibrations are transmitted to the buttocks and back along the vertical axis via the base and back of the seat. On the other hand, the pedals and steering handle transmit additional vibrations to the feet and hands of the rider. During motor cycle riding, due to its unbalancing nature, it creates enormous vibration and affects the bioelectric phenomena.

Table 2 depicts ISO standards with respect to the vibration exposure and its effects on health of the driver/rider.(8)

Table 2: ISO standards for vibration exposure and its effects on health of the driver/rider

Exposure duration in hours	International Standard		
	ISO 2631-1, 1997 Average rms acceleration limits in m/s^2		
	Likely health risk	Caution zone	Comfort level
8	0.8	0.5	0.315
12	0.7	0.4	0.315

Physical factors that influence the effects of vibration on rider during riding are acceleration and frequency, duration of exposure, automobile maintenance and protective practices. Biodynamic factors like grip force, position of the hand/arm relative to the body, texture and type of material of the handle causes the effect. Individual factors like operators control, automobile speed, and skill of driving and individual susceptibility to vibration also leads to the effects.(6)

Hand arm vibration and its effects

Steering wheel vibration levels as high as 1 m/s^2 have been reported in one study. HAV at this level may present a slight risk of injury considering the long exposure durations of driving. It was also observed that the rates of finger numbness, finger stiffness, shoulder pain and shoulder stiffness were significantly higher among traffic motorcyclists as compared with the control group. The subjects with a lifetime vibration dose of more than 20.1 m^{2}h^3/s^4 (natural log scale) showed higher prevalence rates for symptoms in the fingers and shoulders.(9)

Whole body vibration and its effects

Typical whole-body vibration exposure levels of heavy vehicle drivers are in the range 0.4 - 2.0 m/s^2. Vibration is highest in the frequency range 2 - 4 Hz. For a seated person vibration in the range of 4 to 8 Hz cause the entire upper torso to resonate and should be reduced and avoided.(7) Health effects that associated with WBV and especially the driving environment are piles, high blood pressure, kidney disorders and impotence.

Experimental arrangement

The HAV and WBV accelerations were measured by conducting experiments using different motorcycles on different roads.

The acceleration measuring experimental set up is depicted in Fig.1 and consists of:

- One accelerometer mounted on handle of the motorcycle to measure HAV acceleration
- Another accelerometer mounted on seat base of the motorcycle to measure WBV acceleration
- Instrumentation amplifier with power supply
- A lap top computer to store data of 10000 points scanned per minute. The data stored in lap top computer were then analyzed using vibration analysis software.The actual accelerations and frequencies were noted, analyzed and summarized.

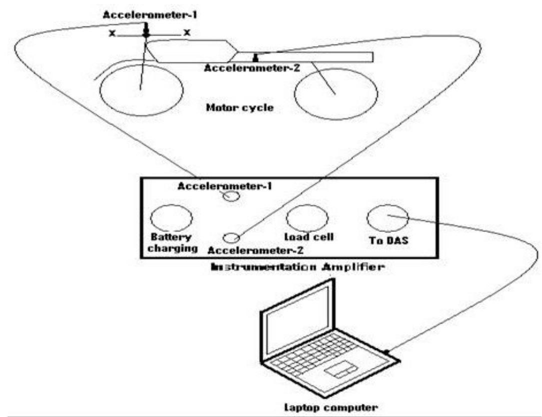

Fig. 1: Experimental set up to measure HAV and WBV accelerations

The 4 types of motorcycles (Table 3) and 7 types of roads (Table 4) at Mandya city (India) were selected for experiments.

Table 3 Motorcycle Specifications

Specifications	Type 1	Type 2	Type 3	Type 4
Stroke of engine (petrol)	Four	Two	Two	Two
Capacity in cc	99	125	150	150
Wheel width in mm	100	90	95	95
Wheel diameter in mm	640	370	480	480
Weight in kg	101	85	120	110

Table 4 Specifications of Road

Road No	Average International Roughness Index* in mm/m
1	1
2	2
3	3
4	5
5	7
6	10
7	12

*International Roughness Index is the index used to specify roughness of the road surface.

Experimental observations:

The HAV accelerations on different roads are tabulated in Table 5, the graphical illustrations of average HAV acceleration on different roads are shown in Fig.2 and maximum, minimum and Rms (Root mean square) HAV accelerations on different roads are shown in Fig.3.

Table 5: HAV acceleration (m/s²) on different roads							
	Road 1	**Road 2**	**Road 3**	**Road 4**	**Road 5**	**Road 6**	**Road 7**
Ave	0.003	0.006	0.007	0.009	0.011	0.013	0.014
Maxim-um	6	12	30	38	52	54	56
Minim-um	-3	-6	-12	-15	-18	-21	-22
Rms	1.4	1.6	1.8	2	2.2	2.4	2.6

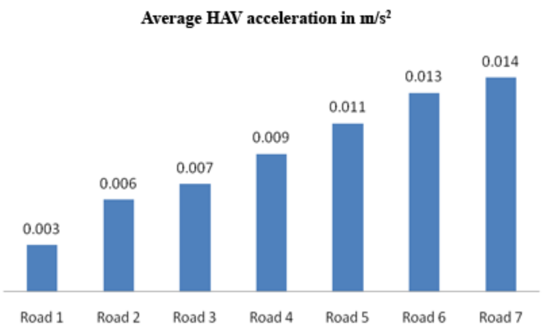

Fig. 2: Graphical illustration of Average HAV acceleration (m/s^2) on different roads

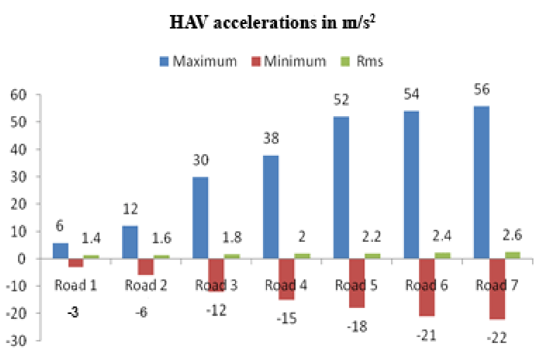

Fig. 3: Graphical illustration of Maximum, Minimum and Rms HAV acceleration (m/s^2) on different roads

WBV accelerations on different roads are tabulated in Table 6. The graphical illustrations of average WBV acceleration on different roads are shown in Fig.4 and maximum, minimum and Rms WBV accelerations on different roads are shown in Fig.5.

Table 6: WBV acceleration (m/s²) of on different roads							
	Road 1	**Road 2**	**Road 3**	**Road 4**	**Road 5**	**Road 6**	**Road 7**
Average	-0.018	-0.019	-0.02	-0.021	-0.022	-0.023	-0.026
Maximum	9	16	30	32	38	40	48
Minimum	-6	-13	-34	-37	-37	-40	-42
Rms	3.4	3.7	3.8	4	4.5	4.7	5

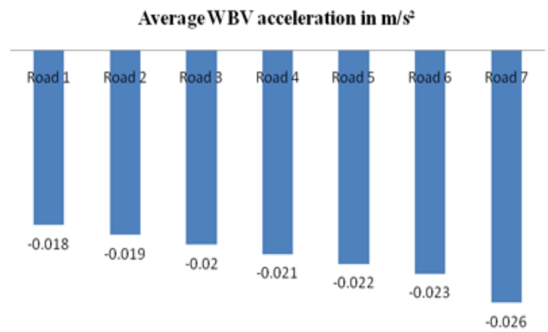

Fig.4 Graphical illustration of Average WBV acceleration (m/s^2) on different roads

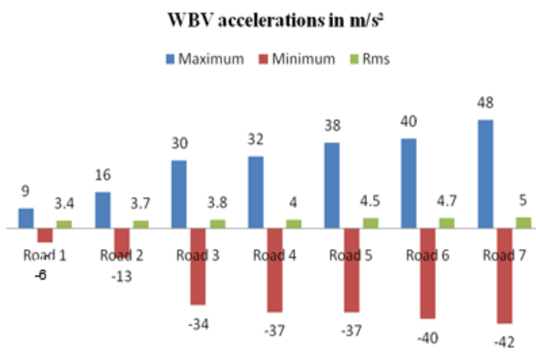

Fig.5 Graphical illustration of Maximum, Minimum and Rms WBV acceleration (m/s^2) on different roads

The frequency of both HAV and WBV varies from 1 Hz to 500 Hz while riding. From Fast Fourier Transform (FFT) analysis it was observed that the maximum HAV acceleration and maximum WBV acceleration all occurs within the frequency of 30 Hz. Between the frequency of 250 Hz and 400 Hz, minimum values of HAV acceleration and WBV acceleration were observed.

Discussion:

Vibration plays a dominant role in creating ill health. The vibrational energy waves transferred to the body of the exposed operator is transmitted through the body tissues, organs and systems of the individual causing various effects on the structures within the body before it is dampened and dissipated. Different magnitude of frequencies effects human body in different types. Even to some extent the human body withstands the vibration and beyond that the health will be affected depending upon the type of vibration, intensity and duration of the exposure in the lifetime.

The effect of vibration on driver/rider depends upon so many physical, biodynamic and individual factors. HAV leads to finger numbness & stiffness and also shoulder pain & stiffness. Further, it leads to Vibration-induced white finger. WBV is one of the strongest risk factors for low back disorders. The vibration with acceleration more than $2.5 m/s^2$ is found to be extremely uncomfortable. But, Long-term vibration exposure (Average acceleration x Exposure duration) is better indicator of the effects on the health of the driver/rider.

In the experiments conducted using different motorcycles on different roads, it was observed that the Rms values of HAV acceleration and WBV acceleration of all roads 1 to 7 is well above likely health risk level of $0.8 m/s^2$ (Table 2) considering 8 hours exposure duration. Practically both HAV and WBV act together while riding. Hence, the effect of sum of Rms values of HAV and WBV accelerations is to be considered while riding which varies from 4.8 (=1.4 HAV + 3.4 WBV) $m/s^2$to 7.6(=2.6 HAV + 5.0 WBV) m/s^2 on roads 1 to 7. These high magnitudes are dangerous even considering short duration of exposure.

Considering HAV acceleration alone, its value above $1m/s^2$ is a slight risk of injury considering the long exposure durations involved in driving/riding. The observed Rms values of HAV of all roads 1 to 7 (Table 5) is well above the risk level of 1 m/s^2. Similarly, considering the Rms values of WBV acceleration alone, its value above $2.5m/s^2$ are found to be extremely uncomfortable. The observed Rms values of WBV (Table 6) are well above this uncomfortable level of 2.5 m/s^2.

According to literature, frequency up to 90 hz (Table 1) affects human body in different types. Since, the frequency of both HAV and WBV varies from 1 to 500 hz while riding definitely it will affect the rider depending on duration of exposure. The low frequency and high acceleration combination creates early fatigue. FFT analysis showed the occurrence of this in both HAV and WBV cases.

Conclusions:

Vibration is a physical disturbance that occurs in machines and automobiles. The nature of vibration that is present in a vehicle depends upon the dynamic characteristics of the automobile and road surface characters. Its effect on the human body depends mainly on the frequency, magnitude, direction, area of contact and duration of exposure.

Exposure to HAV and WBV will result in transmission of vibratory energy to the entire body and leads to localized effects. It affects comfort, normal functioning of the body and health. Exposure to certain frequencies of vibration may have profound effects on specific systems of the body depending upon the natural frequencies of it and acceleration of the vibration at that frequency. The acceleration depending upon its magnitude and duration of exposure leads to unhealthiness of the human being. The HAV and WBV accelerations measured on different roads on different motorcycles shows it is dangerous even considering short duration of riding.

The vibrational effects are more hazardous on motorcyclist. As for as possible, measures is to be taken to avoid prolonged exposure to vibration. Also, it is very important to keep the Rms value of HAV acceleration well below $1m/s^2$, WBV acceleration within 0.315 m/s^2 and total acceleration within $0.8m/s^2$ as safety standard levels of the vibration. If possible it is necessary also to avoid vibrational frequency below 90 hz.

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