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Determination of Rider Comfort in Internal Combustion Engine-based Two-Wheeler

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Abstract – *The current work investigates the rider comfort determination of an internal combustion engine based two-wheeler. Human backbone is a major concern in evaluating the rider comfort especially in a two-wheeler. This work evaluates the comfort criteria considering the seating position of the rider. The data acquisition is conducted using the NI's software, LabVIEW. Evaluation of RMS acceleration at the saddle and obtaining vibration dose value, human comfort is determined by using ISO 2631 standard. It is found that, the vibration amplitudes are higher than the critical VDV limits at higher speeds and is prone to effect the rider comfort in long run. An effective damping system is essential in reducing these vibrations and in turn improve the rider's comfort.*

Keywords: *Rider comfort, Acceleration, Vibration dose value, Human health, Damping.*

1. INTRODUCTION

The recent years, transportation has become very problematic especially in the urban areas due to the quality of roads. The movement of vehicle, traffic density, and busy schedule of people has led to extensive use of two-wheelers compared to four-wheelers due to its ease of drive in the traffic [1]. However, whole body vibration is a major threat faced by the people who extensively use two-wheeler for transportation such as, food delivery people, small business holders, office employees to name a few [2]. Whole body vibration is known to effect riders of all class of vehicles [3]. Rather, these are mostly affected in the case of two-wheelers where the rider is in close contact with the shock and vibration from the roads [4]. These vibrations transferred to human body is hazardous to the human health and proven to cause chronic injuries to the body in the long run.

Rider's saddle is a direct point of contact to the human body [5]. A rider's saddle provides a support to the tuberosity of the Ischium region of the body where the body weight is usually placed [6]. The effects of the vibration mainly affects to these sensitive areas and prone to cause discomfort for the rider.

In attempts to extract these vibration behavior order analysis of a conventional scooter in comparison to an electric drive, a case study shows that, even though the electric drive vibration has decreased effects on the human body considering power drive sources alone, the road excitations influence majorly in deciding the rider's comfort [7]. In this regard, an effective vibration damping technique is required for any class of vehicle. The measurements of these vibrations involves mounting of accelerometers and obtaining the frequency responses. The output of the accelerometer gives the acceleration in terms of 'g' values. Where g = 9.81 m/s^2 [8]. After obtaining the acceleration values, the post processing involves finding the Vibration dose value (VDV) and comparison of the same with ISO 2631 standard. VDV measures the human exposure to vibration and its effects. It compares the value with upper and lower exposure limits. The calculation is as shown in equation 1 [9].

$$VDV = \left[\int_{t=0}^{t=T} a^4(t)dt \right]^{\frac{1}{4}} \quad \text{................(1)}$$

ISO 2631 standard [10] provides the guidance on the measurement of the vibration, mounting position as well as the safe limits of vibration. A human body especially in the case of women are very sensitive to these vibrations and hence ISO 2631 provides a safety limit criteria as shown in table 1.

Table 1: ISO 2631 comfort level criteria

Acceleration (m/s^2)	**Category**
Less than 0.315	Not uncomfortable
0.315-0.63	A little uncomfortable
0.5-1	Fairly uncomfortable
0.8-1.6	Uncomfortable
1.25-2.5	Very uncomfortable
Greater than 2.5	Extremely uncomfortable

The present study involves extraction of vibration from seating position (saddle) and signal analysis techniques for the analysis of rider comfort. The accelerometer output is acquired using NI 9234 DAC system and signal analysis is conducted using NI LabVIEW. The spectral analysis of the data through Fast Fourier Transform (FFT) gives the acceleration v/s time plot. Further analysis gives the excitation frequencies involved during the test. The signal processing flow diagram and the experimental setup is shown in section 2.

2. EXPERIMENTAL SETUP

Figure 1 shows the schematic and actual test setup developed in the laboratory. A PCB Piezotronics made accelerometer with sensitivity of 101.2 mv/g is mounted in rider's seating position and is connected to the NI's data acquisition system. The data is then transferred to the system with sampling rate of 500 S/s for the signal processing and obtaining graphs and amplitudes. The post-signal processing involves obtaining the major amplitudes of vibration and frequencies. Further, vibration dose value is calculated based on the acceleration values obtained.

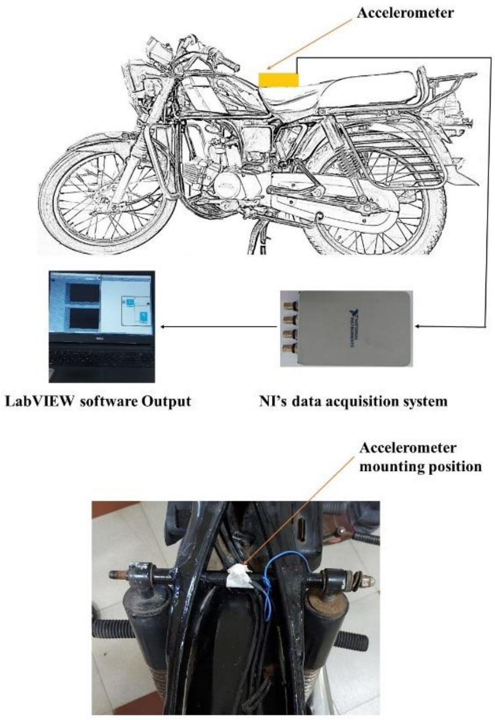

Figure 1. Schematic and Actual test setup

The two-wheeler chosen for the study is the conventional IC engine powered Hero Honda CD 100 SS. The vehicle is tested for the vibration on an actual road condition with a rider as well as a pillion. The vehicle is tested for vibration characteristics at 20 kmph, 30 kmph and random speed. The distance travelled is approximately 300 m for the 20 kmph and 30 kmph tests. For random speed, vibrational characteristics it was tested at a random 1 km distance with different gear combinations. The acceleration values obtained from the software are then used to calculate VDV. Finally, the VDV is compared with the ISO 2631 standard for obtaining the level of comfort.

3. MEASUREMENTS AND OBSERVATIONS

The measurement is carried out using the available accelerometers and data acquisition systems from the laboratory. The vehicle chosen for the study is the Hero Honda CD 100 SS. The road conditions are the normal asphalt road with potholes and bumps. A rider with pillion is considered during the test with a total payload of 160 kgf. The vehicle specifications are as shown in table 2.

Table 2: Test vehicle specifications [11].

HERO HONDA CD 100 SS	
Engine and gearbox	
Engine Details	4 Stroke, Single cylinder, Ai - Cooled, OHC engine
Engine cc (Displacement)	97.20 cc
Maximum Power	7.5 Bhp @ 8000 rpm
Maximum Torque	7.3 Nm @ 5000 rpm
Number of Cylinders	1
Number of Gears	4
Brakes and tyres	
Front Brake	Drum brakes, 110 mm
Rear Brake	Drum brakes, 110 mm
Front Tyre	2.57x18 inch
Rear Tyre	3.00x18 inch
Suspension and chassis	
Front Suspension	Telescopic hydraulic fork
Rear Suspension	Spring loaded hydraulic typ with both side action
Dimensions and weight	
Overall Length	1960 mm
Overall Width	720 mm
Overall Height	1050 mm
Ground Clearance	165 mm
Wheelbase	1235 mm
Kerb Weight	116 kg
Fuel Tank Capacity	12.80 litres

Driving scenario 1

The vibration transferred to the saddle when running on a stretch of approximate 300 m at low speed of 20 kmph using second gear is shown in figure 2. A maximum of 0.27 m/s^2 amplitude is obtained at the saddle at a frequency of 56.19 Hz taking the root mean square acceleration.

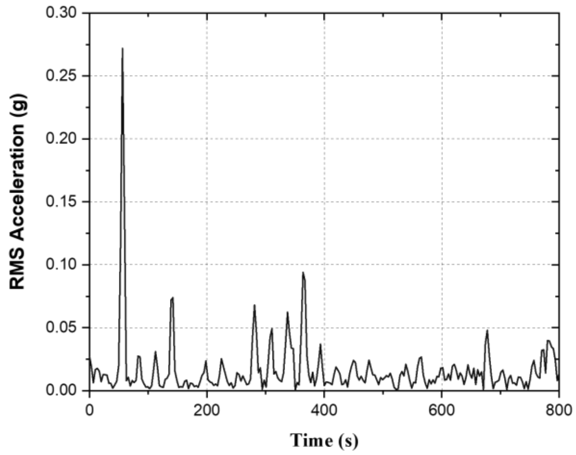

Figure 2: 20 kmph test

Driving scenario 2

The vibration transferred to the saddle when running on a stretch of approximate 300 m at a speed of 30 kmph using third gear is shown in figure 3. Observing the root mean square acceleration an amplitude of 0.29 m/s^2 is obtained at a frequency of 62.80 Hz at the saddle.

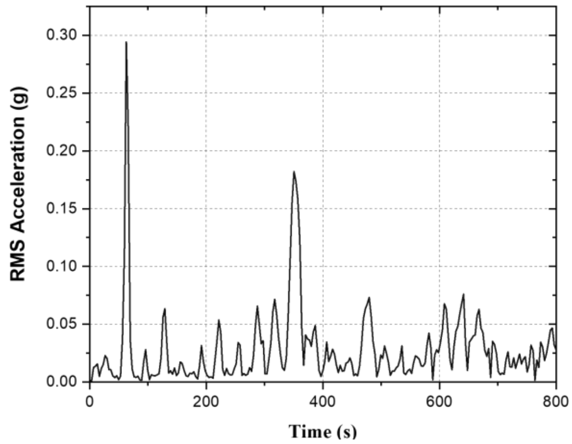

Figure 3: 30 kmph test

Driving scenario 3

The vibration transferred to the saddle when driving at a random speed for a distance of 1 km is shown figure 4.

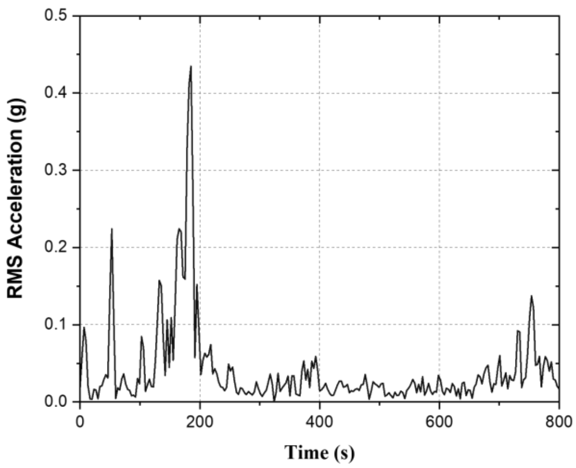

Figure 4: 1-kilo meter test

A normal road scenario where rapid acceleration, gearshift, deceleration and braking is considered for this driving cycle. Potholes, humps and irregularities on the road are the major influencing factors considered. Maximum of 0.43 m/s^2 root mean square acceleration is obtained at a frequency of 185.12 Hz.

4. RESULTS AND DISCUSSION

The plots in the above section indicates the vibration pattern at different speeds along with a random speed test. These vibrations transferred to the human body not only causes discomfort rather, it causes severe health hazards too [12]. Observing the graph and comparing it with table 1 it can be seen that, the obtained acceleration values are slightly higher and fall under uncomfortable category.

The VDV calculated based on these vibration parameters are shown in table 3.

Table 3: VDV calculations results for different driving scenarios

Accelerometer mounting position	VDV @ 20 kmph test	VDV @ 30 kmph test	VDV @ 1 km random test
Rider's saddle	16.82 $ms^{-1.75}$	24.2 $ms^{-1.75}$	10.94 $ms^{-1.75}$

In comparison to ISO 2631 standard the VDV values obtained are much higher than the safe limit (17 $m/s^{1.75}$) at 30kmph. It can be observed that, as the speed is increased the VDV value further increased [13]. Hence, it clearly signifies that, higher speed is not safe for the rider and prone to chronic injuries [14]. The road condition plays an important role in deciding the comfort level of the rider. However, it is found that, increasing the speed of the vehicle increases the effect of vibration on human body. A suitable damping technique is very much essential in order to reduce these vibrations and ill effects on the human body [15].

5. CONCLUSION

Whole body vibration is a major issue faced by the automobiles. Especially in the case of two-wheelers, the WBV is more pronounced. Consideration of road interaction and real driving scenario is important in deciding the comfort level of the rider. This study mainly focusses on the on road condition of an ICE based two-wheeler and its vibrational characteristics. From the overall experimental study the following conclusions can be drawn:

- Vehicle speed is an important parameter that affects the rider comfort.
- Higher the speed higher is the VDV values and lower is the comfort level obtained at the saddle.
- Acceleration values obtained at the saddle is minimized using suitable damping technique.

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