IOP Conf. Series: Materials Science and Engineering **402** (2018) 012114 doi:10.1088/1757-899X/402/1/012114

Whole body vibration analysis for children in midi school bus

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Abstract. The current study objective is to measure the whole-body vibration (WBV) transmitted to children of different age during the operation of midi bus. The results are compared with ISO 2631-1 (1997) health guidance criteria. The vibration values were measured at seat and children interface on x-longitudinal, y-transverse and z-vertical axes at different road profiles like highway road and rough road. The age of the children varies from 4 to 10 years. The finding of the study was at lesser the age more the vibration exposure because of children of less age have less tissue mass to dampen the vibration accelerations. The average root mean squared weighted acceleration, exposure time and estimated VDV on highway road were among the 1.05 to 3.07 m/sec^2, 14 to 200 min and 12 to 24 m/sec$^{1.75}$ respectively. And on rough road 1.16 to 5.65 m/sec^2, 1 to 94 min and 15 to 46 m/sec$^{1.75}$ respectively. This shows the health of the less age children are at risk, the OEM has to work on good suspension and engine mounts to isolate road and engine induced vibrations

1. Introduction

Road irregularities and power train excitations are the major sources of the vibration in the vehicle. Drivers and passengers are exposed to vibrations from the road surfaces during the ride in the vehicle. The type of the road had a significant effect on vibration. Exposure to vibrations have caused discomfort, reduced work ability, and subjected to health effects like muscular skeletal Disorder's (MSD's). It was reported that the vibration exposure was slightly higher in highways, compared to other road types (rough roads, pave roads). Whereas, the roads consisting of rough surfaces and speed humps gave rise to higher z-axis impulse vibration exposures.

Though many researchers have attempted to study the vibration effects on adults [1],[2] investigation on the effect of vibration on children were few [3],[4],[5]. It was observed that on an average, most schools, children are going travelling at least 1-2 hours a day. An attempt has been made here in to profile the vibration exposure of school children at different road conditions via High way road and Rough road. Currently, there are two standards (1997) [6] available for evaluating whole body vibration for a human being. Studies by Giacomin [5] revealed that the dynamic response to vibration levels among small children and adults were different. Therefore the application of these standards to the children has become uncertain. One major challenge in applying these standards to children is the limited knowledge of the biological response of children to whole body vibration. Eadric et al., [7] studied the whole-body vibration of children and adult standing on the vibration platform. Their study indicates that the children transmitted vibration differently than adults on the vibration platform. The complex factors determining the child’s response to vibration and their reactions to different road conditions, this work has been initiated. Knowledge of the vibration exposure would help to design suitable seats and suspension requirement for the school bus.

This study's objective is to experimentally evaluate the whole body vibration characteristic of kindergarten school children (4 to 10years, Weight:16 to 30kgs, Height: 102cm to 130cm) who travels in a midi urban bus at different operating speed and road conditions.

2. Experimental Procedure

Table 1 shows the brief specification of the midibus used for the testing. The vibration signals were measured while driving over two roads, and the driver controls the speed. Figure 1 & 2 shows the highway and rough roads selected for the study. The highway had smooth surfaces and occasional unevenness with minimum disturbances. The rough road had random irregularities. The driving speed over the rough road and highway were maintained at 20km/h and 40km/h, respectively, this is considered to be an average speed that can be maintained in a typical Indian road conditions.

Table 1. Specification of the Midibus.

GVW	4450
Seating Capacity	16+D
Wheel base	2654
Overall length	4939
Overall width	2060
Engine	2.51 MDI
Max.Power (HP)	70@3200 RPM
Max.Torque (Nm)	200 @ 1400-2200 RPM
Type	CRDe
Fuel tank capacity (lt)	60
Clutch type	Dry Single Plate Hydraulic,Dia 240mm
Gear box type	Manual Synchromesh ,5 speed

Figure 1. Highway road.

Figure 2. Rough road.

ICP Type (Model 5313A) 6 seat pad accelerometers and 64 channel data acquisition system (LMS Make) were used for measurement. Before and after the measurement, accelerometers were calibrated by the calibration exciter. Figure 3 shows the data acquisition system and children seating position on the seat pad accelerometer during the test.

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Figure 3. LMS Scadas vibration analyser, Children on the seat pad accelerometer.

The tri-axial accelerometers were mounted in the children seat surface to measure x, y and z axis on the seat vibrations. The axis x, y and z axis represents fore-aft, lateral and vertical axis acceleration respectively. Twelve healthy children were identified and asked to volunteer for the study. The cooperation of the volunteers was ensured by giving initial training needed to measure the vibration. As per the ISO 2631 the vibration evaluations were done. The acceleration was frequency weighted over the frequency range from 0.5 to 80Hz. In ISO 2631, the procedure is defined to evaluate vibration with respect to health. The total vibration value (Av) was defined as the vector sum of the translational axes as shown below in equation (1).

$$A_v = (k_x^2 a_{wx}^2 + k_y^2 a_{wy}^2 + k_z^2 a_{wz}^2)^{1/2} \quad (1)$$

Where aw is the weighted acceleration in the respective axes and k is the multiplying factor as per ISO 2631. While quantifying Av for health effects, kx and ky = 1.4 for x-axes and y-axes and kz = 1 for z-axes. The calculated total vibration values were then compared with the upper and lower exposure limits of the ISO 2631 health guidance caution zones, which is shown in figure 4 to determine the potential health risk.

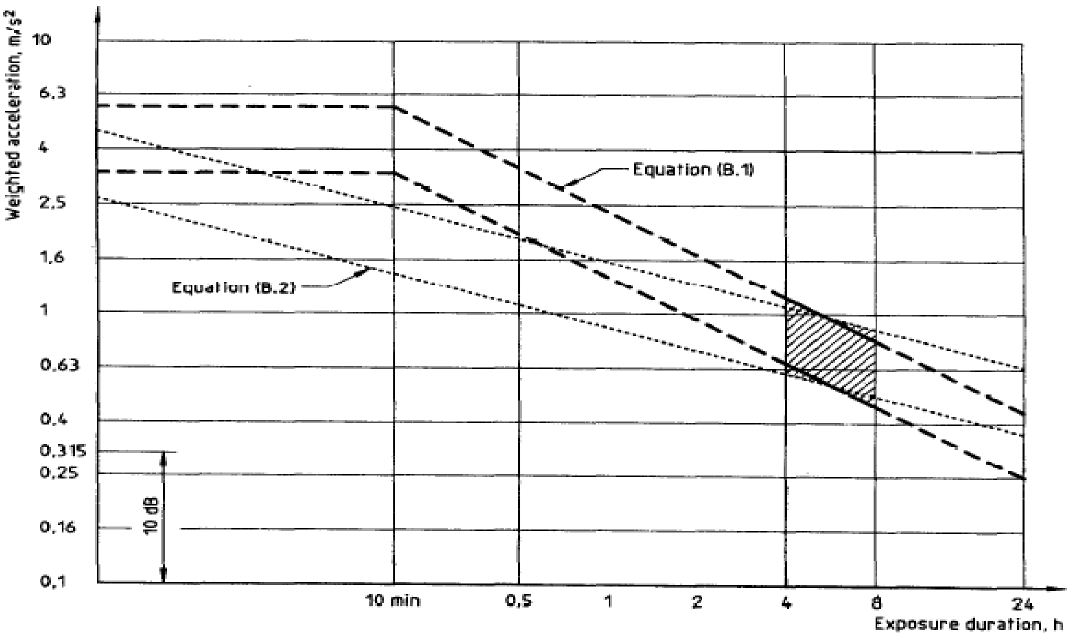

Figure 4. Health guidance cautions zone.

3. Vibration Dose Value (VDV)

VDV is more suitable while the movement of the vehicle includes jolts, intermittent vibration and shocks. It gives the total exposure of the vibration. It increases with measurement duration. The VDV is more sensitive to peaks because the use of the fourth power method. The Vibration Dose Value is defined as

$$VDV(m/sec^{1.75}) = [\int_0^T a(t)dt]^{1/4} \quad (2)$$

Whereas a (t) is the acceleration time history with frequency- weighted. The standard suggests that for continuous vibration which is not time varying in magnitude and of low crest factor between the 3 and 6, the VDV may be determined from the estimated vibration dose value in equation (3).

$$eVDV = 1.4\ a_v\ T^{1/4} \quad (3)$$

Where a_v is the rms acceleration with frequency weighted and T is the duration of exposure in seconds. ISO 2631 recommends 8.5 and 17 $m/sec^{1.75}$ lower and upper estimated vibration dose values as in a health guidance caution zone.

4. Results and Discussion

To measure the vibration exposure in minibus the accelerations with weighted measured in between the children and seat surface. The measurement is done on two different road conditions. The measurement was analysed according ISO 2631 health guidance standard.

Table 2. Different age children whole body vibration in x, y, z and overall levels on highway and Rough Road.

		Highway Road				Rough Road			
Age	**Trials**	**X**	**Y**	**Z**	**Health(Av)**	**X**	**Y**	**Z**	**Health(Av)**
4	1	0.93	0.83	0.75	1.90	1.38	1.96	1.45	3.66
	2	0.91	0.71	0.74	1.78	1.23	1.51	2.01	3.39
	3	1.33	1.42	1.42	3.07	2.29	2.59	2.92	5.65
	Avg	**1.06**	**0.99**	**0.97**	**2.25**	**1.63**	**2.02**	**2.13**	**4.23**
6	1	0.84	0.90	0.71	1.86	1.03	1.29	1.04	2.53
	2	0.78	0.82	1.00	1.87	0.93	0.86	1.31	2.20
	3	0.76	0.90	1.18	2.03	1.04	1.06	1.43	2.52
	Avg	**0.79**	**0.87**	**0.96**	**1.91**	**1.00**	**1.07**	**1.26**	**2.41**
8	1	0.75	0.71	0.60	1.57	0.93	0.83	0.75	1.90
	2	0.72	1.09	0.90	2.04	0.91	0.71	0.74	1.78
	3	0.69	0.68	1.17	1.79	0.71	0.77	0.93	1.74
	Avg	**0.72**	**0.83**	**0.89**	**1.77**	**0.85**	**0.77**	**0.81**	**1.80**
10	1	0.44	0.44	0.58	1.05	0.60	0.76	0.70	1.53
	2	0.50	0.48	0.78	1.24	0.50	0.42	0.71	1.16
	3	0.50	0.42	0.71	1.16	0.47	0.77	0.91	1.56
	Avg	0.48	0.45	0.69	1.15	**0.52**	**0.65**	**0.77**	**1.40**
Grand Average		**0.76**	**0.78**	**0.88**	**1.77**	**1.00**	**1.13**	**1.24**	**2.46**

Table 3 shows the data obtained from the experiments are listed. At each age three trials were conducted and each trial x, y, and z axis data measured. The overall vibration values are computed in equation (1).

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Figure 5&6 shows the weighted average acceleration values for different age group on the highway and rough road.

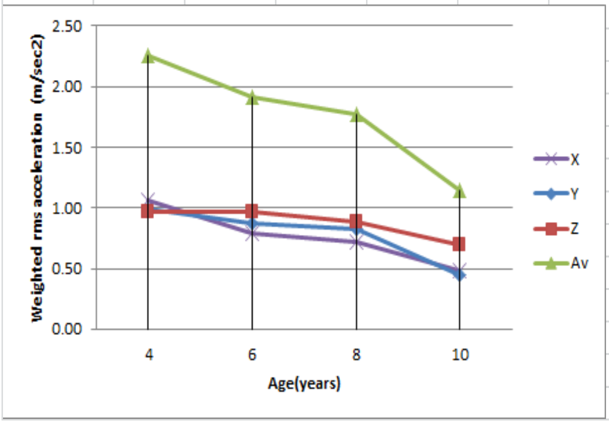

Figure 5. Acceleration values on Highway road.

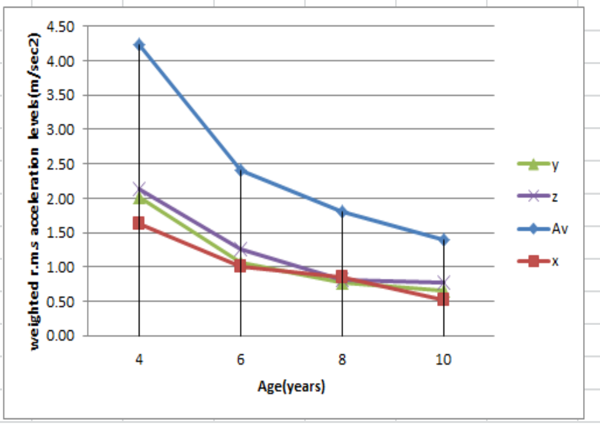

Figure 6. Acceleration values on Rough road.

5. Frequency Weighted acceleration from Midibus

On highway road, the grand average fore-aft, lateral and vertical axes whole body vibration magnitudes were 0.76 m/s^2 rms (0.44 to 1.33 m/s^2 rms, range), 0.78 m/s^2 rms (0.42 to 1.4 2m/s^2 rms, range), 0.88 m/s^2 rms (0.58 to 1.42 m/s^2 rms, range) respectively. And on rough road the grand average fore-aft, lateral and vertical axes whole body vibration magnitudes were 1.00 m/s^2 rms (0.5 to 2.29 m/s^2 rms, range), 1.13 m/s^2 rms (0.42 to 2.59 m/s^2 rms, range), 1.24 m/s^2 rms (0.7 to 2.92 m/s^2 rms, range) respectively. It was observed that the seat vibration magnitude at the lesser age limit are greater than the higher age limit both on the highway road and rough road. It is obvious that less age children have less tissue mass than the higher age children. It also observed that the vibration value of the highway road is lesser compared to rough road. The reason is obvious that the rough road has higher variance than the highway road.

6. Prediction of Health Risk

ISO 2631 health guidance recommends upper and lower bound as shown in the figure 4. Upper bound was considered in this work. To measure the exposure, time the rms weighted acceleration data were compared with health risk guidance upper bound of the zone. The eVDV calculated by the equation (3) and the upper limit is 17 $m/s^{1.75}$.

$$T = (17)^4 / (1.4)^4 * (A_v)^4 \quad (4)$$

Table 3. Children age vs Av, Time of exposure and eVDV on Highway and Rough Road..

	Highway Road (45min)			Rough Road (15min)		
Years	**Av(m/sec2)**	**T(min)**	**eVDV(m/sec1.75)**	**Av(m/sec2)**	**T(min)**	**eVDV(m/sec1.75)**
4	2.25	14	22	4.23	1.13	32
6	1.91	27	19	2.41	10	18
8	1.77	36	18	1.8	35	14
10	1.15	207	12	1.4	94	11
Grand Average	1.77	36	18	2.46	10	19

Equation (4) shows the daily vibration exposure time (T) calculation. Table 6 shows the exposure time, eVDV, Av with respect to age.

On the highway, the daily travel time was 45 min, the estimated vibration dose values were 22, 19, 18 and 12 $ms^{1.75}$ for 4 ,6,8 and 10 years respectively. The eVDV value surpasses the daily vibration dose of eVDV 17 $ms^{1.75}$ for 4 and 6 years. And 8 years, it is on the borderline and for 10 years, it is within the limit. And on the rough road the daily travel time was 15min., The estimated vibration dose values were 32,18,14 and 11 for 4,6,8 and 10 years respectively. The eVDV value surpasses the daily vibration dose value of eVDV 17 $ms^{1.75}$ for 4 years. And 6 years, it is on the borderline and for 8 and 10 years, it is within the limit. Figure 7&8 shows the Age Vs Exposure time and eVDV.

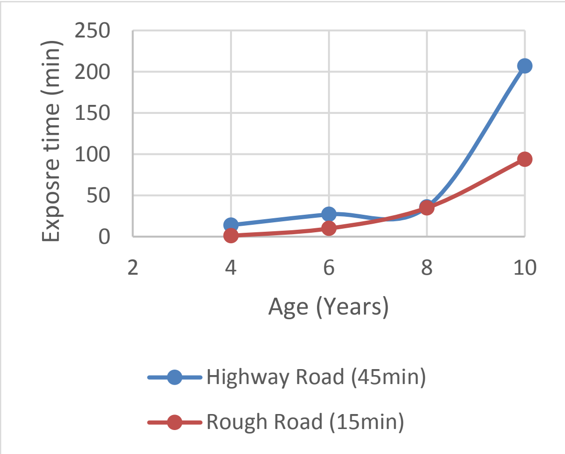

Figure 7. Children age Vs Exposure time.

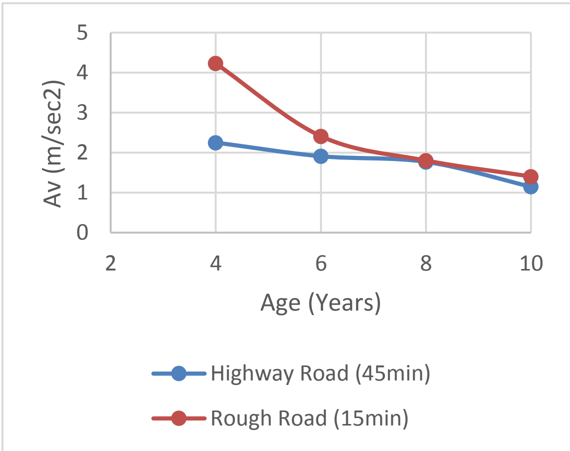

Figure 8. Children age Vs eVDV.

Higher exposure to vibration will cause high risk of injury. It is clear that the less age children are exposed to high vibration values. Therefore, new seat suspension, vehicle suspension mechanisms should be required for fulfilling the different driving conditions.

7. Prediction of Health Risk

The current study was carried out to estimate the children ergonomics threats associated with the use of midi bus. The measurement and assessment of health risk were carried out in accordance with the ISO 2631-1 1997. Below are the major finding of the study

- At lesser the age more the vibration exposure because of children of less age have less muscle tissue mass to absorb (dampen) the vibration vibration accelerations.
- The grand average x, y, and z axes whole body vibration magnitudes on the highway by minibus were 0.76 m/s^2 rms (range,0.44 to 1.33 m/s^2 rms), 0.78 m/s^2 rms (range, 0.42 to 1.42 m/s^2 rms), 0.88 m/s^2 rms (range, 0.58 to 1.42 m/s^2 rms) respectively.
- The grand average x, y, and z axes whole body vibration magnitudes on rough road by midibus were 1.00 m/s^2 rms (range, 0.5 to 2.29 m/s^2 rms), 1.13 m/s^2 rms (range, 0.42 to 2.59 m/s^2 rms), 1.24 m/s^2 rms (range, 0.7 to 2.92 m/s^2 rms) respectively.
- The estimated vibration dose value of midibus on highway road was 18 $m/sec^{1.75}$ which is above the upper bound limit 17$m/sec^{1.75}$ and on rough road 19 $m/sec^{1.75}$ which is also above the upper bound limit. If is the individual age 4 and 6 years children are at risk, there values are above the acceptable value.

Acknowledgement
The author would like to thank Engineer Krishna Moorthy (AL), for his help in conducting the experiment and discussion.

8. References

[1] Paddan G S and Griffin M J 1998 A Review of the transmission of translational seat vibration to the head *J. Sound and Vibration*. **215(4)** 863-882
[2] Paddan G.S and Griffin M. J 2002 Evaluation of whole body vibration in vehicles *J. Sound and Vibration.* **253 (1)** 195-213
[3] Giacomin and Gallo 2003 In-Vehicle vibration study of child safety seats *Ergonomics*. **46(15)** 1500-12
[4] Giacomin J 2004 Apparent mass of small children:experimental measurements J. *Ergonomics*. **47(13)** 1454-74
[5] Giacomin J 2005 Absorbed power of small children J.*Clin. Biomech.* **20** 372-380
[6] International organization for standardization ISO 2631-1 1997 Mechanical Vibration and Shock:Evaluation of Human Exposure to whole body vibration in the Working Environment: Part 1, General Requirements, Geneva
[7] Eadric B, Gerald S and Jaimie B 2010 Transmission of whole body vibration in children while Standing *J. Clinical Biomechanics***. 25** 181-186