Effect of Vibration Magnitude and Seated Posture on Reading Activity in Fore and AFT Vibration

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Abstract **– A large number of passengers prefer to utilize the time while commuting from one place to other in public transport like train, car and other vehicles. Traveling time can be utilized performing many sedentary activities e.g. Reading, writing, sketching etc. Reading activity is the most preferred activity for utilization of time. Experimental study has been performed to find the effect of vibration magnitude and different posture. Six healthy subjects were exposed sinusoidal vibrations, total 28 conditions while performing reading activity: one direction: fore and aft, two magnitudes: 0.6 and 1.2 ms^{-2} rms (un-weighted), seven frequencies: 2, 3, 4, 5, 6, 8, 10 Hz and two postures: vertical backrest and 30^{o} inclined backrest. Significant effect of vibration magnitude and different posture are observed for both subjective and objective measure. Reading performance decreases with the increase vibration magnitude and with the inclined backrest conditions.**

Keywords – Whole body vibration, Reading Activity, vibration magnitude, backrest.

I. INTRODUCTION

Passenger surveys shows that reading is one of the most common activities while travelling by train (Westberg, 2000; Sundstrom, 2006; Krisnakant, 2007. Reading difficulty can be increased by vibrations which are induced in the bogie, car body and seats. Causes include various irregularities and rough sections of the track. Disruption to reading and writing is potentially a problem for elite passenger groups such as business people, students, researchers, and casual readers who wish to read while commuting. Reduction in magnitude of vibration not only reduce the activity (reading, writing or any other activity) interference, but also increase comfort and passengers willingness to pay for the higher price of tickets when compared to other forms of transport. As car passengers are willing to pay more for higher comfort in train travel the improvement in train environment could encourage a modal shift from car use to train travel. Sundstrom, J. and Khan, S., (2008) conducted a laboratory experiment to study vibrations influence the difficulty to read and write. The study involved 48 subjects (24F and 24M) divided into three age groups. Two levels of sinusoidal vibrations were applied at nine discrete frequencies (0.8–8.0 Hz). Subjects performed both reading and writing tasks under two sitting positions (leaning against the backrest and leaning over a table). The judgments of perceived difficulty to read and write were rated using Borg's CR-100 scale. The study confirmed the maximum perceived difficulty for reading and handwriting to be closer to 4Hz than 2 Hz. Bhiwapurkar et al (2010) conducted a laboratory experiment on 18 healthy male subjects exposed to random vibrations to study the effect of vibration on reading activity. The results revealed that the perceived difficulty in all three directions of vibration increases with the increase of vibration magnitudes, suggesting a proportional relation to the experienced perceived difficulty.

II. METHODOLOGY

Subjects Description

The study involved 6 healthy male subjects of 23 to 27 yr of age group and with normal eyesight or corrected normal visual acuity (6/6 vision) and no color blindness. All participants were fluent in English (read/write/speak) and were either Post Graduate Students or Research Scholars from IIT Roorkee. The subjects participated voluntarily under informed written consent and were given a small remuneration. Ethical approval was obtained from the Institute Human Ethical

Committee. The anthropometric effects were taken care of by restricting the variations in body measures. In order to limit small variations among the participants, persons who fulfilled the anthropometric inclusion criteria as mentioned in Table 1, were only recruited for the study.

In direct association to the experiment all subjects were required to fill in a questionnaire on their personal background: level of education, experience of traveling with train, fitness and reading habits to assure the suitability of subjects for experimental task.

Table 1: Anthropometric data of test subjects.

	Age (Yrs)	Weight (Kg)	Height (cm)	Seated Height (cm)	Arm Length (cm)
Mean	26	69	172	70	62
SD	2.0	6.1	7.2	6.4	3.2

In the first posture the subject is seated with back supported against the back rest vertical position with the text material held in his hand. In the second posture, the back rest is inclined at 30^0 with the vertical and the seated subject leans against the back rest with the text material held in his hand. The distance of 45 (SD ± 2) cm was maintained from the subject's eyes to the reading material in both the subject's posture. The variation in distance was due to variability in anthropometric parameter of subjects.

Experimental setup and design

The study was conducted on the vibration simulator developed as a mockup of a railway vehicle, in Vehicle Dynamics Laboratory, M.I.E.D, IIT Roorkee, India. The vibration simulator was located in a room with sound absorbing materials pasted on the walls to obtain reduced noise environment. It consists of a platform of size 2 × 2 m, fabricated from a light aluminum alloy frame with thick stainless steel corrugated plates at the top and bottom to which the three exciters pushrods are bolted via ball joints. The platform incorporates a table and two wooden chairs

Fig. 1: Seated posture with vertical and 30^0 inclined backrest

having provision to change the angle of inclination of back rest with vertical. The table and the chairs were securely fixed and rigidly attached with the platform for seating the test subjects as shown in Figure 3. The seat consisted of a 42 × 42 cm^2 flat seat and the height of the seat from floor is 48 cm. The backrest of the chair is rigid, flat, and vertical. None of the seats, backrest, or table had any resonances within the frequency range studied (up to 20 Hz) in any of the three axes**.** The weight of the platform was supported by four helical springs which were placed under its each corner. Three Electro-Dynamic Vibration exciters were used to provide the desired sinusoidal or random vibration stimuli to the platform in three axes: Fore-and-aft (X-axis), Lateral (Y-axis) and Vertical (Z-axis).

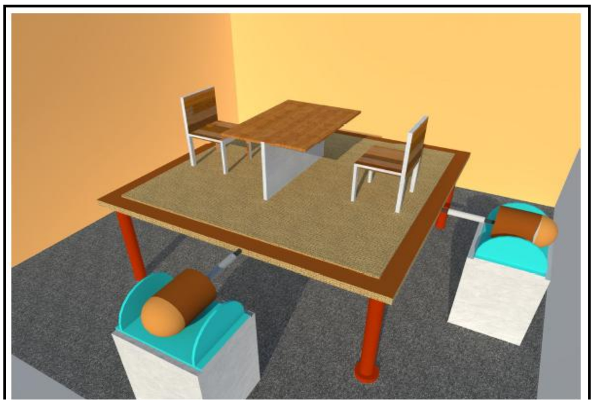

Fig. 2: Schematic model of vibration simulator (Not to scale)

For monitoring purpose, the onboard vibrations of the platform were measured on line by using a tri-axial accelerometer (PCB 356B41), which was securely fixed and rigidly attached on the platform with help of wax and medical tapes. The signal from the accelerometer was then acquired and analyzed in a Four Channel Sound and Vibration Level Meter and 0.5 Hz to 20 kHz Signal Analyzer (SVAN- 958) with help of suitable cables and connectors.

Experimental Task

To accomplish the reading task the subject was required to read a paragraph clearly and loudly, that was published in Editorial Section of a daily English newspaper "The Times of India" under various vibratory conditions and in two subject postures. The terminals of the paragraphs were marked with the help of a marker so that subject gets aware of the passages and its content to read. The subjects reading performance was thus measured by measuring the total time taken to read paragraphs completely and thereafter calculating number of words read correctly per minute CWPM) by the subject. After completion of the reading task, the subject was given a two minute break to relax while the stimuli were stopped.

Test signals and procedure

Sinusoidal vibration levels of 0.6 and 1.2 ms^{-2}rms were chosen for Fore-and-Aft direction in the laboratory study as these magnitudes were similar to those that were generally encountered during train travel (Bhiwapurkar et al (2011 b) In addition, control (static) condition with no vibration was presented before the start of experiment. Therefore, (two vibration magnitudes × two seating postures × seven frequency levels × one vibration directions) total 28 conditions were presented for each subject. Each subject was exposed to a total of 28 conditions in Fore-and-Aft direction (X-axis) resulting from a combination of two levels of vibration magnitudes (0.6 and 1.2 ms^{-2}r.m.s), two types of subject postures (vertical with backrest and inclined at 30^o with backrest) and seven discrete vibration frequencies ranging from 2-10 Hz . A static condition with no vibrations in both postures was also presented before the subjects. The vibration conditions presented to the subjects were in random order so as to minimize the order effects.

To start with the experiment the test subject were provided required reading material, sheet containing ratings of perceived difficulty and necessary stationeries. When the subject was completely ready a START signal was given by the experimenter to the subject to perform the reading task for a particular condition. Time taken to complete the reading task for that condition was measured with help of a digital stopwatch. After the end of each condition a STOP signal was given by the experimenter to the subject to indicate them to end the reading task. While conducting the experiment, the subjects were required to rate their perceived difficulty on a seven point rating scale as shown in table 2. This procedure was repeated for all the vibration levels, vibration frequencies and postures.

Table-2- Rating scale for perceived difficulty

1	2	3	4	5	6	7
Not diffi cult at all	Very weak	Weak	Mode rate	Strong	Very Strong	Alm ost Impo ssibl e

While the experiment was being performed by the subject, the experimenter stood nearby the subject to carefully observe and mark the errors made by the subject while performing the reading task so that the task performance could be measured in terms of reading speed expressed as number of words read correctly per minute (expressed as % of static speed). The reading errors taken into account by the experimenter were as follows-

- Pronouncing a word incorrectly.
- Repetition of same word or sentence.
- Pausing in between while reading.
- Omitting a word while reading.

III. RESULT & DISCUSSION

To understand the effect of seated postures in Fore-and-Aft direction on reading speed expressed as CWPM (% static speed) for different vibration magnitudes (0.6 and 1.2 ms^{-2} r.m.s) and vibration frequencies, the median values of CWPM (% static speed) of all the subjects were plotted against vibration frequencies as shown in Figure-3, 4. The results obtained from Figure 3 reveals that for seated posture with vertical backrest, the reading speed decreases proportionally with increase in vibration magnitude for Fore-and-Aft direction which can be seen with help of the trend line.

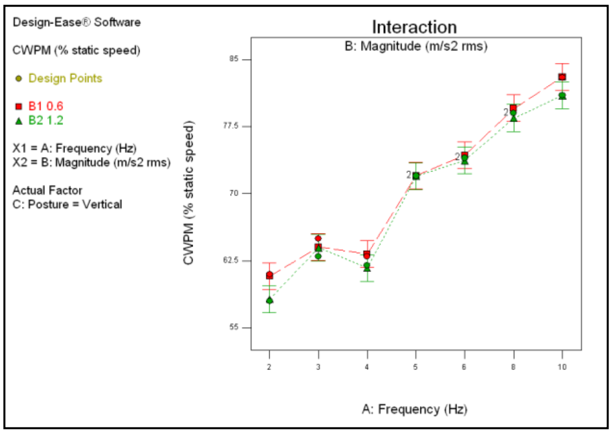

Fig. 3: Influence of vertical posture on reading speed (% static speed) for different magnitudes (0.6 and 1.2 ms^{-2} r.m.s.)

Increase in reading speed observed with increase in frequency except for 2 and 4 Hz, with a minimum reading speed of 57 CWPM (% static speed) for 0.6 ms^{-2} r.m.s magnitude and 60.5 CWPM (% static speed) for 1.2 ms^{-2} r.m.s magnitude at 2 Hz and a maximum reading speed of 79 CWPM (% static speed) for 0.6 ms^{-2} r.m.s magnitude and 83 CWPM (% static speed) for 1.2 ms^{-2} r.m.s vibration magnitude at 10 Hz.

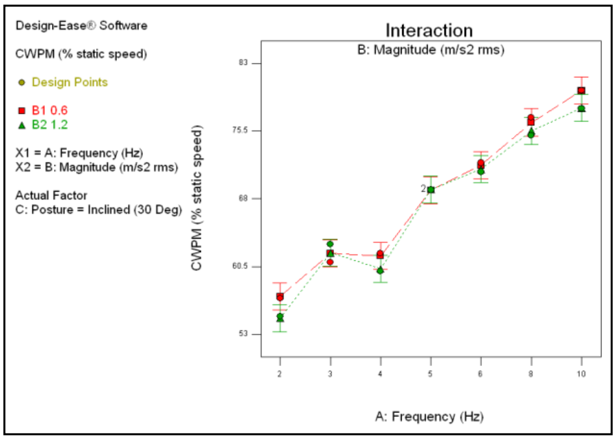

Fig. 4: Influence of inclined posture on reading speed (% static speed) for different magnitudes (0.6 and 1.2 ms^{-2} r.m.s.)

Figure 4 shows how reading speed is affected for different vibration magnitudes for inclined backrest. Reading speed decreases with increase in vibration magnitude for the inclined backrest condition. The same trend of increase in reading speed with increase in vibration frequency except for 4 Hz is also seen here with a minimum of 58 and 56 CWPM (% static speed) respectively for 0.6 ms^{-2} r.m.s and 1.2 ms^{-2} r.m.s vibration magnitude at 2 Hz and a maximum of 80 and 78 CWPM (% static speed) respectively for 0.6 ms^{-2} r.m.s and 1.2 ms^{-2} r.m.s magnitude at 10 Hz.

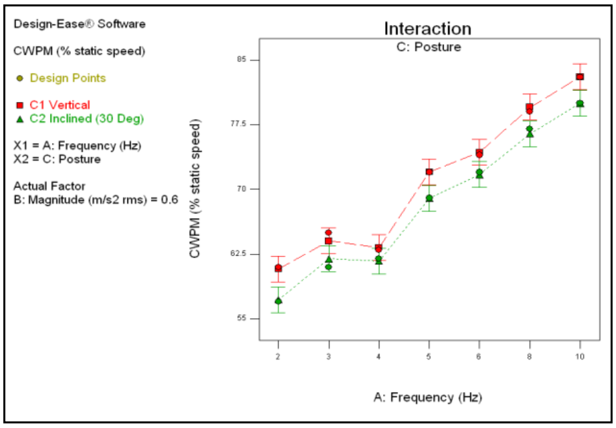

Fig. 5: Influence of 0.6 ms^{-2} r.m.s magnitude on reading speed (% static speed) for different postures (vertical and inclined)

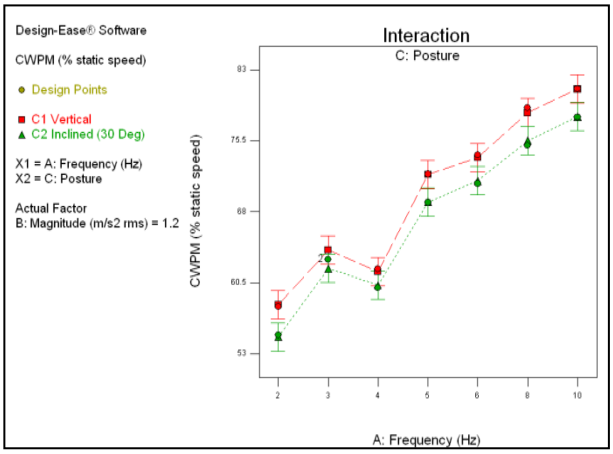

Fig. 6 : Influence of 1.2 ms^{-2} r.m.s. magnitude on reading speed (% static speed) for different postures (vertical and inclined)

The results from figure 5 and figure 6 reveals that the reading speed, for 0.6 and 1.2 ms^{-2} r.m.s magnitude, is more for seated posture with vertical backrest as compared to that of seated posture with inclined backrest. This shows that difficulty in reading with inclined backrest seated posture is more than the reading difficulty with vertical backrest for both the magnitude.

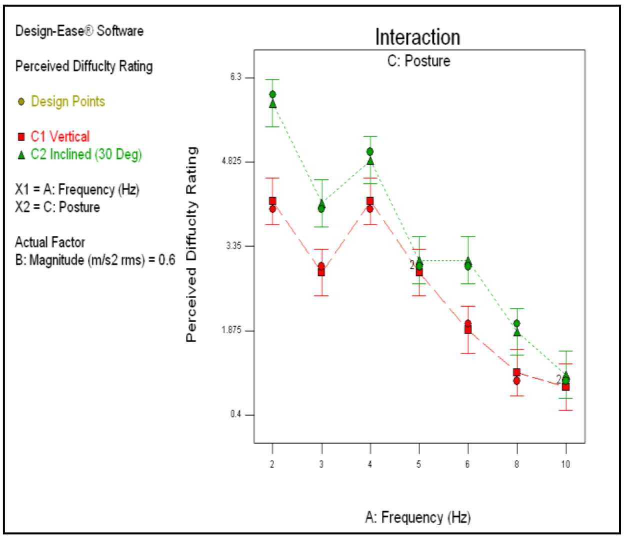

Fig. 7: Influence of 0.6 ms^{-2} r.m.s. magnitude on perceived difficulty for different postures (vertical and inclined)

Perceived difficulty for vertical backrest condition is less compared to that with inclined backrest condition, for both the magnitude, as evident from figures 7 and 8. For 0.6 ms^{-2} rms magnitude, maximum difficult was perceived at 2 Hz followed by the 4Hz for both the seated posture. At the frequency of 5Hz, perceived difficulty is same for both the Seated condition for 0.6 ms^{-2} rms as well as 1.2 ms^{-2}rms magnitude.

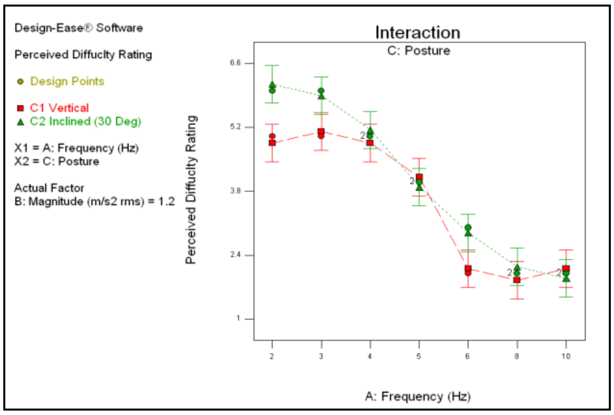

Fig. 8: Influence of 1.2 ms^{-2} r.m.s. magnitude on perceived difficulty for different postures (vertical and inclined)

Therefore performing reading task becomes more difficult as vibration magnitude increases for both seated postures. The reading task is also more difficult to perform when we lean against a backrest at an inclination as compared to that in vertical backrest posture. More Transmission of vibration from backrest to the body for inclined backrest posture may be the reason for making reading more difficult when compared to reading with vertical backrest condition.

Both the objective and subjective measures revealed that for each vibration magnitudes, seated posture with inclined backrest caused more reading impairment with decrement in reading speed and extent of perceived difficulty compared to that in seated posture with vertical backrest.

IV. REFERENCES

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