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Influence of reading format on reading activity under uniaxial whole body vibration

Vikas Kumar*, V.H. Saran

Mechanical and Industrial Engineering Department, Indian Institute of Technology, Roorkee, India

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ABSTRACT

In a railway vehicle, the vibrations are transmitted to the passengers through the various interfaces such as floor, seat, backrest etc. These vibrations affect the passenger comfort as well as their performance to do any work such as reading, writing, typing etc. In the present work, effects of vibration magnitude, direction of vibration, postures and reading formats have been studied on the reading activity. Thirty healthy male subjects have performed reading task, one at a time. All subjects were exposed to uni-axial whole body vibration in 1–20 Hz frequency range at 0.5, 1 and 1.5 m/s^2 rms vibration magnitude. The experimental task involved reading a paragraph under the different 54 experimental conditions (three magnitude, three direction, two posture and three reading format). The task performance has been evaluated in terms of time taken by the subjects to read a given paragraph and also the subjective evaluation of perceived difficulty on Borg's CR 10 scale. Perceived difficulty and performance degradation in reading have been found to increase with the increase in vibration magnitude in each direction of vibration. The perceived difficulty and performance degradation in reading have been observed to be higher in the fore-&-aft direction in with-backrest posture. In vertical and lateral vibration, perceived difficulty and performance degradation have been higher in without-backrest posture compare to with-backrest posture. The perceived difficulty and performance degradation have been lower for the triple-column format.

Relevance to industry: There is no availability of standards for the activity comfort in railway vehicles. Consideration of reading discomfort would be useful for vehicle design optimization to facilitate reading comfort.

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1. Introduction

Railway passengers often perform some sedentary activity like writing, reading, sketching, eating etc. during their journey time. Performance of such sedentary activities could be affected by the vehicle environment. Vibration present in the railway compartment adversely affects the performance of various sedentary activities (Corbridge and Griffin, 1991; Bhiwapurkar et al., 2010b; Sundström and Khan, 2008; Wollstrom, 2000). Field studies conducted on trains in different countries reported that reading is the most preferred sedentary activity performed by passengers (Bhiwapurkar et al., 2009; Khan and Sundström, 2004). Also, a majority of the passengers have reported train vibrations as the cause of discomfort, in response to a questionnaire in these studies. Laboratory studies have established significant influence of acceleration amplitude and vibration frequency on reading and writing activity (Griffin and Hayward, 1994; Bhiwapurkar et al., 2011, 2010a; Sundström and Khan, 2006). Influence of other variables like seated posture and type of activities, on activity performance, has been investigated. Reading performance was greatly affected by vibrations in fore-aft (X-axis), between 5.6 and 11 Hz frequency (Wollstrom, 2000). However, the effect was predominant when a seat with a backrest was used. Recent laboratory studies (Bhiwapurkar et al., 2011, 2012) on the reading a word chain in English, a Hindi newspaper and an English e-paper in vibration environment by measuring the subjective as well as objective responses, have reported significant influence of the whole body vibration on the reading activity. The resonance behaviour has been observed in human body in the frequency

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* Corresponding author. Tel.: +91 1332 285682; fax: +91 1332 285665.
E-mail addresses: viksmied@gmail.com (V. Kumar), saranfme@iitr.ernet.in (V.H. Saran).

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range from 1 to 20 Hz and having peak acceleration between 3 and 6 Hz when exposed to whole body vibration (Kitazaki and Griffin, 1997; Paddan and Griffin, 1988; Andersson et al., 2005). Variables like vibration magnitude, frequency, direction of vibration and subject posture affect the reading performance of the subjects which was evident from both subjective and objective measures of the perceived difficulty. Moreover the font type and font size of reading material had a strong influence on the perceived difficulty while reading in the vibrating environment. Arial type of all font sizes has shown less perceived difficulty in vibration, compared to Times New Roman type of font size (Bhiwapurkar et al., 2010c). There was an increase in perceived difficulty and degradation in reading performance for vibration in dual and multi-axes compared to mono axis vibrations.

Various studies (Griffin and Hayward, 1994; Sundström and Khan, 2008; Bhiwapurkar et al., 2011, 2012) have investigated the effect of different variables e.g. magnitude, frequency, type of vibration, font size, font type, language etc. The reading matters in newspapers, magazines, books or any other printed forms available in different formats vary from single column format to multi-column format. Reading format is a very important aspect of the reading matter, as reading activity involves the eye movement of the subjects while reading any printed matter (Griffin, 2003). The influence of reading format on reading performance under the whole body vibration exposure has not been investigated hitherto. In the present work, the effects of reading formats along with vibration magnitude, direction of vibration and postures on reading performance have been reported by conducting experimentation. The obtained results can be useful to enhance the reading comfort in the railway vehicles.

2. Methodology

2.1. Laboratory experimental setup

The experiment was carried out on the vibration simulator available in the Vehicle Dynamics laboratory, Indian Institute of Technology (IIT), Roorkee, India. The vibration simulator was developed as a mock-up of a train compartment and used in many previous studies (Bhiwapurkar et al., 2009, 2010a, 2010b, 2010c, 2011, 2012). The simulator consists of a platform (size 2 m × 2 m, made of stainless steel sheets) which can be excited with the help of three electro-dynamic vibration exciters, in three directions: vertical (*Z*-axis), lateral (*Y*-axis) and fore-&-aft (*X*-axis). Gaussian random vibrations (a type of broadband random vibration) can be generated by each vibration exciter having a capacity of 1000 N force and maximum stroke length (peak–peak) of 25 mm. A table and two chairs have been rigidly fixed on the platform of the vibration simulator (Fig. 1). On the basis of field study carried out in Indian railway, the surface of the chair seat and table was at heights of 45 cm and 75 cm respectively from floor. A fixed seat-table height ratio (3/5) was maintained throughout the experiment. The backrest was fixed in a vertical position at 90° to the chair seat. The chair seat and backrest both were made of wooden without cushion.

None of the accessories attached to the platform had shown any resonance in the frequency range 1–20 Hz (considered in this study) in any of the three axes. The platform vibrations were measured by mounting a tri-axial accelerometer (PCB PEZIOTRONICS-356A32), and the signals were transmitted to the Labview software via a data acquisition device (NI cDAQ-9174). The air conditioned environment at 26 °C temperature and 57% RH humidity, was maintained inside the chamber. The illumination from all direct and indirect light sources was 412–417 Lux and well-distributed over all the seat and table surfaces. The illumination level of 412–417 Lux was sufficient for reading activity (Charness and Dijkstra, 1999). The test subjects were seated on the chairs rigidly mounted on the platform of the vibration simulator such that these were excited with the same frequency as the platform, up to 20 Hz. The frequency of vibrations produced on board the railway vehicle ranges from .5 to 20 Hz which is also a critical range for the human beings (ISO 2631-4; Griffin, 2003; Mansfield, 2005).

2.2. Vibration parameters

In the present study, a continuous Gaussian random vibration in the frequency range 1–20 Hz was employed to provide excitation to the vibration platform. The typical power spectral density (PSD) generated by one of the vibration exciter over the frequency range of interest is shown in Fig. 2.

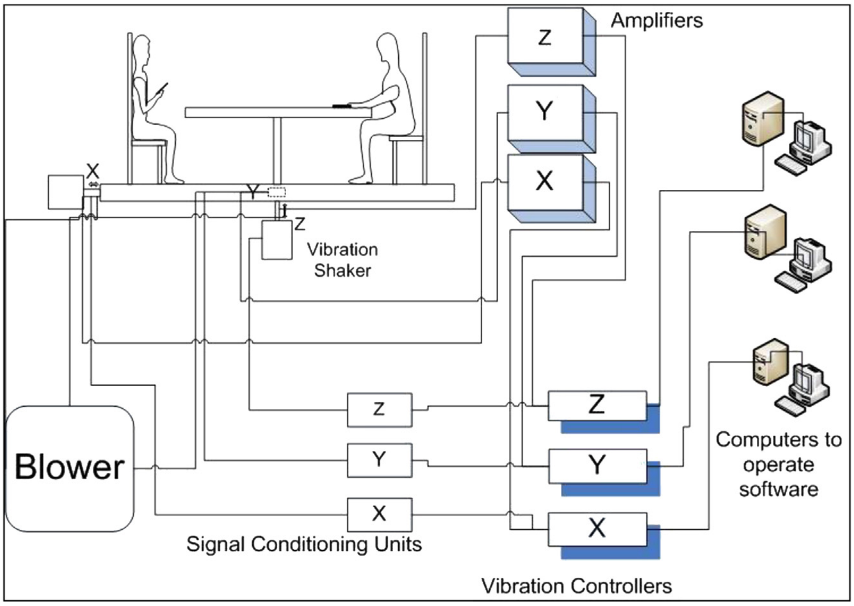

Fig. 1. Schematic diagram of computerized controlled vibration simulator.

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