Seat-to-Head Transmissibility and Reading Discomfort of the Seated Subjects Exposed to Whole Body Vibration

Vikas Kumar

Mechanical and Automation Engineering Department, Amity University Uttar Pradesh, India

V. H. Saran

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

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The transmission of vibration from the vibrating interface to various organs of the human body may influence their functioning during the vibration exposure. Therefore, an experimental study on a vibration simulator has been performed to find the effects of vibration on reading performance, and also to establish the relationship between seat-to-head transmissibility (STHT) with reading difficulty and reduction in reading performance. Twelve seated male subjects were exposed to sinusoidal vibration with three magnitudes (0.5, 1.0 & 1.5 m/s2 rms) at seven different frequencies (4, 5, 6.3, 10, 16, 20, and 25 Hz) in three independent directions (vertical, fore-and-aft, and lateral). The results show that three output measures - STHT, reduction in reading performance, and perceived difficulty in reading - are significantly affected by the frequency of vibration in each direction. All three measures have shown the peak at 4 or 5 Hz in three independent directions of vibration. Another peak at 25 Hz has also been observed for reduction in performance and perceived reading difficulty in vertical direction vibration. The results also show decrease in resonance frequency of the transmissibility with an increase in vibration magnitude, which represents nonlinear behaviour in biodynamic response by the human body.

1. INTRODUCTION

There are diverse effects of whole body vibration (WBV) exposure on the human body, such as discomfort, performance difficulty in various sedentary activities, and health effects. The biodynamic response of the human body to WBV may be used for the quantification of the diverse effects of vibration exposure.[10] Biodynamic responses are measured in terms of two functions: the 'to the body' function, and the 'through the body' function. The 'through the body' function describes the transmission of vibration from the input point to the various segments of the human body during the WBV exposure. The STHT measurement has been found to be appropriate for describing seated body responses to higher frequency vibration.[27]

The STHT measurement may be considered for the quantification of the activity discomfort in the WBV environment. The transmissibility is measured as the ratio of output acceleration to the input acceleration.[10]

$$\text{STHT} T_{STH}(f) = \frac{a_{head}(f)}{a_{seat}(f)}; \tag{1}$$

where $a_{head}(f)$ is acceleration at the head, and $a_{seat}(f)$ acceleration at the seat.

A large number of experimental studies[6,7,11,17,18,21,22,25] have focused on the transmissibility of vibration to various parts of the human body, such as seat-to-head, pelvis, lumber/cervical, etc., with a broad range of experimental conditions. Griffin and Whitham have observed the significant effect of individual variability on transmissibility of WBV through the seated subjects.[6] Many previous studies[17,19,27] have shown the relationship between STHT and Apparent Mass (APMS) of the seated subjects exposed to WBV with various experimental conditions, *e.g.* vibration magnitude, frequency range, vibration type, subject's anthropometric data, etc. The measured data in these studies have revealed nonlinearities in both APMS and STHT responses, and also shows stronger effects of hand position, backrest conditions, etc. In the field studies of Bhiwapurkar, *et al.*[1] and studies of Indian and Swedish trains by Khan and Sundström,[12] reading activity has been found to be the most preferable of all sedentary activities- *i.e.* writing, sketching, eating, etc.- to the passengers while travelling. Also, most passengers reported reading discomfort due to the train vibrations in response to a questionnaire used in these studies. Bhiwapurkar, *et al.*,[3,4] conducted the laboratory experiment on reading of a word chain in English, a Hindi newspaper, and an English e-paper under vibration exposure by measuring subjective and objective responses. The results revealed a strong influence of the WBV on the performance reduction in reading performance and increase in perceived difficulty. Experiments on reading and writing activity[3,4,8,12] show the strong influence of vibration amplitude and vibration frequency on the performance of these activities. The studies also show that a moderate level of discomfort has been found at low magnitudes of WBV. These results depend upon various conditions, such as sitting posture, direction of vibration, type of task to be performed, etc. Wollstrom observed a decrease in the reading performance in fore-and-aft (x-axis) vibrations be-