TRANSMISSIBLITY OF WHOLE_BODY VIBRATION FROM FLOOR TO SEAT EXPERIENCED BY SCRAPER OPERATORS IN THE CONSTRUCTION INDUSTRY

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Previous research suggests that seats may not be properly matched to equipment resulting in amplified exposure to whole-body vibration (WBV). The purpose of this study was to evaluate the transmissibility of WBV exposures from the floor to the seat experienced by scraper operators in the construction industry. In total 33 scrapers were tested. Tri-axial accelerometers and a Biometrics™ data logger were used to measure the vibration at both the seat and floor. Data collection and analysis complied with the 1997 ISO 2631 standards. The measurement period lasted until the operators completed three work cycles. The mean seat effective amplitude transmissibility (SEAT) factors were calculated in accordance with the 1992 ISO 10326 standards for each vehicle. Results indicated that on average the seats reduce the level of exposure by 4% (mean SEAT values of 0.96). However, the dampened values all exceed the ISO 2631 guidelines for the health caution zone.

Key words: whole-body vibration, transmissibility, seating

FACTEURS DE TRANSMISSION DES VIBRATIONS GLOBALES DU CORPS, À PARTIR DU SOL AU SIÈGE, ÉPROUVÉES PAR LES CONDUCTEURS DE SCRAPER DANS LE SECTEUR DE LA CONSTRUCTION

Les recherches antérieures laissent supposer que les sièges puissent ne pas correspondre adéquatement à l’équipement donnant lieu à une exposition accrue des vibrations globales du corps. La présente étude visait à évaluer les facteurs de transmission des vibrations globales du corps, à partir du sol au siège, éprouvées par les conducteurs de scraper dans le secteur de la construction. Au cours de l’étude, 33 conducteurs de scraper ont été testés. On a utilisé des accéléromètres à trois axes et un enregistreur de données Biometrics^{MD} pour mesurer les vibrations au niveau du siège et du sol. La collecte des données et l’analyse étaient conformes aux normes de l’ISO 2631 de 1997. La période d’évaluation s’est étalée sur trois cycles de travail complets. Les facteurs de moyenne de la transmissibilité de l’amplitude effective du siège ont été calculés selon les normes de l’ISO 10326 de 1992 pour chaque véhicule. Les résultats ont indiqué que les sièges ont en moyenne réduit le taux d’exposition de 4 % (valeurs de moyenne de transmissibilité de l’amplitude du siège de 0,96). Toutefois, les valeurs atténuées étaient toutes plus élevées que les valeurs établies dans les normes de l’ISO 2631 en ce qui concerne la mise en garde pour la santé.

Mots clés : vibrations globales du corps, transmissibilité, siège.

INTRODUCTION

A limited amount of research exists concerning whole-body vibration (WBV) in the construction industry. Cann et al. (2003) measured WBV exposures and doses of 14 different types of heavy equipment used in the construction industry and found that 10 out of 14 types of equipment placed operators at an increase risk of adverse health effects based on the ISO 2631 (1997) guidelines, with scrapers (figure 1) having the greatest WBV levels. Even fewer studies have reported on the transmissibility of vibration from the floor to the seat. Paddan and Griffin (2002) found that WBV exposures could have been improved by properly matching seating in 94% of the vehicles they tested. The purpose of the present study was to evaluate the transmissibility of WBV from the floor to the seat experienced by scraper operators in the construction industry.

Figure 1: Scarper used for moving soil.

METHODOLOGY

Operator and Equipment Information

Thirty-three scrapers from two large construction companies operating on residential and road construction projects in Southern Ontario during the summer of 2004 were tested. Each scrapper was controlled by the individual employed to operate the machine. Table 1 presents the descriptive data for the scrapers tested. It is important to note that the hours of operation frequently role over on the equipment and may not be an accurate indication of vehicle age. Typical durations of operation in the construction industry are eight-hour shifts; however, it is not uncommon for operators to work overtime depending on the workload.

Table 1: Description of Equipment Tested.

Model*	Number Tested	Road (#)	Residential (#)	Equip. Age (hrs)**	Seat Type
621B	13	1	12	8265	Spring
621E	7	0	7	18433	Spring
621F	5	2	3	9719	Pneumatic
621G	8	3	5	1132	Pneumatic

*All Scrapers tested were manufactured by Tormont Caterpillar.
** Mean hours of operation per machine.

Data Collection & Analysis

Test sessions for each piece of equipment lasted until three work cycles had been completed (approx. 20min.). Operators were instructed to go about their normal routines during the test session. The ISO 2631 (1997) WBV guidelines were followed for mounting of the vibration measurement equipment. A tri-axial seat-pad accelerometer was placed on the seat between the operator's ischeal tuberocities and a second tri-axial accelerometer was placed on the floor at the base of the seat. Each accelerometer was calibrated prior to the initiation of testing at each construction site in accordance with the manufacturer's guidelines. The tri-axial accelerometers (NexGen™ model S2-100-MF) collected data in all three orthogonal axes, with the x-axis positioned to measure vibration in the anterior-posterior direction, the y-axis in the medial-lateral direction, and the z-axis in the vertical direction. The vibration signal was sent to a Biometrics™ DataLog II data logger with a full scale range of ± 10 g at a sampling rate of 500 Hz. Data was downloaded to a PC computer for data analysis using the Biometrics DataLog II™ software and the Vibration Analysis ToolSet™ software from NexGen™. The vibration data originating from the seat was analyzed separately from the floor. Each file was filtered using a second order Hanning filter with a low-pass cut off of 100 Hz and a high-pass cut off of 0.5 Hz. The first step of the analysis was to calculate the root-mean-square (RMS) accelerations from the data files according to the ISO 2631 (1997) WBV guidelines. The ISO 2631 health caution zone weighting factors for seated exposures (W_d = 1.4[x and y axes], W_k = 1.0 [z-axis]) were applied to the RMS accelerations for comparisons with health caution zone guidelines. Other calculations included the vector sum of the weighted RMS accelerations for all three orthogonal axes, as well as the vibration dose value (VDV). The transmissibility of the WBV from the floor to the seat was evaluated using the seat effective amplitude transmissibility (SEAT) values. SEAT values are the ratio of the WBV exposure at the seat to that of the WBV at the floor, where a complete rigid seat would have a value of 1.0. SEAT values were calculated using VDVs at the seat and the floor.

RESULTS

Table 2: Mean VDVs and SEAT values by type of equipment for each axis.

Model	**VDV_{floor}**				**VDV_{seat}**			
	X-axis (m/s$^{1.75}$)	Y-axis (m/s$^{1.75}$)	Z-axis (m/s$^{1.75}$)	Vector Sum (m/s$^{1.75}$)	X-axis (m/s$^{1.75}$)	Y-axis (m/s$^{1.75}$)	Z-axis (m/s$^{1.75}$)	Vector Sum (m/s$^{1.75}$)
621B	4.5(±.1)	4.5(±.2)	10.9(±.4)	15.6(±.4)	6.0(±.1)	5.9(±.1)	11.8(±.3)	16.7(±.3)
621E	4.2(±.1)	4.2(±.1)	9.0(±.7)	13.1(±.6)	4.8(±.3)	5.1(±.1)	7.9(±.7)	12.6(±.7)
621F	4.9(±.1)	4.9(±.2)	13.7(±.2)	17.6(±.3)	5.4(±.1)	6.6(±.2)	10.0(±.2)	15.6(±.3)
621G	5.2(±.4)	5.2(±.2)	12.3(±.3)	16.9(±.6)	5.5(±.4)	6.6(±.2)	9.9(±.5)	15.6(±.7)
		SEAT Values						
	X-Axis	Y-Axis	Z-Axis	Vector Sum				
621B	0.91	1.32	1.08	1.07				
621E	0.87	1.23	0.88	0.96				
621F	0.88	1.25	0.72	0.89				
621G	0.85	1.27	0.80	0.92				
Overall	0.88	1.30	0.87	0.96				

Results of the WBV analysis using frequency-weighted RMS accelerations indicated that on average exposure for each model exceeded the ISO 2631 (1997) guidelines at the seat for each axis (X-axis: Range = 0.79 m/s^2 – 0.83 m/s^2, Y-Axis: Range= 0.81 m/s^2 - 0.97 m/s^2, Z-Axis: Range = 1.08 m/s^2 – 1.36 m/s^2). Due to frequent shocks the VDV was used for both comparisons to the ISO 2631 (1997) guidelines and for determining the transmissibility of vibration from floor to seat. Due to the high multi-axial values the vector sum of the orthogonal axes for the VDV was used for comparisons to the ISO guidelines, for which VDVs exceeding 8.5 m/s$^{1.75}$ for an eight-hour shift is the lower limit of the caution zone (ISO, 1997). Table 2 presents the average VDVs for each model of equipment at the floor and seat for all three axes and for the vector sum of the three orthogonal axes. The vector sum VDVs for each model exceeded the ISO guidelines indicating that scraper operators are at an increased risk of adverse health effects from the dose of WBV they experience during typical operation. Also contained in Table 2 are the SEAT values, indicating the overall effect the seat had in dampening the vibration experienced by scraper operators. There was an average dampening effect of 4%. However, operators of the model 621B were exposed to vibrations that were actually amplified. The data indicates that the y-axis was most responsible for greater overall vibration dose (vector sum of the VDV) from the floor to the seat in all models. Further information (Table 3) on the dominant frequencies at the floor and the seat indicate that only the newer models (621F & 621G) actually reduced dominant frequency of the vibration exposure. This was an important finding due to the fact that frequencies in the range of 4-8 Hz are most detrimental to the low back region (Griffin, 1990). However, the dominant vibration frequencies of the older seats was also below this range.

Table 3: Dominant frequencies at the floor and seat for each model.

Model	N	Location	X-Axis	Y-Axis	Z-Axis
621B	13	Floor	1.25	1.25	3.15
		Seat	1.25	1.25	3.15
621E	7	Floor	1.25	1.25	2.5
		Seat	1.25	1.25	3.15
621F	5	Floor	1.25	1.25	5
		Seat	1.25	1.25	3.15
621G	8	Floor	1.25	1.25	4
		Seat	1.25	1.25	2.5

DISCUSSION

On average only a 4% reduction in the levels of WBV dose from the floor to the seat was found in the present study. The seats in earlier models of (621B) scarpers actually amplified the vibration doses. Small reductions in dose at the seat in comparison with the floor were seen in the newer models, a fact that also corresponded to decreases in the dominant frequencies from 3.15 Hz to 2.5Hz. Despite the small reductions in transmissibility of the seats, the vibration doses and exposures still exceeded the ISO 2631 health caution zones. Therefore, more research needs to be done to improve seat designs. This is especially true in terms of multi-directional dampening, since most studies to date have only addressed the vertical access.

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