INFLUENCE OF SPEED IN WHOLE BODY VIBRATION EXPOSURE IN MINING HEAVY EQUIPMENT VEHICLES

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Introduction

Occupational exposure to WBV in professional vehicle operators is associated with an increased risk of work-related low back pain[1]. Heavy equipment vehicles (HEVs) are used extensively in large scale mining operations, exposing drivers regularly to WBV through various forms of work-related activities[2-3]. Operators in the mining industry consistently work 12-hour shifts with limited breaks and approximately 90% of their shift time is spent driving[3] and production demands also constrain the operation to few or no interruptions, 24 hours a day, 7 days a week and almost 365 days a year. Mining HEV fleets include large capacity haul trucks, graders, hydraulic and electric shovels, scrapers, front loaders, bull dozers and wheel dozers which expose operators to potentially harmful levels of WBV. The goal of this study was to characterize the daily average-continuous [A(8)] and cumulative-impulsive [VDV(8)] WBV exposures across six different types of mining HEVs, with the goal of determining whether the HEV operators' WBV exposures were above ISO daily vibration action limits, and to whether there were WBV exposure differences between the two WBV exposure parameters.

Methods

WBV exposures were measured from six HEVs (Table 1) and represented a total of 411 hours of full-shift WBV exposure data collected from 60 HEV operators. WBV exposure data were collected according to ISO 2631-1 standards at 1280 Hz using a seat pad accelerometer (Model 356B41; PCB Piezotronics; Depew, NY) connected to either a four or an eight-channel data recorder (Model DA-20 or DA-40; Rion Co., LTD.; Tokyo, Japan). Continuous and impulsive WBV exposures were collected, and to enable comparisons across HEVs, WBV exposures normalized to represent a daily exposure of 8 hours [A(8) and VDV(8)]. Since some data was not normally distributed, all data were summarized using median values and the minimum and maximum values to show the range of the measurements.

Results

WBV exposures grouped by their predominant axis appeared to be dependent on the average speed of the HEV (Table 1). The x-axis predominated for the slowest speed HEVs, the y-axis for the intermediate speed HEVs, and the z-axis for the HEVs with the highest average speeds. The average-continuous A(8) and the cumulative-impulsive

Table 1. Median (min – max) daily WBV exposures by parameter and axis arranged in ascending order of vehicle speed, Σxyz is the vector sum exposure of all three axes. The shaded

cells under each parameter indicate the predominant exposure axis for each HEV. Recommended daily vibration action limits are provided above each exposure parameter.

HEV	# of Meas	Average speed (km/h)	A(8) 0.5 m/s^2				VDV(8) 9.1 $m/s^{1.75}$			
			1.4x	1.4y	z	Σxyz	1.4x	1.4y	z	Σxyz
Bull Dozer	14	2.4	0.60 (0.47 - 0.80)	0.56 (0.46 - 0.87)	0.44 (0.29 - 0.76)	0.91 (0.75 - 1.4)	13.9 (11.4 - 17.2)	12.7 (10.5 - 18.4)	9.9 (6.8 – 16.0)	16.6 (13.5 - 22.8)
Front Loader	9	2.9	0.57 (0.42 - 0.67)	0.57 (0.43 - 0.71)	0.27 (0.22 - 0.37)	0.87 (0.64 - 0.98)	13.7 (10.8 - 15.1)	12.9 (11.7 - 36)	8.0 (6.5 - 10.8)	16.4 (14.5 - 36.1)
Grader	9	6.8	0.41 (0.24 - 0.53)	0.58 (0.33 - 0.82)	0.48 (0.31 - 0.57)	0.89 (0.52 - 1.14)	10.9 (8.9 - 18.4)	14.0 (9.3 - 23.9)	10.8 (9.2 - 13.8)	16.6 (13.6 - 24.3)
Scraper	10	12.0	0.51 (0.38 - 0.94)	0.69 (0.51 - 0.96)	0.65 (0.51 - 0.83)	1.10 (0.82 - 1.47)	12.3 (9.0 - 55.7)	14.8 (11.7 - 19.8)	14.4 (11.6 - 16.3)	19.3 (14.4 - 55.8)
Water Truck	10	14.0	0.36 (0.26 - 0.48)	0.38 (0.23 - 0.54)	0.48 (0.23 - 0.48)	0.72 (0.46 - 0.95)	9.6 (8.2 - 25.6)	9.9 (6.2 - 22.5)	11.8 (8.4 - 13.2)	14.5 (10.4 - 26.2)
190 Ton Truck	8	20.2	0.38 (0.26 - 0.50)	0.30 (0.24 - 0.52)	0.48 (0.27 - 0.69)	0.70 (0.50 - 0.81)	9.1 (7.0 - 23.8)	6.6 (5.6 - 26.4)	11.0 (9.8 - 12.2)	13 (11.9 - 29.6)

VDV(8) exposure metrics had similar trends with respect to HEV speed.

Most of the predominant axis WBV exposures were above the ISO daily vibration action limits and all the vector sum-based (Σxyz) WBV exposures were considerably higher than the predominant axis exposures.

Based on the predominant axis of exposure and the vector sum exposures, the amount of time the HEVs could be operated until reaching ISO daily vibration action limits was often shorter than a 12 hour shift. Comparing the A(8) and VDV(8) WBV exposure parameters, HEV operation time was considerably shorter for cumulative-impulsive VDV(8) WBV exposures in comparison to the more traditional average-continuous A(8) WBV exposures.

Discussion

A notable finding in this study was the apparent relationship between the predominant axis of WBV exposure and average HEV speed. The VDV(8) WBV exposures were higher and reduced acceptable HEV operation times by one-half to two-thirds relative to the A(8) WBV exposures. These parameter-based differences in WBV exposure risk would impact the prediction/estimation of adverse health outcomes. These results indicated that HEV mining operators are exposed to high levels of both continuous and impulsive WBV exposures. Finally, the larger vector sum exposures indicated that a single, predominant axis of exposure was uncommon.

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