EVALUATION OF SCRAPER OPERATOR EXPOSURE TO WHOLE-BODY VIBRATION IN THE CONSTRUCTION INDUSTRY

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ABSTRACT

Whole-body vibration (WBV) exposure is a major concern for large equipment operators in the construction industry. The objective of this study was to determine if the exposure to whole body vibration of scraper operators exceeded the 1997 ISO Standard 2631. The operator completed five distinct tasks: 1) traveling fully loaded with dirt, 2) dumping and distributing dirt, 3) traveling empty, 4) idling while waiting to be pushed by a bull-dozer to scrape more dirt, 5) scraping a new load of dirt. Twenty-minute vibration samples that included at least three work cycles were taken using 33 scrapers. The average rms acceleration of the z-axis was 1.21 m/s^2. The dominant axis for which the vibration acted through the seat was the z-axis (vertically through the seat pan). Vector sum values were 2.08 m/s^2. The WBV values obtained demonstrate that a major health hazard exists for the operators of scrapers.

Keywords: Vibration, scrapers, health hazard

ÉVALUATION DE L'EXPOSITION AUX VIBRATIONS GLOBALES DU CORPS CHEZ LES CONDUCTEURS DE SCRAPER DANS LE SECTEUR DE LA CONSTRUCTION

Résumé

L'exposition aux vibrations globales du corps représente une préoccupation importante pour les conducteurs d'équipement lourd dans le secteur de la construction. La présente étude avait pour but de déterminer si l'exposition aux vibrations globales du corps dépassait les normes 2631 de l'ISO, mises en vigueur en 1997. Le conducteur devait réaliser cinq tâches distinctes : 1) rouler avec un chargement complet de terre; 2) décharger et étaler la terre; 3) rouler sans charge; 4) faire rouler le moteur au ralenti en attendant d'être poussé par le bouteur pour racler la terre; 5) racler un nouveau chargement de terre. Des échantillons de vibrations d'une durée 23 minutes, relevés pendant au moins trois cycles de travail, ont été prélevés sur 33 conducteurs de scraper. L'accélération R.M.S. moyenne de l'axe z était de 1,21 m/s^2. L'axe dominant sur lequel agissait les vibrations à travers le siège était l'axe z (passant verticalement à travers le plateau du siège). Les valeurs de somme vectorielle étaient de 2,08 m/s^2. Les valeurs de l'exposition aux vibrations globales du corps recueillis ont démontré que les conducteurs de scraper étaient exposés à des risques importants pour la santé.

Mots clés : vibrations, scraper, risque pour la santé.

INTRODUCTION

Despite the fact that the construction industry in North America and Europe is heavily mechanized and therefore a significant number of workers (as many as 540,000 in USA) are exposed to WBV, Kittusamy (Kittusamy & Buchholz, 2004) suggest that there have been few studies conducted to assess exposure to whole-body vibration (WBV) in the construction industry. They suggest that there is very little reliable data from the construction industry that characterizes exposure levels to various hazards including WBV or the health outcomes from such exposure and that there is a need for more exposure data. Many papers linking exposure to WBV to adverse health effects, such as low back pain, have not directly measured vibration characteristics of the jobs being studied (Seidel & Heide, 1986). In a recent exploratory study of heavy construction equipment Cann (Cann, Salmoni, Vi, & Eger, 2003) looked at vibration levels for 14 different types of construction equipment. Eight of the 14 pieces of equipment tested exposed operators to levels of WBV that exceeded the recommended limits for an 8-hour period when comparing the measured VDV to the ISO 2631-1 standards. A limitation of this study, however, was that very small numbers of vehicles in each category were tested. Nonetheless, based on the exposure values observed, it seemed that scrapers would be an important place to begin a more detailed assessment of exposure to WBV in the construction industry. The four scrapers tested produced a mean weighted RMS acceleration of 1.61 m/s^2 with a range of 1.3-2.0 m/s^2.

In many industries such as forestry, mining, and construction, specialized pieces of equipment often perform a particular set of tasks repeatedly throughout a workday. For example, LHD or load-haul-dump vehicles in mining travel back and forth from the ore site (where they are loaded) to a dumpsite (from which the ore is transported for further processing). As reported above, Village (Village, Morrison, & Leong, 1989) broke the operation of LHD mining vehicles into five tasks: idling, mucking, driving full, dumping, and driving empty. They found the two driving tasks to produce the greatest levels of WBV. To determine daily exposures the exposure levels for each task were weighted by the amount of time spent under each task condition. For example, Village et al, (1989) reported that LHDs spent from 8-14% of their time mucking. Time weighted daily exposure values were reported separately for each machine and compared to the exposure limits for a 6-hour day. Therefore, the purpose of the present research was not only to test a larger number of scrapers than in our previous work, but also to investigate scraper operator exposure to WBV separately for each task.

METHODS

34 scrapers were evaluated for whole body vibration in a variety of residential and road construction projects. One scraper was eliminated from the study due to errors in the transmission of collected data leaving 33 scrapers analysed. Testing equipment consisted of triaxial accelerometers (NexGen™ Ergonomics model S2-100-MF) that allowed vibration data collection 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. Each accelerometer was calibrated prior to the initiation of testing at each construction site in accordance with the manufacturer's guidelines. The vibration signal detected by the accelerometers was filtered using a low pass filter set at 100 Hz prior to being sent to a Biometrics™ DataLog II (P3X8) data logger with a full scale range of $\pm$ 10 g at a sampling rate of 500 Hz. Data was stored in the data logger on a 128 Mb Simpletech™ multimedia card and then downloaded onto a laptop PC computer for data analysis, which was conducted using the Biometrics Datalog II™ software (Version 3.00) and the Vibration Analysis ToolSet™ software (Version 2.4.0) from NexGen™ Ergonomics. Root mean square accelerations (aRMS), vibration dose value (VDV), crest factor, and maximum transient vibration value (MTVV) were derived from this software and exported to an Excel™ spreadsheet for later data analysis.

Test sessions for each piece of equipment lasted for approximately 20 minutes until at least three work cycles had been completed. Operators were told to engage in normal scraping routines during the test session. Each test session was videotaped using a JVC mini-DV camcorder. The purpose for videotaping the test sessions was to identify the individual subtasks in each work cycle. Work cycles tested represented all tasks for which the equipment was typically used throughout the day. Tasks included: idling while waiting for a bulldozer to push the scraper through the scraping phase, scraping, traveling loaded, dumping and traveling empty.

RESULTS

Task breakdown by time reveals that approximately 23% of the work cycle was spent traveling fully loaded with dirt, 20% dumping, 22% traveling unloaded, 15% idling and 20% scraping. Calculation of aRMS vector sums gave values of 2.55 m/s^2 during loaded transport, 2.46 m/s^2 during dumping, 2.31 m/s^2 during unloaded travel, 0.55 m/s^2 during idling and 1.46 m/s^2 during scraping (see Table 1). The highest acceleration values recorded were found in the z-axis during fully loaded transport reaching an average aRMS over three work cycles of 2.55 m/s^2.

Peak values can be seen in Table 2. These acceleration values followed a similar trend to aRMS. Because of the relatively low Crest Factors (<9) it is reasonable to trust the aRMS data (Table 1) as being representative of the WBV experienced by operators (Griffin, 1990; ISO, 1997). However, peak values followed a similar trend to aRMS values with the z-axis exhibiting the highest values (Table 2).

Table 1: Summary of Whole Body Vibration aRMS from the x,y,z axes *n=33*

aRMS (m/s$^{2)}$	*Loaded*	*Dump*	*Unloaded*	*Idle*	*Scrape*	*Overall*
X (m/s^2)	0.972005	0.939853	0.881099	0.234901	0.597173	0.814794
Y (m/s^2)	1.039127	0.994199	0.945996	0.212603	0.59443	0.863697
Z (m/s^2)	1.547658	1.49347	1.391072	0.318516	0.827509	1.282011
Vector Sum (m/s^2)	2.554516	2.46132	2.307009	0.552645	1.457328	2.121071

Table 2: Summary of Whole Body Vibration Peak Values from the x,y,z axes *n=33*

Peak Value (m/s^2)	*Loaded*	*Dump*	*Unloaded*	*Idle*	*Scrape*	**Overall**
X (m/s^2)	4.786353	4.667217	4.393374	1.489637	3.071722	5.574684
Y (m/s^2)	4.975314	4.815351	4.91602	1.331404	3.062997	6.047195
Z (m/s^2)	12.66757	12.40512	11.53527	2.402871	5.833824	15.81211

Individual measurements were recorded by equipment model. Analysis of variance (ANOVA) demonstrated no significant differences between equipment models. Pairwise comparisons revealed significant differences in accelerations when analysed between tasks. As can be seen in Table 3, traveling loaded, dumping and traveling unloaded are significantly different from both idle and scrape *(p<.001)*.

Pairwise Comparisons

Measure: MEASURE_1

(I) cond	(J) cond	Mean Difference (I-J)	Std. Error	Sig. [a]	95% Confidence Interval for Difference [a] Lower Bound	Upper Bound
1	2	.093	.104	.378	-.119	.305
	3	.248*	.102	.022	.039	.456
	4	2.002*	.139	.000	1.720	2.284
	5	1.097*	.142	.000	.807	1.387
2	1	-.093	.104	.378	-.305	.119
	3	.154	.109	.167	-.068	.377
	4	1.909*	.117	.000	1.671	2.146
	5	1.004*	.112	.000	.776	1.232
3	1	-.248*	.102	.022	-.456	-.039
	2	-.154	.109	.167	-.377	.068
	4	1.754*	.104	.000	1.543	1.966
	5	.850*	.143	.000	.557	1.142
4	1	-2.002*	.139	.000	-2.284	-1.720
	2	-1.909*	.117	.000	-2.146	-1.671
	3	-1.754*	.104	.000	-1.966	-1.543
	5	-.905*	.112	.000	-1.133	-.676
5	1	-1.097*	.142	.000	-1.387	-.807
	2	-1.004*	.112	.000	-1.232	-.776
	3	-.850*	.143	.000	-1.142	-.557
	4	.905*	.112	.000	.676	1.133

Based on estimated marginal means

Table 3: Statistical Analysis of Differences Between Scraper Tasks
(1=Travel Loaded, 2=Dump, 3=Travel Unloaded, 4=Idle, 5=Scrape) *n=33*

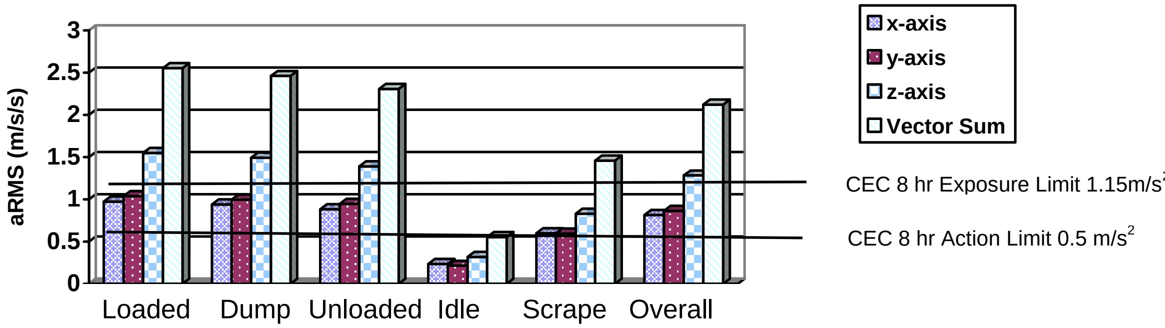

Figure 1: Comparison of Scraper aRMS Values to CEC WBV Limits

DISCUSSION

The overall vector sum aRMS values exhibit accelerations well beyond the Commission of European Communities (CEC) recommended 8 hour levels (Figure 1). In a review of European Union whole body vibration exposure standards Griffin confirms the 8 hour action limit to be 0.5 m/s^2 and the 8 hour exposure limit of 1.15 m/s^2 (Griffin, 2004). Results are consistent with whole body vibration measurements from previous work. Accelerations are repeatedly in excess of maximal exposure limits recommended by ISO. This leads one to conclude that all scrapers will expose the operator to excessive levels of whole body vibration that may lead to injury or illness. Some steps can be taken to decrease WBV risk through analysis of elimination, substitution, isolation, engineering controls, administrative considerations and health surveillance. The solution to harmful vibration does not lie in spending more time and money testing construction equipment, especially scrapers. Research has confirmed that according to the CEC, scraper operators are exposed to higher than recommended levels of vibration. The solution lies in the engineer's hands. Attacking this problem through better seat design is thought to enable a decrease of over 50% of floor to seat WBV transmissibility (Griffin, 1990). Improving vehicle suspension, cab vibration absorption and vehicle engine mounts will keep the solution at the source of the problem rather than at the operator.

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