LABORATORY ASSESSMENT OF VIBRATION EMISSIONS FROM VIBRATING FORKS USE SIMULATED BEACH CLEANING

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1. INTRODUCTION

As part of NIOSH's response to the BP Deepwater Horizon oil spill, representatives traveled to the gulf coast to observe and assess workers involved in beach cleaning operations, to identify potential hazards and to provide guidance for protecting response workers. One beach cleaning operation involved the use of lightweight, battery-powered, motorized vibrating manure forks to remove tar balls and patties from beach sand. To investigate the vibration exposures associated with these operations, we performed a laboratory study on the vibrations produced by the forks operated during simulated beach cleaning. The objectives of this study were to characterize the vibrations associated with the use of vibrating manure forks and to estimate vibration exposure time limits based on the recommendations of ANSI S2.70-2006.

2. METHODS

The test apparatus for the laboratory study consisted of a mortar-mixing tub filled with a fairly homogenous mixture of moist sand and debris (pine bark mulch and golf balls). The vibrating forks evaluated in this study were Shake'n Fork™ models (Equi-Tee Manufacturing, Oregon, USA). Two fork models were evaluated in the study. One featured a variable-speed motor with a top speed of 980 rpm; the second fork had a top speed of 1400 rpm. There were two different basket arrangements evaluated. Both baskets featured plastic tines with 1/2-inch spacing. One basket featured a section of wire screen (1/4-inch mesh) attached to its tines. With two motors and two baskets, there were four different tool configurations evaluated in the experiment.

Eight adults (four male, four female) were recruited to operate the forks. To complete the simulated work task, the operator used a fork to scoop sand and debris out of the mortar-mixing tub. As shown in Figure 1, the subject stood on a platform-mounted force plate and used a two-handed posture to control the tool. The subject placed their dominant hand on the upper handle, while their non-dominant hand supported the fork handle near its midpoint. The operator inserted the fork into the tub, scooped a load of sand and debris, and lifted the loaded fork 12 to 18 inches directly above the tub. Once the basket load was weighed and adjusted to within 50±5 N, the operator was signaled to start the fork's shaker motor by fully depressing the tool's handle-mounted trigger.

The four tool configurations were presented to the subjects in random fashion. Each tool configuration was subjected to a measurement sequence of eight consecutive trials. first five trials in the sequence were completed wit basket loaded; the next three trials were completed w empty basket. Vibration data were collected for seconds per trial. Once eight trials were completed v particular motor/basket combination, the next motor/b configuration was presented to the operator anc sequence was repeated.

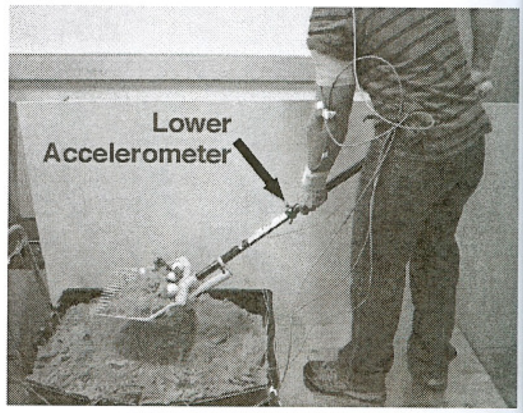

Figure 1. Simulated beach cleaning operation.

Two piezoelectric triaxial accelerometers were use measure the vibration emissions. The lower accelero was affixed near the midpoint of the tool handle just b the operator's non-dominant hand (see Figure 1). The u accelerometer was affixed near the handle-mounted tri The root-sum-of-squares (total) values of the r accelerations were weighted according to the freque weighting factors given in ISO 5349-1, 2001.

Estimated daily vibration exposure values, A(8), calculated using the methods outlined in ISO 5349-2, and ANSI S2.70-2006. The vibration measurements used to estimate the maximum amount of vibration exp time per eight-hour work shift that a user could oper particular fork configuration without exceeding the A Daily Exposure Action Value (DEAV=2.5m/s^2) and Daily Exposure Limit Value (DELV=5.0m/s^2).

3. RESULTS

The frequency-weighted acceleration means fo upper and lower accelerometers are presented in Figu ANOVA results indicate that the mean acceleration fo fast fork was significantly higher than that for the slow The tines-only basket produced higher accelerations tha basket with the wire mesh screen. Acceleration was higher for the unloaded forks as compared to the loaded forks. The accelerometer mounted lower on the fork measured higher vibrations than the upper accelerometer.

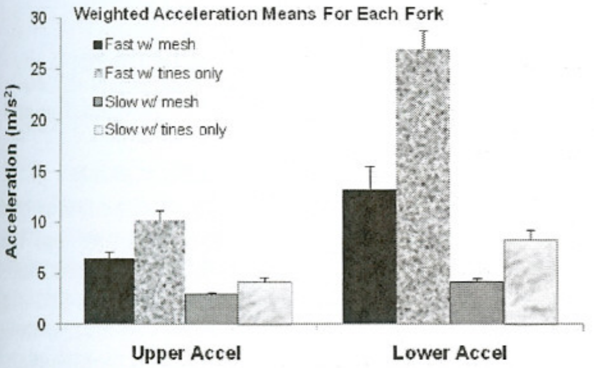

Figure 2. **Weighted acceleration means for each fork with the baskets in the loaded condition. (Error bars equal +1 SD).**

As indicated in Table 1, the tines-only fast fork could be operated for only four minutes at maximum speed before reaching the ANSI DEAV. On the other hand, the slow fork with the mesh basket could be operated at full throttle for almost three hours before reaching the action value.

Table 1. **Operation time limits for each configuration to remain below the ANSI S2.70-2006 DEAV and DELV.**

Motor	Basket	a_{hv} (m/s^2)	T_{DEAV} (min)	T_{DELV} (min)
Fast	Wire mesh	13.10	17	70
Fast	Tines only	26.89	4	17
Slow	Wire mesh	4.14	175	702
Slow	Tines only	8.27	44	175

4. DISCUSSION & RECOMMENDATIONS

The frequency-weighted accelerations in this study were found to be substantial, especially those for the non-dominant hand. It should be noted that all of the measurements were collected with the fork motors operating at maximum speed. In actual beach cleaning operations during the BP Deepwater Horizon oil spill cleanup, these tools were not always operated at full speed. Furthermore, the forks were seldom operated without a load. Thus, actual hand-arm vibration exposures in the field may be lower than the values reported here.

The dominant frequency of these tools is about 20 Hz. There is little to no epidemiological evidence to indicate that tools with dominant frequencies below 25 Hz can be associated with vibration-induced white finger (Griffin, 1990). And while low-frequency percussive tools have been linked to bone and joint disorders (Gemne and Saraste, 1987), non-percussive tools have not been implicated in the causation of such disorders. These observations have led to much debate about the appropriateness of the frequency weighting presented in the ISO standard, especially at lower frequencies (Bovenzi, 1998). Therefore, it remains debatable whether or not the ANSI DEAV and DELV limits are applicable to low-frequency, non-percussive tools, such as the vibrating forks evaluated in the present study. Even if the ANSI action and limit values are too conservative for this tool type, the high levels of vibration observed could cause considerable discomfort in the arms, shoulders, neck, and head, because low-frequency vibration can be effectively transmitted to these substructures. Recommendations based on this study are as follows:

Limit run time – Operators of these forks should reduce the amount of "trigger time" to short bursts that are just sufficient to separate the debris from the beach sand.
Operate the forks at the lowest possible speed – The forks are equipped with variable-speed motors. Faster operating speeds results in higher vibration exposures. These forks should be operated with just enough speed to get the job done; it is usually not necessary to fully depress the trigger.
Do not operate the forks unloaded – The loaded basket helps to dampen the vibration. These forks should not be operated in the unloaded condition.
Do not use anti-vibration gloves with these tools – Anti-vibration gloves are not effective at attenuating low-frequency vibrations, and may even amplify certain frequencies below 150 Hz (ISO 10819:1996). The dominant frequency for these vibrating forks is around 20 Hz, therefore use of anti-vibration gloves is not appropriate

REFERENCES

ANSI S2.70, (2006). *Guide for the Measurement and Evaluation of Human Exposure to Vibration Transmitted to the Hand* (American National Standards Institute, New York).

Bovenzi, M. (1998). "Exposure-response relationship in the hand-arm vibration syndrome: an overview of current epidemiology research," Int. Arch. Occup. Environ. Health, **71**, 509-19.

Gemne, G., and Saraste, H., (1987). "Bone and joint pathology in workers using hand-held vibration tools," Scand. J. Work Environ. Health, **13**, 290-300.

Griffin, M. J. (1990). *Handbook of Human Vibration* (Academic Press, London).

ISO 10819 (1996). *Mechanical Vibration and Shock -- Hand-Arm Vibration -- Method for the Measurement and Evaluation of the Vibration Transmissibility of Gloves at the Palm of the Hand* (International Organization for Standardization, Geneva).

ISO 5349-1 (2001). *Mechanical Vibration -- Measurement and Evaluation of Human Exposure to Hand-Transmitted Vibration -- Part 1: General Requirements* (International Organization for Standardization, Geneva).

ISO 5349-2 (2001). *Mechanical Vibration -- Measurement and Evaluation of Human Exposure to Hand-Transmitted Vibration -- Part 2: Practical Guidance for Measurement at the Workplace* (International Organization for Standardization, Geneva).

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