OCCUPATIONAL VIBRATION IN THE FOUNDRY

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ABSTRACT

Occupational exposure of workers to vibration in foundries is discussed, including hand-arm vibration during chipping and grinding and whole-body vibration in the mold shakeout areas. The use of various vibration transducers, measuring techniques, and methods of data analysis are briefly presented with practical examples cited. An interim work practices guide is suggested for workers exposed to whole-body and hand-arm vibration.

INTRODUCTION

In the early 1970's NIOSH was asked to help determine the health and safety effects of occupational vibration on workers. Before embarking on actual field, laboratory, and epidemiology studies it was necessary to first attempt to define the worker populations exposed to occupational vibration (1). In 1971, we conducted an extensive series of walkthrough plant and worksite tours. The results of these tours, together with population extrapolations using Department of Labor job statistics, indicate that some 8 million workers in the U.S. are exposed to occupational vibration. Of this number, some 6.8 million are exposed to "whole-body vibration" (head-to-toe vibration as one might experience from a vehicle or plant floor); and the remaining 1.2 million are exposed to "hand-arm" or segmental vibration (as one might experience from a vibrating hand tool such as a chain saw, chipping hammer, or grinder)(2).

Three of the plant worksites toured in 1971 were foundries. A summary of our observations made at that time is as follows:

> Two foundries manufactured large castings, the third manufactured smaller castings in volumes of 60 to 70 per hour. In all cases severe whole-body, segmental, and intermittent vibrations were observed. In particular, intermittent, whole-body vibration appeared during the mold shakeout operation where the special sand and other material surrounding the castings were removed. Workers were closely coupled to the vibration source in this operation. Acceleration levels appeared high. Segmental vibration was observed in the hand tamping, casting, and

chipping operations. Workers in these operations were closely coupled to their hand tools. Finally, vibration was observed in the overhead cranes. Noise levels were high, but workers wore hearing protection (2)

The 1971 job statistics indicated there were some 487,400 foundry workers at that time and we estimated that 40% of these workers (about 194,000) were exposed to occupational vibrations (3). The job categories included chippers and grinders, mold shakeout workers, workers operating overhead cranes, and lift-truck operators. Thus, there appears to be reasonable cause to conduct occupational vibration research in the foundry industry in conjunction with other industries in an effort to determine the health and safety consequences to foundry workers of occupational exposure to vibration.

The purpose of this paper is to familiarize and up-date the reader with NIOSH vibration activities related to foundries. This includes briefly describing measurement methods employed in foundry studies and suggesting a work practices guide.

WHOLE-BODY VIBRATION

Whole-body vibration is referred to as a generalized stressor which appears to affect multiple body sites and organs, depending on the vibration characteristics. The human body has a tendency to "resonate", that is, to act in concert with externally generated vibration and to actually amplify the vibration of certain frequencies and reject other frequencies. For example, the entire body tends to resonate at about 5 Hz and the head and shoulders can resonate in the 20 to 30 Hz range. The eyeballs can resonate in the 60 to 90 Hz range. The hand-arm system can resonate in the 100 to 150 Hz range. In general, the larger the system mass the lower the resonant frequency.

Little is known about the chronic effects of whole-body vibration on man. However, human studies have indicated such subtle effects as the inability to maintain posture, increased oxygen consumption, and increased pulmonary ventilation due to vibration exposure (4, 5, 6,7). However, in the human performance area, with its possible safety implications, studies of vibration have shown that the lowest subjective-discomfort-tolerance level occurs around the 5 Hz resonant point. Manual tracking capability is also most seriously affected at this 5 Hz point. Visual acuity is severely impaired in the 1 to 25 Hz range.

On the other hand, performance of tasks such as those involving pattern recognition, reaction time, and monitoring appears not to be affected by exposure to vibration (8, 9). Simulated heavy equipment driving tests which compared the effects of a mixture of simultaneous vibratory frequencies (similar to actual occupational vibration) revealed that human subjects performed worse under the mixed conditions, gradually improving as the mixture was replaced by nonresonant single sinusoidal vibratory conditions (10).

HAND-ARM VIBRATION

Hand-arm or segmental vibration, unlike whole-body vibration, appears as a localized stressor creating injury to the fingers and hands of exposed workers using such vibratory hand tools as chain saws, and pneumatic and electrically operated rotary grinders. Extensive use of such tools (especially in cold environments) has led to Raynaud's Phenomenon, i.e., "dead hand" or "vibration white fingers (VWF)". This condition is characterized by numbness and blanching of the fingers with probable loss of muscle control and reduction of sensitivity to heat, cold and pain (11). Medically, the occurrence of Raynaud's Disease (as distinguished from Raynaud's Phenomenon) in the normal population is about 6-8% and is not necessarily associated with use of vibrating hand tools (12).

NIOSH WHOLE-BODY VIBRATION FIELD STUDIES

Past NIOSH whole-body vibration epidemiology and field studies have concentrated principally in the area of vehicular transportation (13, 14, 15, 16). We have developed unique capabilities to measure vibration and other physiological and environmental factors which affect the worker in moving vehicles as well as in stationary situations such as plant environments. These studies have been concentrated in the area of heavy equipment operation (17, 18). To date we have not conducted a whole-body engineering study in a foundry situation.

Vibration is a vector quantity possessing both a magnitude and a direction and must be carefully measured. There are three quantities of interest in the quantification of vibration:

1. Displacement, the distance between the normal resting position of an object and its position at a given time in its vibratory cycle.

2. Velocity, the time rate of change of displacement.

3. Acceleration, the time rate of change of velocity.

Acceleration has been the most frequently used measure of vibratory magnitude because of readily available transducers and because both vibration velocity and displacement can be easily derived from this single measure with electronic integration. Acceleration is measured in gravitational (g) units, expressed also in meters/second^2, where $1 \text{ g} = 9.8 \text{m/sec}^2$.

Generally, in whole-body vibration measurements it is necessary to measure low frequencies (0 to 100 Hz) at low to moderate accelerations (<10 g), thus only lightweight piezoresistive or strain gauge type accelerometers should be used. These accelerometers are used singly or in multiples of three, mounted on a metal block, each mutually perpendicular to each other in three axes depending on the vibration source and direction.

Measurement of vibration impinging on a person is not straightforward since vibration reaching a person is highly dependent on how the person is coupled to the vibrating source(s). Knowledge of such variables as grip strength, grip orientation, mechanical filtering, and characteristics of clothing are crucial elements. Accelerometers should not be mounted onto fleshy body parts, but rather should be fastened on the skin adjacent to external body bones using a stiff carpet tape.

Vibration measurements in themselves are insufficient to determine potential hazard and risk. These data must be tape recorded on an FM instrumentation tape system for later computer analysis. This analysis usually results in the form of a Fourier spectrum, which, simply stated, means that each vibration measurement has a characteristic "finger print" or spectrum. This spectrum indicates each and every frequency element composing the original composite vibration measurement and how much of each frequency element is present. From a knowledge of human response and resonance characteristics, exposure time and conditions, coupling elements, and spectrum, risk determination is attempted.

NIOSH HAND-ARM VIBRATION FIELD STUDIES

NIOSH hand-arm vibration field studies have concentrated on foundry chippers and grinders and miners who use the so called "jack-leg" drill. Studies in other countries have been conducted principally on chain saw operators where high prevalences of Raynaud's Phenomenon were discovered (11, 12). Eventually these studies resulted in the design of new "antivibration" chain saws which subsequently reduced the prevalence of the white finger problem. Little is known of the effects of pneumatic tools on workers. Thus, in 1975, the NIOSH International Conference on Hand-Arm Vibration emphasized the urgent need to:

1. Determine the effects of pneumatic tool exposure.
2. To minimize this exposure.

Before we performed these field studies it was necessary to:

1. Assemble a ten person international team of engineers, physicians, epidemiologists, physiologists, biostatisticians, and technicians who collectively represented many years of vibration study experience.

2. Develop a comprehensive, unique, and multidisciplined study protocol which consisted of: medical and physiological testing of workers; an epidemiological examination of their health records; an intensive work history record of their past vibrating tool exposure; and engineering assessment of the vibration parameters appearing on the vibratory tools measured under actual working conditions.

3. Develop and evaluate under laboratory conditions a series of specialized diagnostic tests suitable for field study usage (19, 20, 21).

A field study was subsequently conducted on some 400 chippers and grinders along with other workers not exposed to vibrations in two large foundries and a shipyard. This was followed by a second study of 134 uranium miners.

The study reports are now being prepared for publication. A preliminary examination of the study data on chippers and grinders indicated a Raynaud Pehnomenon (VWF) problem in the populations studied, refuting the claims of Pecora (22) that VWF did not exist in the United States.

Vibration measurements on hand-tools have proven to be extremely difficult and costly due to the tools' very high acceleration levels. The result has been a destruction of the crystal accelerometers used for measurements, especially at the chisel end of the chipping hammer where the worker's guide is placed (11). Our upcoming study report will elucidate this problem.

INTERIM VIBRATION WORK PRACTICES

Whole-Body Vibration: There is little epidemiological, medical, and engineering information available which defines safe and healthful operating levels. The exposure of workers to whole-body vibration should be minimized by:

1. Limiting the time spent on a vibrating surface to no more than is absolutely necessary to safely perform the job.

2. Having machine controls moved, wherever possible, off of the vibrating surface.

3. Mechanically isolating the vibrating source and/or the surface where the workers are stationed in order to reduce the exposure.

4. Carefully maintaining vibrating machinery to prevent excess vibration from developing.

Hand-Arm Vibration: Nearly all vibrating hand tools, including pneumatic and electrical tools, with the exception of some chain saws, present a potential hazard to workers using them. There is little epidemiological, medical, and engineering data available which defines and clarifies safe and healthful operating levels of vibratory hand tools for workers. Until the needed information becomes available, occupational physicians, industrial hygienists, management, labor, and workers are all confronted with the consequences of exposure to vibrating hand-tools. A work practice guide such as the one presented below is, therefore, suggested.

SUGGESTED WORK PRACTICES FOR WORKERS USING VIBRATING HAND TOOLS

1. Any worker who may encounter exposure of the hands to vibratory hand tools should, prior to employment, be physically examined and questioned as to:

    a. Signs and symptoms of Raynaud's Disease or Raynaud's Phenomenon.
    b. Detailed history of previous vibration exposure. These previous vibration exposure data should be recorded. Based upon present medical evidence, it is not advisable to allow workers with Raynaud's Disease or Phenomenon to use vibratory hand tools.

2. Vibratory hand tools should be carefully maintained according to manufacturers' recommendations.

3. Workers are advised to:

   a. Wear gloves at all times when using vibrating hand tools.

   b. Wear adequate clothing to keep body core temperature at a stable and normal level.

   c. Warm the hands before starting the job and keep them warm during the job.

   d. Not allow the hands to become wet and chilled. Should this happen, they should dry and warm the hands and insert them into a pair of dry warm gloves. This may require more than a single pair of gloves on the job.

   e. Reduce smoking while using the vibratory hand tool since nicotine acts as a vasoconstrictor reducing the blood supply to the hands and fingers.

   f. Let the tool do the work, grasping it as lightly as possible consistent with safe work practices and tool control, with the tool resting on the workpiece or support as much as possible.

   g. Use the tool only when absolutely necessary.

   h. See a physician promptly should signs of tingling, numbness, white or blue fingers occur.

4. It is known that the hazard of vibration white fingers (VWF) is reduced if continuous vibration exposures over long periods are avoided. Therefore, work schedules with rest breaks are recommended.

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