DEVICE FOR MEASURING DAYLONG VIBRATION EXPOSURE AND GRIP FORCE LEVELS FOR DURING HAND-TOOL USE

D. R. Peterson, A.J. Brammer, M.G. Cherniack
Biodynamics Laboratory, University of Connecticut Health Center, U.S.A.

Introduction

Over the past two decades, there have been significant reductions in industrial exposures to hand-arm vibration, especially when specific tools and work processes have been redesigned to incorporate anti-vibration and ergonomic principles. Nevertheless, Hand-Arm Vibration Syndrome (HAVS) remains a significant occupational health problem as disease symptoms continue to occur even when vibration exposure levels believed to incur low risks have been reached[2]. This inconsistency may be related to the methodology that is typically used to estimate workday vibration exposure levels, involving laboratory and/or very short duration field measurements coupled with estimates of overall eight-hour tool operation times determined from brief observations of tool tasks and/or self-reported surveys. One solution is to use small, commercially-available, personal vibration dosimeters to calculate, record, and display long-duration vector sums and energy equivalents of vibration. However, since these devices are attached to the worker and require tool-mounted accelerometers, they are incompatible with the worker performing normal duties involving putting down or changing tools. In addition, these commercial systems do not allow for the characterization of the transmission of vibration to the hand such as monitoring the mechanical coupling between the hand and the tool handle (e.g., grip forces). O'Boyle and Griffin showed that variations in applied force can alter vibration transmission characteristics by 50% or more indicating that the measurement of grip force is essential for modeling vibration transmissibility and vibration exposures[5]. In summary, a need exists for the development of a method and device that will more accurately characterize workday-long vibration exposures.

Methods

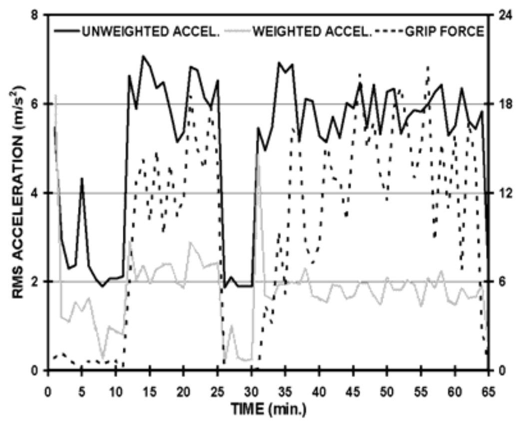
A portable, light-weight, Vibration Exposure Monitor (VEM) system was developed to record user-specific tool-operating times, vibrations, and grip forces throughout all, or a representative part, of a workday. It monitors frequency weighted and unweighted accelerations from a palm-mounted uni-axial accelerometer (Model 352C22, PCB Piezotronics, Depew, NY) and calculates exposure levels using the root-mean-square (RMS) and higher power mean values, such as the root-mean-quad (RMQ) and the root-mean-oct (RMO). Grip forces are also monitored using a palm-mounted force sensor (Model 400, Interlink Electronics, Camarillo, CA) from which average grip force levels and exerted grip extrema are calculated.

At the core of the VEM system is a commercially available, battery-powered microcomputer (Tattletale, Model 8v2, Onset Computer, Onset, MA) with one megabyte of memory and eight analog channels using 12-bit sampling at a single-channel maximum of 100 kHz. Analog signal processing (i.e., anti-aliasing, with cutoffs at 4 and 1250 Hz, and ISO 5349-1[3] frequency weighting) is accomplished using custom circuitry that is directly interfaced with the microcomputer. An embedded C-based protocol governs the data collection from each channel at a 3 kHz sampling frequency and performs all vibration and grip force calculations. The entire VEM system, including the ICP-type accelerometer, is powered using three 9 V batteries and can provide measurements for up to 12 hours, while retaining data in the RAM for up to 72 hours.

Results

Measures of acceleration and grip were validated through laboratory studies involving an electro-dynamic shaker outfitted with a handle and actual power tools. The frequency response of the palm-mounted sensors was measured at a 100 N grip and showed a flat response up to 3 kHz. Results for weighted and unweighted vibration and grip force are presented in Fig. 1 for a 65-minute window of debrushing operations during forestry work.

FIG. 1: DEBRUSHING VIBRATION EXPOSURE



Discussion

Given the nature of the root-mean and averaged calculations, the measurements made using the VEM system only provide estimates of the time histories of accelerations entering the hands and for the grip forces exerted throughout the workday. These estimates have been seen to be more accurate than traditional methods and can be used to assist in the subsequent construction of vibration exposure metrics for the development of exposure-response relationships as described in ISO 5439-2[4] and more complex metrics involving biologically plausible models of tissue burden and dose[1]. These metrics may also assist in determining why deviations from ISO's energy-based exposure-response models occur.

References

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