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

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Introduction

Millions of workers are exposed to vibration at their job, whether it is from a power tool that causes hand and arm vibration or from heavy machinery that exposes them to whole body vibrations. These vibrations are known to result in physical disorders, such as Hand-Arm Vibration Syndrome (HAVS), and can be debilitating to the point where workers can no longer do their job effectively. The symptoms reported continue to occur even when what is believed to be a low amount of vibration exposure is seen.[1] Research groups have taken an interest in identifying the vibration characteristics that are most harmful and choose to record vibration information using data-logging devices. Many data-logging devices, whether they are commercial or custom-built, use the frequency weightings defined in ISO 5349-1[2] and full day estimations in order to assess levels of vibration exposure. Furthermore, it is not uncommon for data be lost due to pre-software filtering and short measurement durations in these devices. For example, a representative device made by Larson Davis, Model HVM 100, captures vibration signals with a frequency range from 0.4 Hz up to 1250 Hz. It allows for three acceleration sensor inputs, measuring X, Y, and Z directions of vibration and uses the A(8) exposure metric, where the amount of vibration exposure from a tool is estimated for 8 hours of use without necessarily having the subject wear the device all day. Peterson et al. developed a datalogger called the Vibration Exposure Monitor (VEM), which was used to capture full day vibration waveform metrics using a uni-axial accelerometer and a force sensitive resistor mounted on the subjects palm.[3] Datalogging devices created for purposes other than vibration are not capable of measuring acceleration signals properly. This is due to the lack of one or many of the following specifications: resolution in amplitude or time domain, cyclic lifetime, number of channel inputs, and/or dynamic range. In order to fully understand the extent of vibration exposure, raw waveforms of grip force and acceleration are desired and have led to the creation of a second generation Vibration Exposure Monitor (VEM2).

Methods

The device presented in this abstract is 8.70 inches by 4.30 inches by 1.75 inches in size and is capable of measuring complete vibration waveforms from eight force sensors and eight accelerometers over an eight hour workday. The VEM2 system was designed with this number of channels to allow for the simultaneous collection of force and vibration data from ring and palm adapters placed on both hands. (The development of the ring and palm adapters is nearing completion and is subject of a later publication.) Due to advances in technology from the previous VEM system, higher sampling rates, longer battery life, and a much larger non-volatile memory storage unit were implemented in the design. In addition, the gains associated with each channel can be modified to accommodate a range of thin-film force sensor and ICP accelerometer models. The primary component of the device is a microcontroller (dsPIC30F6015, Microchip Technology Inc., Chandler, AZ), where eight onboard 10-bit analog-

to-digital (A/D) converters sample, at 908 Hz per channel, the analog front end circuitry used to filter and amplify the signal from force sensors. The microcontroller also communicated with an a separate 14-bit A/D converter used to sample, at 5000 Hz per channel, the front end circuitry that filters and amplifies the signal from the accelerometers. Samples are stored to buffers within the microcontroller and are written to an Extreme Secured Digital (SD) card in FAT32 format for easy data extraction and post processing. To ensure that data is not lost, the system incorporates a low power circuit used to close the current data file when the power switch is turned off or if the voltage of the battery stack drops below a set reference. Due to an increase in electronic complexity, the VEM2 system required a larger battery stack compared to the original VEM in order to accommodate the current draw of the device for data collection in excess of an 8 hour workday.

Results

In preparation for extensive field studies, the performance of several VEM2 systems has been validated, with respect to the following:

- each of the eight force sensor inputs quantized into 10 bits at 908 Hz per channel,
- each of the eight accelerometer inputs quantized into 14 bits at 5000 Hz per channel,
- the unit has a operating lifetime, based on battery power, of over 8 hours,
- has a storage capabilities up to 64 GB,
- a dynamic range of 0 to 100 lbs for force measurements,
- a dynamic range of 1.5 to 1000 m/s^2 for acceleration measurements, and
- allows for vibration waveforms beyond the dangerous frequencies described in ISO-5349 to be completely captured.

Discussion

In contrast with the currently available commercial products used to measure vibration exposure, the new VEM2 device is capable of recording full sets of force and acceleration data that can be filtered and analyzed in post processing. In the previous VEM device, only estimations and waveform metrics were recorded, from which the actual force and acceleration waveforms could not be reconstructed. By capturing entire waveforms with the VEM2 device, any metric can be calculated and more detailed data analyses can be accomplished, such as frequency spectrum analyses of vibration frequencies up to 2500 Hz and force frequencies up to 454 Hz. Sixteen channels of force and acceleration allow for measurement versatility and for investigation of long-duration vibration exposure on both hands.

References

1. ISO 5349-1 Mechanical Vibration - Measurement and assessment of human exposure to hand-transmitted vibration - Part 1: General guidelines. ISO, Geneva Switzerland. (2001).
2. ISO 5349-2 Mechanical Vibration -- Measurement and evaluation of human exposure to hand-transmitted vibration -- Part 2: Practical guidance for measurement at the workplace. ISO, Geneva, Switzerland. (2001).
3. Peterson, D. R., Brammer, A. J. & Cherniack, M. G. Exposure monitoring system for day-long vibration and palm force measurements. International Journal of Industrial Ergonomics 38, 676–686 (2008).

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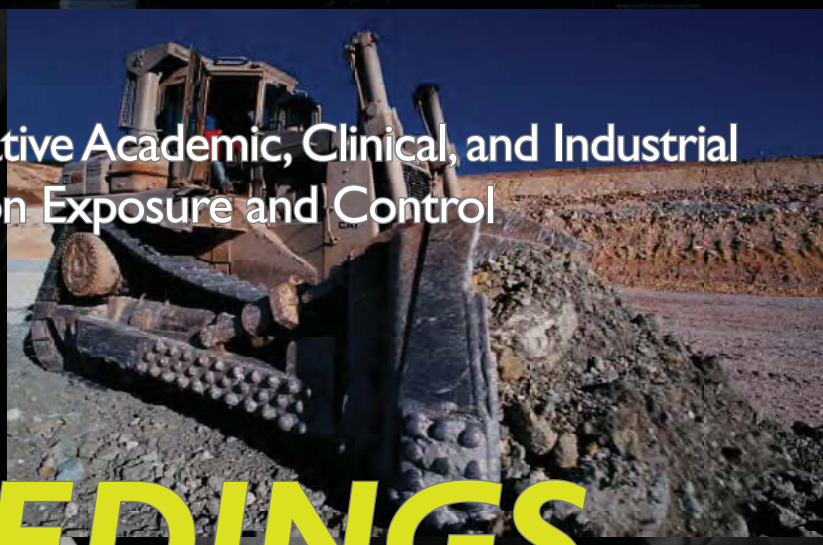
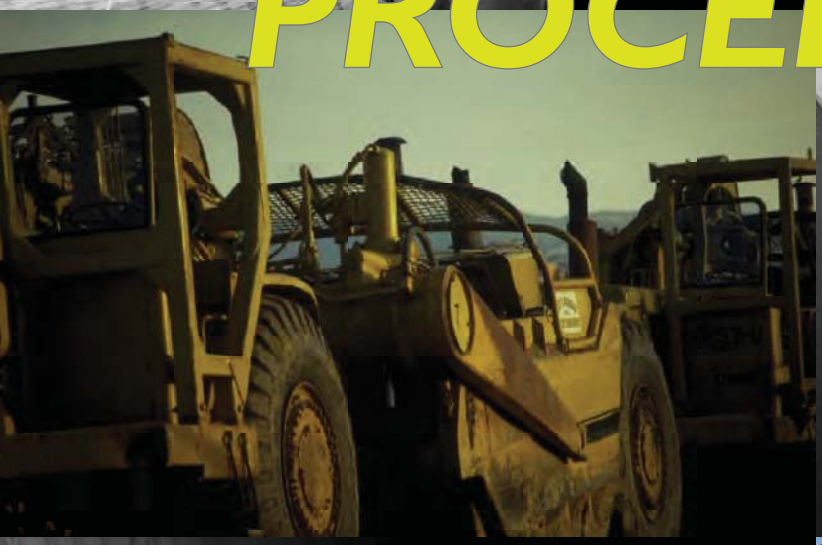
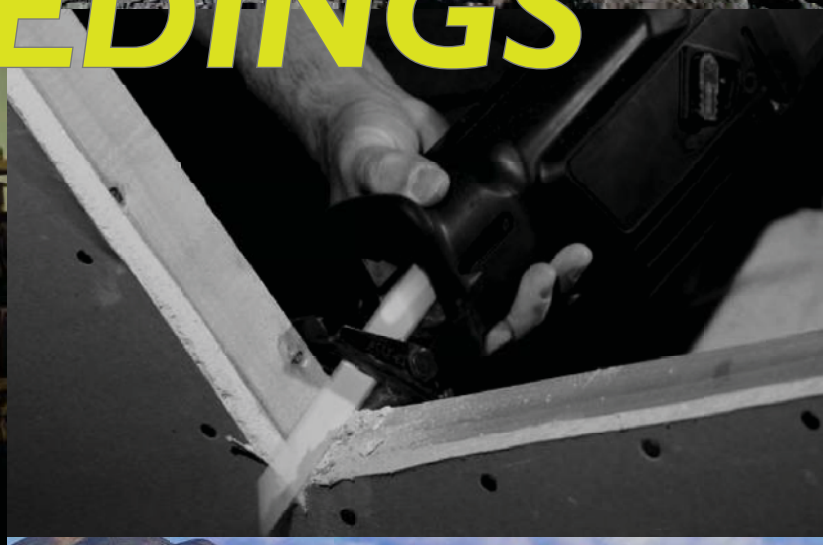
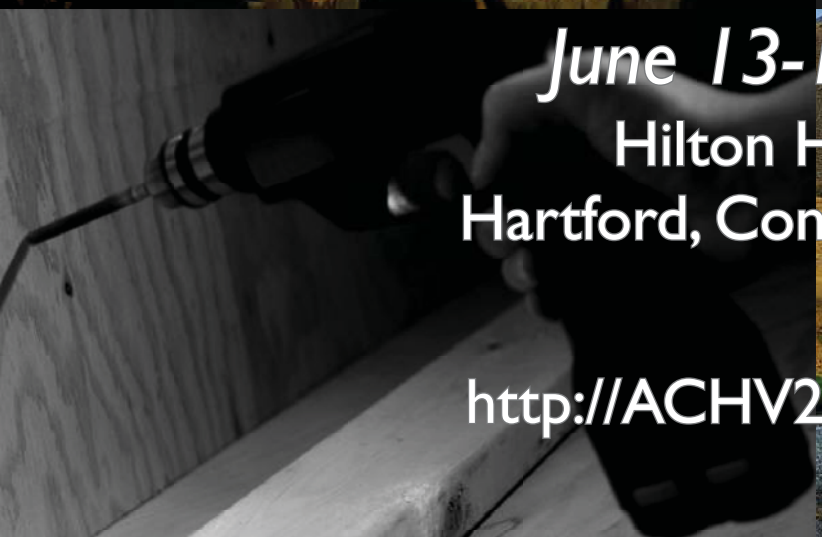


PROCEEDINGS







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