New, Inexpensive Methods Monitor Off-road Vibration Exposure

NIOSH researchers use an iPod app to assess whole-body vibration

By A.G. Mayton and Bryan Kim

Cumulative exposure to whole-body vibration (WBV) adversely impacts the health and safety of exposed mine workers. Mining equipment-induced vibration depends on factors such as equipment type, task and operator skill. Generally, it is time-variant and widely broadband in frequency content. Exposure to such vibration can also cause fatigue or reduce fine motor skills. Moreover, WBV may contribute to the development of musculoskeletal disorders (MSDs) of the spine among exposed workers.

Off-road mining equipment operating on rough surfaces under harsh conditions can produce WBV and mechanical-shock exposure to equipment operators. Until recently, the only methods to measure WBV were through expensive vibration measurement systems that may cost $4,000 to $50,000 or more and require significant technical expertise to analyze the data and arrive at meaningful results. University of Queensland researchers have investigated the use of a personal electronic device as a means for providing an uncomplicated and economical method to estimate WBV exposure in a mining environment. The whole-body vibration measurement application (WBV app) uses the built-in triaxial accelerometer of an iPod touch (model A1509, iOS version 9.3.5) to collect acceleration data and calculate frequency-weighted estimates of WBV exposure.

The National Institute for Occupational Safety and Health (NIOSH) recently conducted a study focusing on the measurement accuracy of the WBV app. The NIOSH field study involved data collection for 13 mobile machines (seven front-end wheel loaders and six haul trucks) operating at one sandstone mine and three limestone mines in central and southwestern Pennsylvania and northern Virginia. A major objective of the NIOSH research study was to assess the accuracy of the WBV app and determine if it can be a useful low-cost tool for monitoring WBV exposure on mobile mine and quarry equipment. Through field evaluations, the exposure levels measured with the WBV app collected with an iPod touch device were compared to exposure levels measured simultaneously with the Siemens/LMS SCADAS data recording system.

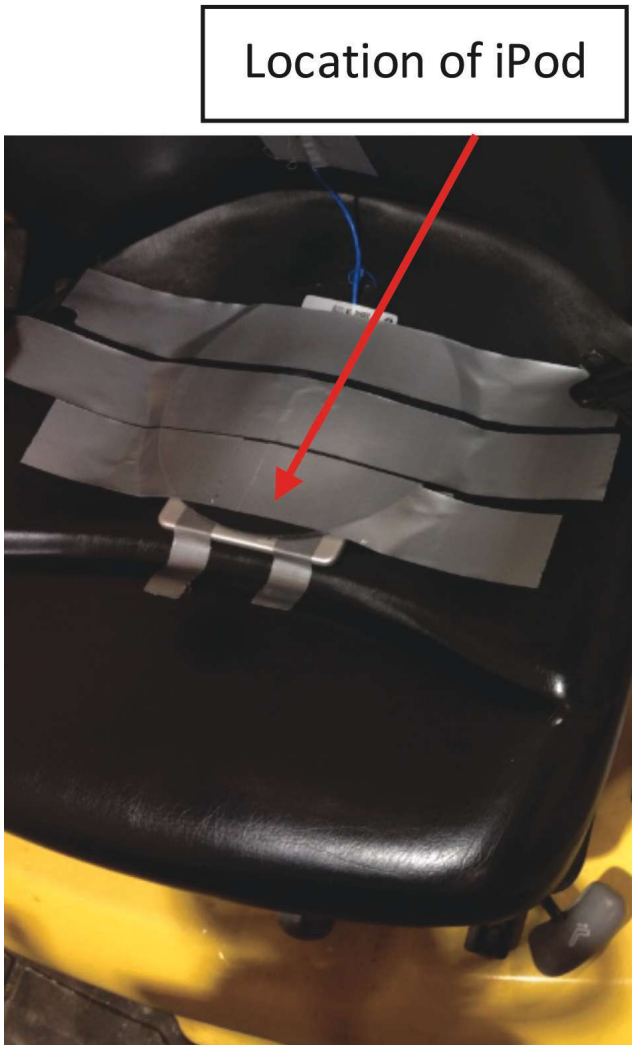

Figure 1—A typical setup of the instrumentation on the operator seat with the iPod placed 'face down on the seat …with the long axis of the iPod perpendicular to the direction of travel,' as stated in the WBV v2.1 User Manual.

Approach

NIOSH researchers measured WBV in three directions, X (fore-aft), Y (side-to-side), and Z (vertical) for operators of mobile mining equipment as they performed their normal work. NIOSH used a Siemens SCADAS–SCR05 16-channel data recorder with 24-bit resolution as the reference, high-quality precision system to which the iPod touch device running the WBV app was compared. To measure WBV, NIOSH used a PCB 356B40 seat-pad accelerometer with the SCADAS recorder. Collected data were stored in flash memory on a SD card. The iPod touch device was placed under the front-most portion of the circular seat pad according to the WBV app User Manual (downloadable from University of Queensland website at http://ergonomics.uq.edu.au/WBV/WBVpod/Index.html).

Measures of Interest Explained

Weighted-root-mean-square acceleration (a_w) is frequency-weighted acceleration, expressed in m/s^2, and used to describe

Standard/EU Directive	Lower Boundary—EAV	Upper Boundary—ELV
ISO/ANSI	0.45 m/s^2	0.90 m/s^2
EUGPG	0.50 m/s^2	1.15 m/s^2

Table 1—Health guidance caution zone limit in frequency-weighted acceleration (a_w).

Standard/EU Directive	Lower Boundary—EAV	Upper Boundary—ELV
ISO/ANSI	8.2 $m/s^{1.75}$	16 $m/s^{1.75}$
EUGPG	9.1 $m/s^{1.75}$	21 $m/s^{1.75}$

Table 2—Health guidance caution zone limit in vibration dose value.

levels of vibration exposure in three directions: X (fore-aft), Y (side-to-side), and Z (vertical). The term a_w (8) represents levels normalized to an 8-hr shift. The results presented in this paper focus on vibration in the Z direction, since it is typically of greatest interest and can be associated with the greater risk for back injury/pain.

Vibration dose value (VDV) is a cumulative measure of vibration received by a person during the measurement period. This measure is more sensitive to peak levels and transients and is expressed in $m/s^{1.75}$. The term VDV (8) represents levels normalized to an 8-hr shift.

Health guidance caution zone (HGCZ) is a metric that uses vibration level and duration to evaluate when a subject is at risk of overexposure to WBV. The boundaries expressed in frequency-weighted acceleration and VDV are shown above for both the International Standards Organization/American National Standards Institute (ISO/ANSI) and European Union Good Practices Guide (EUGPG) for Directive 2002/44/EC. These boundaries represent the minimum health and safety requirements for exposure of workers to the risks arising from physical agents, such as vibrations. The exposure action value (EAV) is the level below which health effects have not

been clearly documented. Those levels within the HGCZ indicate caution with respect to potential health risks. The exposure limit value (ELV) is the level above which health risks are likely. Tables 1 and 2 display the EAVs and ELVs in terms of aw and VDV.

Results

Figures 2 and 3 are the graphical displays of a_w and VDV in the vertical direction and the percent difference between the Siemens/LMS and the iPod measured at the seat and normalized for an 8-hour exposure duration. The figures indicate good agreement between the two systems for the selected equipment. Absolute differences in percent for a_w (8) measures comparing the Siemens/LMS and iPod measurement systems ranged from 0.1 to 8.5. Twelve of the 13 instances showed percent differences of 4.2% or less.

Absolute differences in percent for VDV (8) measures comparing the Siemens/LMS and iPod measurement systems ranged from 0.3% to 18.8%. Elev-

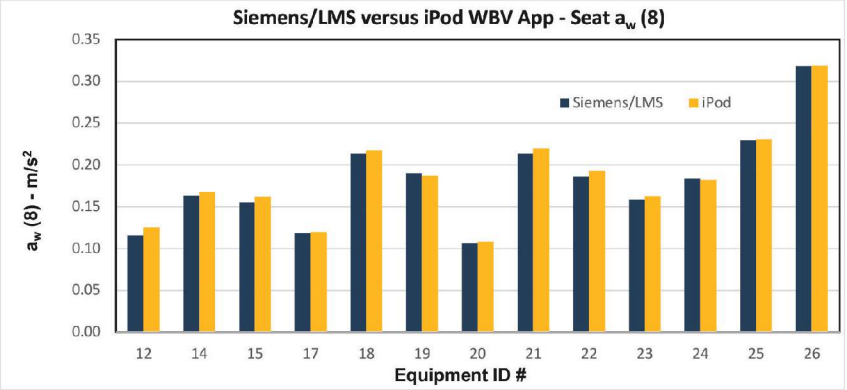

Figure 2—A_w measured in the vertical direction at the seat and normalized to an 8-hr shift for equipment ID Nos. shown above.

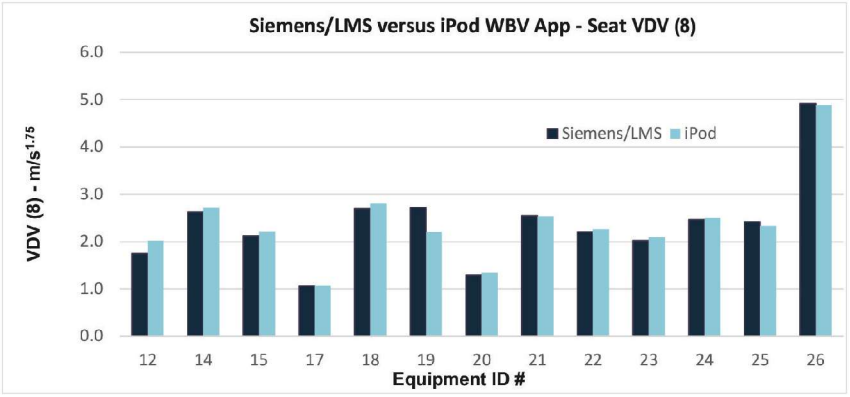

Figure 3—VDV measured in the vertical direction at the seat and normalized to an 8-hr shift for equipment ID Nos. shown above.

en of the 13 instances showed percent differences of 4.4% or less. Moreover, the a_w and VDV levels show strong Pearson correlation coefficients of 0.998 and 0.981, respectively. This statistic represents the strength of the relationship between two variables. Values of the Pearson correlation coefficient range between 0 (indicates no relationship) and 1 (indicates a perfect relationship).

This research showed that the iPod touch using the WBV app can serve as a low-cost tool to estimate operator WBV exposures on mobile mining equipment and demonstrates results similar to those obtained by Burgess-Limerick et al. In their 2016 ACARP project report, "Managing Whole-Body Vibration at Surface Coal Mines," Burgess-Limerick and Lynas obtained 96 vertical measurements of acceleration using the app and a commercially available vibration measurement device, the Svantek SV 106. They concluded that the WBV app downloaded to an iPod touch provided a 95% confidence of ± 0.07 m/s^2 for the vertical direction and their results were consistent with those they previously obtained using the app.

In addition, there were some functional issues associated with data collection. For future users of the iPod touch who are interested in assessing WBV for mobile mining equipment operators, please consider the following suggestions to ensure proper data collection:

- Power the iPods off and on immediately before data collection as a hard reset to clear the cache and ensure they are in their most stable state.
- Ensure that displays are left on when securing the iPods in place. Some iPods are able to acquire data with the screen off.
- Set the Maximum Time per Sample to 20 minutes; the total sampling duration may then include multiple 20-minute samples.
- Place the iPod face down on the seat near the right or left bony part of the operator's buttocks with the long dimension of the iPod perpendicular to the direction of travel.
- Ensure that the tape affixing the iPod to the surface firmly secures the device.

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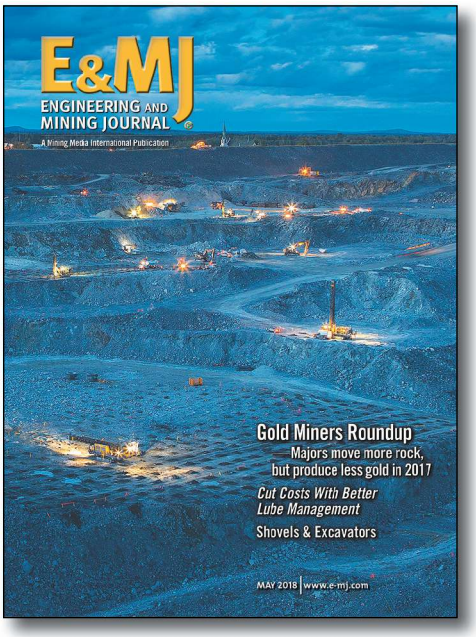

This month, E&MJ *offers extended coverage on major gold producers in its annual Gold Miners Roundup. On the cover, the Canadian Malartic mine in Quebec, Canada's largest gold mine. (Photo: Agnico Eagle)*

DEPARTMENTS

Steve Fiscor
Publisher & Editor-in-Chief

Competing for Investment Dollars

In this month's edition, *E&MJ* offers a profile of the gold mining industry with reporting on the activity among the majors. The difficulties the gold sector faces exemplify the issues affecting most of the mining industry, a lack of exploration and development investment. The reserve base among the gold majors is shrinking and no new major discoveries have been made. That can be directly attributed to a lack of greenfield investment.

There's no better place to get a feel for mining-related exploration and development investment than the Prospectors & Developers Association of Canada (PDAC) meeting, which is held annually in early March in Toronto, Canada — the mining investment capital of the world. During his presentation at the 2018 PDAC keynote session, Sean Roosen, chairman and CEO, Osisko Gold Royalties, touched on several of the salient factors explorers and developers face. Osisko Gold Royalties was created when Agnico Eagle and Yamana Gold acquired Osisko Mining Corp. and the Canadian Malartic mine — the mine on the cover of this magazine.

Mineral exploration today is more difficult. Many prospectors believe that most of the easy-to-find deposits have been discovered and the new prospects lie at depth. While there is some truth to that, the bigger problem facing explorers is a lack of investment. "There is less money available today," Rosen said. "In the past, people used to invest in prospectors and exploration because they wanted to take a risk and have fun. That money has moved to crypto currencies and 'weed' stocks, which is less regulated and more like a casino. We need to take a step back and regain those investors." Roosen asked the crowd: "How do we get the next generation of investors interested in our space?"

Today, actively managed money is being challenged by passive funds. Billions of dollars are moving into index funds and quant trading, which mostly look backward at historical comparisons. "Without active management, we won't be able to finance projects," Roosen said. "You can't explain why you need $50 million to drill holes over here to a computer." Tongue in cheek, Roosen said he has tried to schedule meetings with these computers and it's difficult.

Major mining projects are capital intensive and the money is no longer available. Shareholders are less likely to approve that $15 billion investment. Roosen believes the larger companies will have to return to the old playbook, where mining companies enter joint ventures and syndicate bigger deals. "There is no long-term vision with today's investors and shareholders," Roosen said. "Only a few understand the importance of a 25-year investment. They are mostly Chinese and state-sponsored companies and they are buying a lot of things that we should own. Look what has happened in Canada. We have lost a lot of our status. We lost Falconbridge, Inco and Alcan. And, Goldcorp and Barrick are one-third the size they used to be."

The development of natural resources is vital to the Canadian economy and Roosen is passionate about the mining business. Referring to his experience with Canadian Malartic, he explained that the only way to sustain rural communities, especially those in northern Canada, is to develop assets that live and provide in their world. Future discoveries will require experienced geologists, boots on the ground, drill rigs turning and active investors.

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