A LOW COST WIRELESS ACQUISITION SYSTEM FOR MULTI-CHANNEL VIBRATION MEASUREMENT

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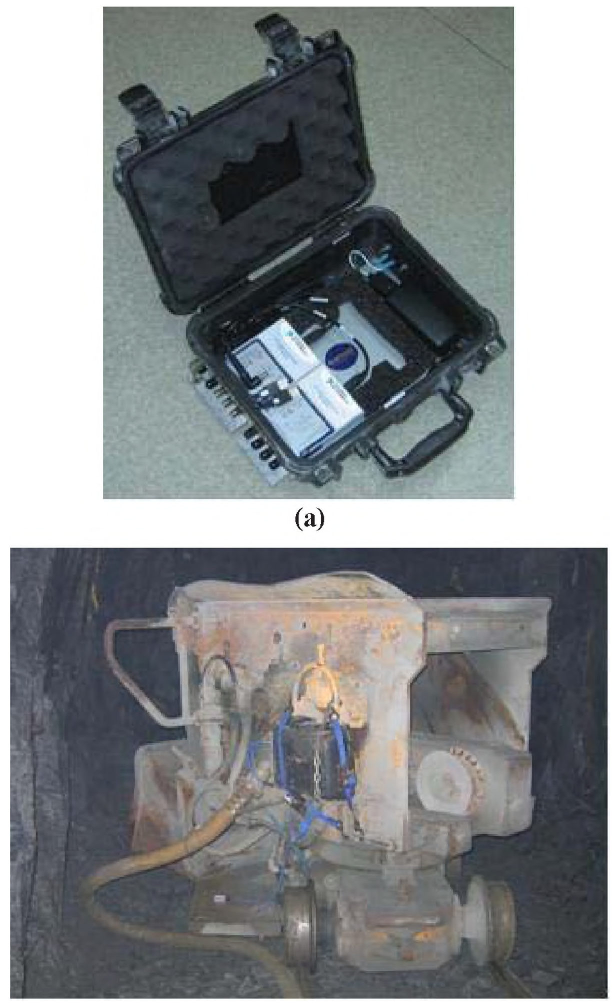
1. INTRODUCTION

In order to perform multi-channel time signal acquisition in harsh environments like underground mines, where there is a high risk of having the equipment damaged or destroyed, it is convenient to use a robust low cost system that allows remote control and monitoring. Such a system, with at least 6 input channels, was not available on the market at the time it was needed to perform a study on human vibration in underground mines. Thus, an acquisition system based on *National Instrument* NI-9234 boards and *LabVIEW*™ has been developed and successfully tested in underground mines for human vibration assessment, and will be presented in this paper.

2. METHODS

The acquisition system was built using two *National Instrument* NI-9234 USB boards (IEPE, 24 bits), giving a total of 8 channels, an external LI-ION battery, one minicomputer with solid-state hard disk for added robustness, and a small waterproof *Pelican*™ case. Pictures of the acquisition system are shown in Figure 1. The system had to be very compact in order to be installed on certain equipment where the space is very limited (see Fig. 1b). The acquisition process was implemented under *LabVIEW*™, with two different sampling rates for hand-arm (5120 Hz) and whole-body vibration (512 Hz). Using the "*Remote desktop*" function of *Windows XP*®, a second laptop computer was used to wirelessly control and monitor (time signals and spectra) the acquisition process.

The IEPE mode of the NI-9234 boards was used to supply electrical power to the accelerometers, requiring the use of AC coupling. Since the NI-9234 board has, in AC coupling, a roll-off of 3 dB at 0.5 Hz, a digital FIR filter was added to correct the low frequency response in whole-body vibration (WBV) measurement mode, in order to satisfy the newer standard ISO 8041 (2005). In addition, Notini et al. (2006) have shown that low frequency components can have a significant effect on WBV metrics. The digital FIR filter coefficients for the sampling rate of 512 Hz were calculated using the FIR2 function of *MATLAB*®. The target frequency response of the filter was the measured compensation needed to achieve a flat response in the entire frequency range. In practice, compensation was only needed between 0 and 6.3 Hz. A total of 2000 coefficients were used for the FIR filter. Having a linear phase, the FIR filter resulted in a time delay of 2 seconds, and thus it was possible to implement the filter in real time during the acquisition of the vibration signals.



(a)

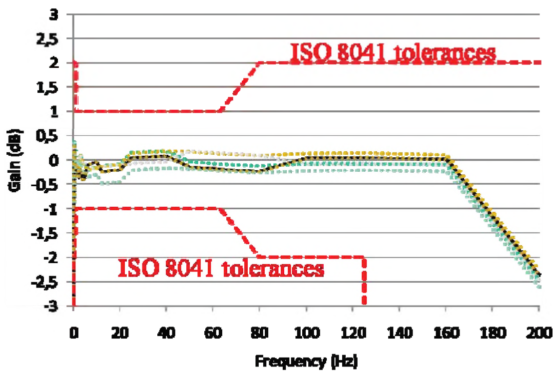
(b)

Figure 1. Acquisition system: (a) without the mini Laptop to show the components; (b) with a triaxial accelerometer installed on a "muck machine".

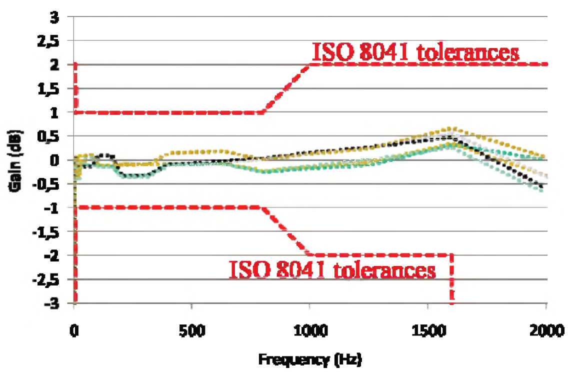
3. RESULTS

3.1 System validation

The acquisition system was validated using a function generator to generate a swept sine of 4.5 V peak amplitude, using a logarithmic sweep between 0.1 and 5000 Hz over a period of 180 seconds. Figure 2 shows the differences, in dB, between the reference signal magnitude and the signal as measured by the acquisition system for the first 6 channels in "hand-arm" and "whole-body" acquisition modes. The results are presented in one-third octave bands between 0.8 and 2000 Hz for hand-arm vibration (HAV) and between 0.1 and 200 Hz for WBV. The allowed tolerances of ISO 8041 (2005) standard for HAV and WBV are also presented in these figures. For the WBV mode, the low frequencies are compensated by a FIR filter, as described previously. It is noted that the acquisition system completely satisfies the ISO 8041 standard tolerances.



(a)



(b)

Figure 2. Differences between reference signal and acquisition system for first 6 channels: (a) WBV; (b) HAV.

Frequency weightings ISO 5349-1 (2001) for HAV and ISO 2631-1 (1997) for WBV were applied in postprocessing on the recorded accelerations time signals. The weightings were applied using the *LabVIEW*™ "*Sound and Vibration*" module. It is also possible to implement these weightings directly using digital FIR or IIR filters (Rimell and Mansfield, 2007). Then, from the weighted accelerations, vibration exposure values such as the weighted rms acceleration (a_w) and the vibration dose value (VDV) for WBV were calculated.

3.2 Application example and artefacts detection

The acquisition system was used to measure vibration levels of 28 different mining equipments operating in 8 underground mines located in Quebec. Figure 3 shows an example of measured acceleration on a "CAVO" (similar to the "muck machine" shown in figure 1b). The measurement was performed on the "CAVO" floor (where the operator is standing) in the x_h-axis direction, as defined in ISO 2631-1 (1997). The signal clearly shows some DC shift, even if the measurement was carried out with an accelerometer of relatively high capacity (500 g or 5000 m/s^2) for WBV. Usually, DC shift occurs with impact hand-held power tools while assessing HAV. Since DC shift does not necessarily produce saturation of the signal, it can be difficult to detect it without having the time signal. As recommended by the ISO 5349-2 (2001) standard for HAV, measurements containing DC shift were not considered for WBV assessment.

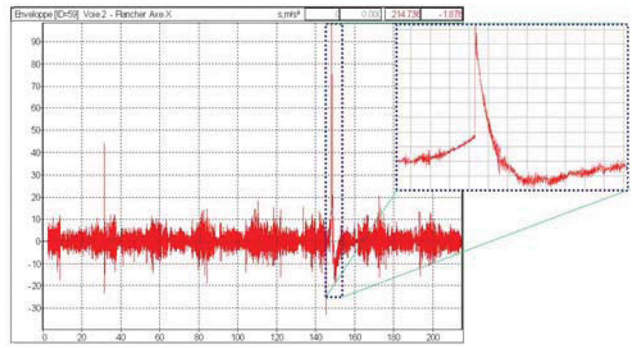


Figure 3. Time signal showing an example of DC shift.

4. CONCLUSION

A low cost acquisition system has been developed, validated and successfully used to assess human vibration in different underground mines. Acquisition of the time signal allowed the detection of DC shift artefacts.

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