Noise controls for roof bolting machines

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Introduction

The Bureau of Labor Statistics (BLS) classifies hearing loss as a separate illness category. Hearing loss accounted for 11% of all illnesses in 2005 (U.S. Department of Labor Bureau of Labor Statistics, 2006a). According to occupational data for coal mining provided by the Mine Safety and Health Administration (MSHA) from 2000 to 2005, operators that exceeded 100% noise dosage were from only seven types of machines: auger miners, bulldozers, continuous mining machines, front end loaders, roof bolters, shuttle cars (electric) and trucks (Title 30 CFR Part 62, 2000-2005). Roof bolting machine operators rank second among all underground machine operators that exceed 100% noise dose. There are approximately 600 underground coal mines with 3,930 roof bolting machine operators (U.S. Department of Labor, Mine Safety and Health Administration, 2005; U.S. Department of Labor Bureau of Labor Statistics, 2006a). Figure 1 shows the percentage of roof bolting machine operators that exceeded 100% noise dose from 2000 to 2005 according to the MSHA database (Title 30 CFR Part 62, 2000-2005).

The roof bolting machine operator is exposed to several noise sources. These include vacuum pumps, hydraulic pumps, drill chucks, drill steel and drill bits. Both vacuum and hydraulic pumps contribute some to overall noise emissions. However, tests at PRL confirmed that the hydraulic and vacuum pumps are not a major noise source for the roof bolting machine (Peterson et al., 2006). The dominant noise source on a roof bolting machine is the result of the drilling process (Peterson and Alcorn, 2007).

To reduce noise exposure caused by roof bolting machines generated during the drilling process, two engineering noise controls were developed. Specifically, this paper concentrates on the noise emitted from the drill chuck, the drill steel and the drill bit while drilling with a J.H. Fletcher & Co. HDDR roof bolting machine. This type of roof bolting machine is representative of industry usage. This research is providing the mining community with a bit isolator and a drill chuck isolator as noise controls to be utilized in the drilling process of the roof bolting machine. This could provide operators of these machines an opportunity to be within the MSHA-Permissible Exposure Limit (MSHA-PEL).

Abstract

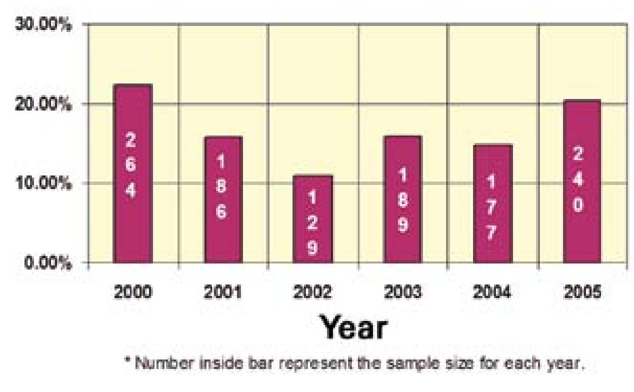
Prior to 2004, the Bureau of Labor Statistics (BLS) classified hearing loss in the "all other illnesses" category. However, in 2004 hearing loss was categorized as a separate illness that accounted for 11% of work related illnesses. Most categories of illnesses and injuries associated with mining have improved, with the exception of hearing loss. The drilling of rock in a confined work environment contributes to high levels of noise exposure. Information gathered from the Mine Safety and Health Administration (MSHA) coal database from 2000 to 2005 has shown that roof bolting machines were second among all equipment whose operators exceed the MSHA Permissible Exposure Limit (PEL). In response, the National Institute for Occupational Safety and Health (NIOSH) at the Pittsburgh Research Laboratory (PRL) has been conducting research to reduce noise overexposure caused by roof bolting machines and to prevent additional cases of noise-induced hearing loss (NIHL). This is achieved through the development and application of engineering noise controls. This paper describes the procedure used to evaluate noise generated by a roof bolting machine and its components. Two engineering noise controls for the roof bolting machine were evaluated: a bit isolator and a drill chuck isolator. Acoustic beamforming measurements were performed at the PRL hemi-anechoic chamber to assess the noise controls developed for the roof bolting machine. Results showed that in combination, the bit isolator and the drill chuck isolator provided a 7 dB(A) reduction in sound pressure level at the operator position.

Test procedure

Testing was conducted in the hemi-anechoic chamber at PRL with a Fletcher HDDR roof bolting machine, shown in Fig. 2. The interior dimensions of the room are approximately 17.7 m long x 10.4 m wide x 7 m high (58

FIGURE 1

MSHA coal noise sample data: roof bolting machine operator's noise dose samples that exceeded 100% dose from 2000 to 2005.



x 34 x 23 ft), with a volume of approximately 1,300 m^3 (45,900 cu ft). This facility utilizes Eckel Industries Supersoft Panels on the walls and ceiling to yield a free-field over a reflecting plane, which meets the requirements of ISO 3744 down to approximately 100 Hz. The chamber was utilized primarily for noise source identification testing on the Fletcher HDDR roof bolting machine. Also, sound pressure level measurements were taken at the operator's position to determine the overall A-weighted sound level at the operator's ear while drilling.

Baseline data was collected first using beamforming along with sound pressure level data at the position of the roof bolting machine operator. The beamforming and sound pressure level data were collected simultaneously. The beamforming data identified the noise sources from the drilling process of the machine. The sound pressure level data at the position of the roof bolting machine operator quantified the noise at the operator position. This was important because the frequency content of the two may be different. The baseline data was used for the evaluation of the engineering noise controls for the roof bolting machine.

The noise source identification measurements were conducted using the beamforming technique. Beamforming is a method of mapping noise sources by differentiating sound levels based on the direction from which they originate. The method is very quick, allowing a full map to be calculated from a single-shot measurement. The technique is also well suited for high-frequency noise sources (Brüel & Kjaer, 1995). A Brüel & Kjaer pulse data acquisition system with 46 input and two output channels served as the data acquisition system for the beamforming technique. Figure 3 shows the 42-channel beamforming wheel array used for the noise source identification at PRL.

A LMS Pimento system served as the data-acquisition system for collecting the sound pressure level data at the roof bolting machine operator position and the thrust and speed of the roof bolting machine. The recorded sound pressure was post-processed to calculate the A-weighted, one-third-octave-band sound level spectra. Figure 4 shows the microphone placement used for the sound pressure level data at the position of the roof bolting machine operator.

A large steel support stand comprised of rectangular tubes was fabricated by PRL to hold the drilling media, shown in Fig. 2. To prevent the support stand from radi-

Table 1

Drilling parameters.

Parameter	Values
Drilling type	vacuum
Drill steel	round, hexagonal
Drill bit size	34.9 mm

FIGURE 2

PRL's hemi-anechoic chamber and support stand for rock media.

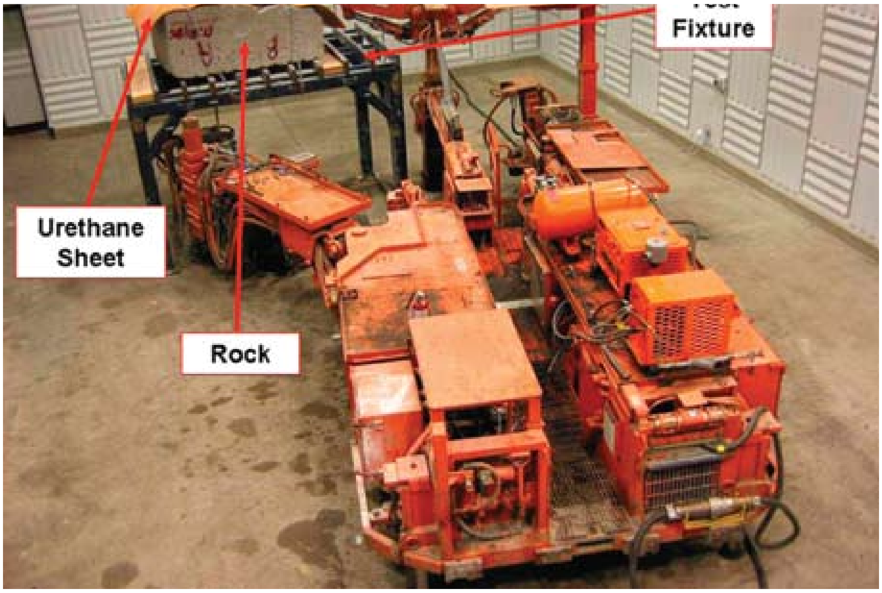


FIGURE 3

Forty-two channel acoustic beamforming wheel array.

FIGURE 4

Microphone location at the operator's ear.

ating significant amounts of sound, sand was used to fill the hollow tubes except for the diagonal tubes and the horizontal tubes along the short direction at the top of the structure. This was done for convenience and to create a vibration impedance mismatch in the structure to reduce vibration transmission. In addition to filling the tubes, two layers of a urethane material were bonded to the rock support tubes to break direct contact between the rock and the structure. Finally, a 12.7-mm- (0.5-in.-) thick layer of urethane was placed between the rock and the chain used to support the rock media.

In formulating a test plan, researchers decided to use drill bits and drill steels that were representative of industry usage. The drilling parameter configuration is listed in Table 1. Granite was chosen as the drilling media because it is a high compressive strength material. Past NIOSH research shows that higher compressive strength material generates more noise then lower compressive strength materials (Peterson and Alcorn, 2007). This would provide the worst-case scenario for noise emission. Also, a low rotation speed of 200 rpm and a low thrust of 962 kg (2,121 lbs) were used. Past NIOSH research has shown that when drilling into hard materials, lower rotation speeds should be used (Peterson and Alcorn, 2007). The lower thrust was used so a longer drill time could be obtained.

Results

A baseline drilling measurement identified where noise was coming from and the frequency content. Beamforming results, shown in Fig. 5, indicated that the majority of drilling noise is radiated by two areas: at the drill bit and rock interface and at the drill steel and drill chuck interface. Figure 6 shows the one-third-octave band spectrum at the position of the roof bolting machine operator ear. The A-weighted sound level at the operator's position was 99.7 dB. The frequency content of the noise radiated toward the operator was dominated by the 1,250 Hz through 8 kHz bands. Also, the drill steel type and drilling depth had no effect on the beamforming results, as was expected based on past research at PRL (Yantek et al., 2007).

To reduce the sound level at the operator's ear while drilling, noise controls must be developed that target the noise generated at the drill bit and rock interface and the drill steel and drill chuck interface. In addition, the controls must address the mid- to high-frequency components of the drilling noise. To reduce the radiated noise at both the bit and chuck interface, isolation techniques were used. A bit isolator was developed to reduce the noise radiated at the bit and rock interface,

FIGURE 5

Beamforming data from 1 to 6.3 kHz with vacuum drilling, round drill steel and a 34.9-mm (1.37-in.) drill bit.

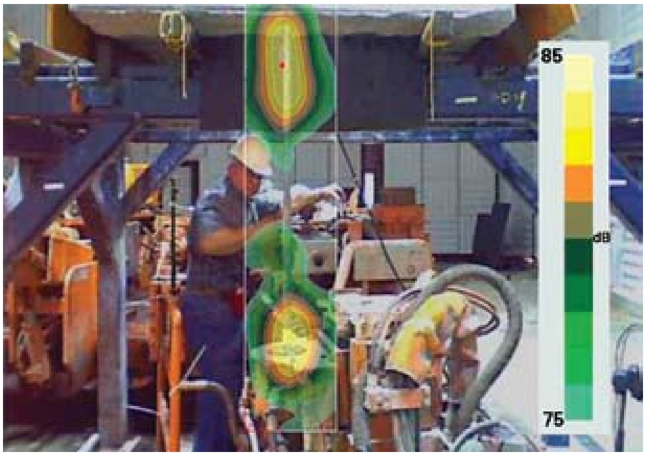


FIGURE 6

Baseline operator ear sound pressure level.

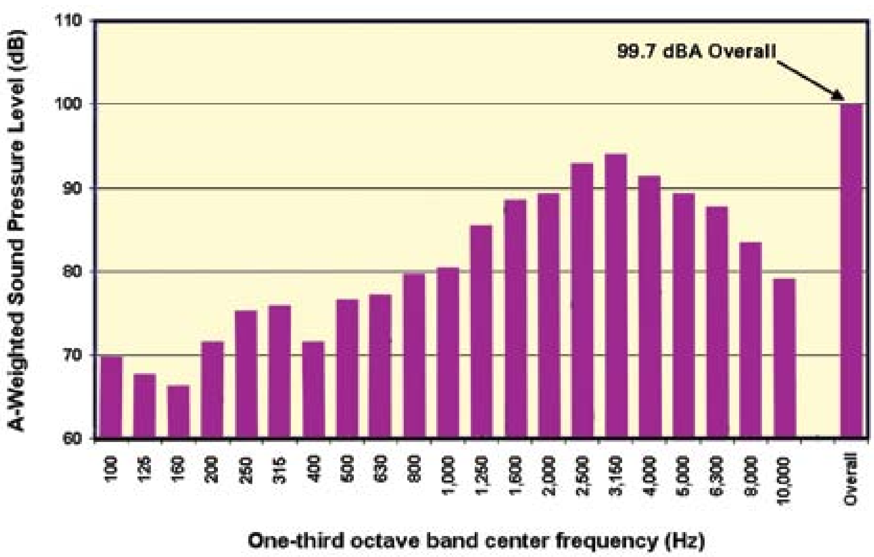
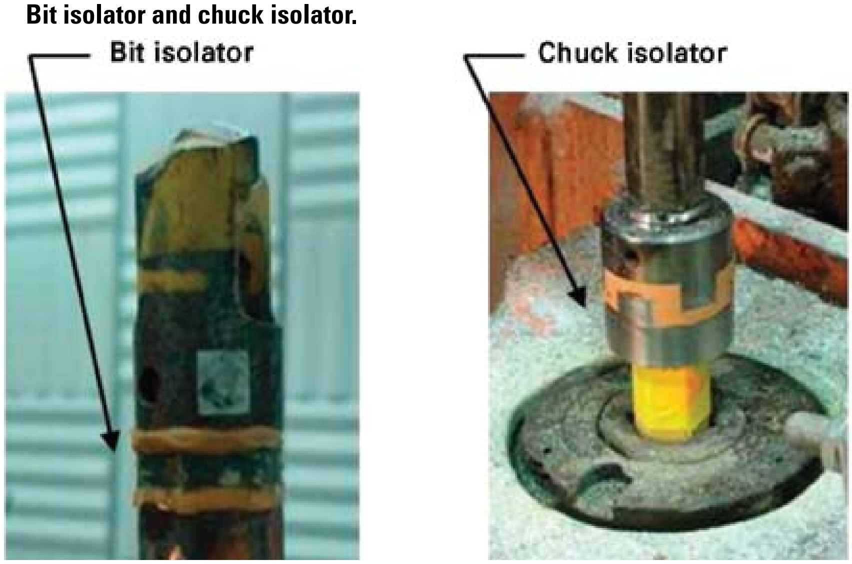


FIGURE 7

Bit isolator and chuck isolator.



shown in Fig. 7. A chuck isolator was developed to reduce the noise radiated at the drill steel bit and drill chuck interface, also shown in Fig. 7. Both isolators were designed to reduce the noise emitted during drilling by limiting the vibration transmitted down the drill steel from the drill bit/media interface. A urethane material with a durometer of 58 Shore D was chosen for both isolators in reducing the dominant frequency bands from 1,250 Hz through 8 kHz. The chuck isolator used a LoveJoy coupler with the 58 Shore D durometer urethane.

Noise controls were examined alone and in combination in the hemi-anechoic chamber using the same test parameters as Table 1. Again, granite was used as the drilling media and the rotation speed of 200 rpm and a thrust of 962 kg (2,121 lbs) were used, as in the baseline test. The results at the operator's ear showed noise reductions of 2 dB(A) with the bit isolator, 3.5 dB(A) with the chuck isolator and 7 dB(A) in combination (Fig. 8). Figure 9 shows the beamforming contour plots of the four scenarios from 1,000 to 6,300 Hz. As expected, the bit isolator showed reduction at the higher frequencies, frequencies from 1,200 to 10,000 Hz. However, the chuck isolator showed most of the reduction from 1,200 to 3,150 Hz. When using the combina-

FIGURE 8

Operator ear sound pressure level.

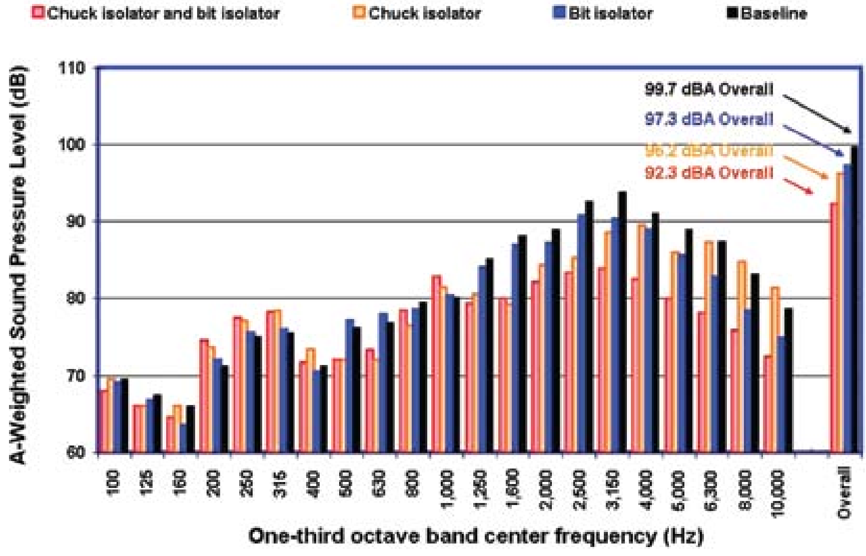
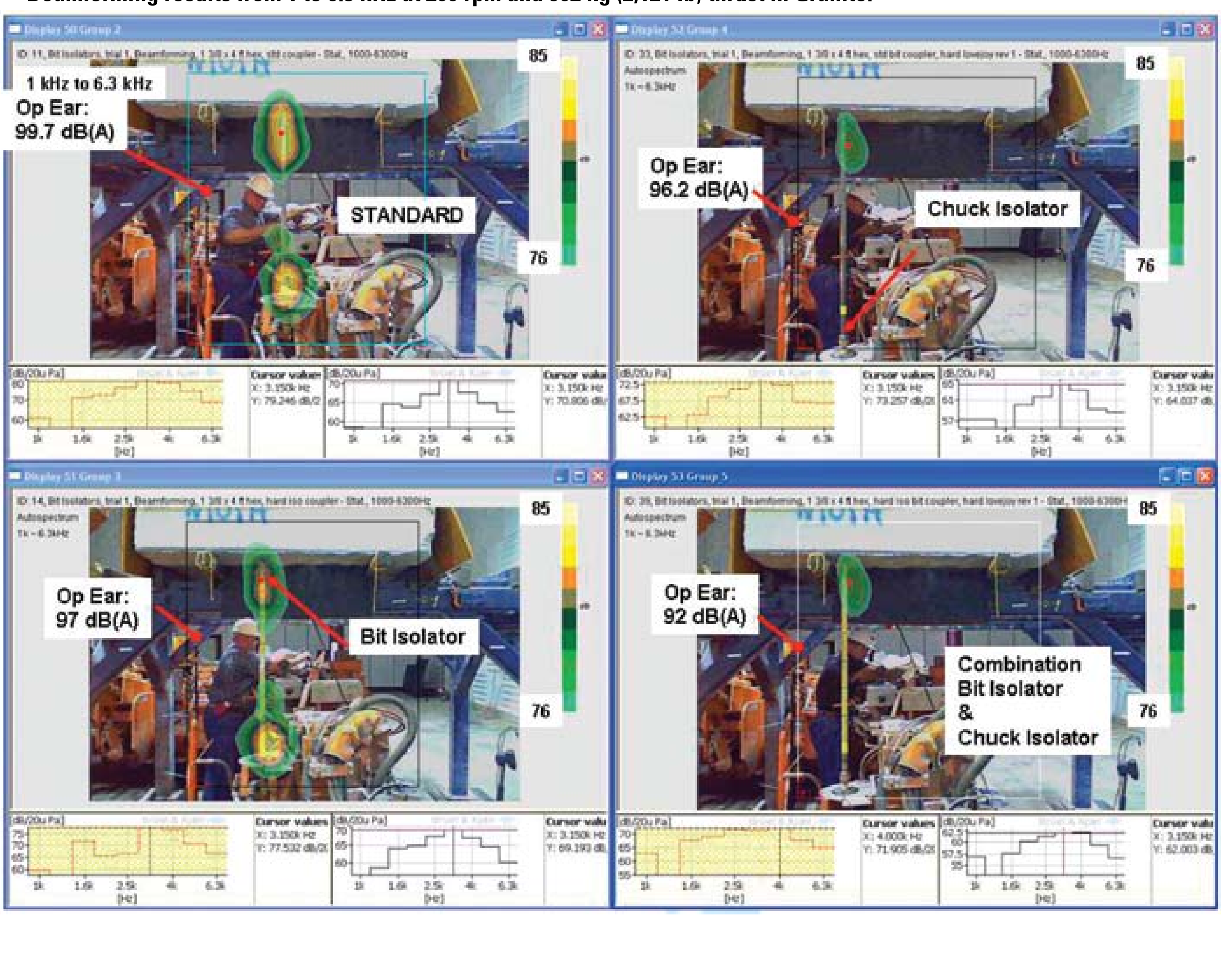


FIGURE 9

Beamforming results from 1 to 6.3 kHz at 200 rpm and 962 kg (2,121 lb) thrust in Granite.



tion of the bit isolator and the chuck isolator the results were promising and showed a reduction in the dominant frequency bands, 1,250 Hz through 8 kHz, thus reducing the noise radiated toward the operator by 7 dB(A).

Conclusion

The drilling noise sources on a Fletcher HDDR roof bolter were identified by using the beamforming technique. Two areas radiate the majority of the drilling noise: the drill-bit/rock-interface and the drill-steel/drill-chuck interface. It was also determined that the drill-steel-type and drilling depth had no effect on the beamforming results. NIOSH laboratory results showed that the chuck isolator and the bit isolator had a significant influence on lowering the sound pressure level at the position of the roof bolting machine operator. In general, experimental results showed the chuck isolator to be more effective as a noise control, but the combination of both controls had the greatest effect on reducing the sound pressure level at the operator's position. Noise controls demonstrated in this research are providing the mining community with an opportunity to reduce roof bolting machine operator noise overexposures.

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