Continuous Mining Machine Conveyor System Sound Power Levels

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ABSTRACT

Occupational hearing loss is a permanent illness with no recovery currently possible. For underground coal mine workers, Noise Induced Hearing Loss (NIHL) continues to be a serious health issue. One of the principal and fundamental machines used in underground mining operations is also one of the loudest. Noise generated on the continuous mining machine is the result of 3 operational components: the cutting system, the dust collection system, and the onboard conveying system. During underground acoustic evaluations, the conveyor system noise was observed to be dominant. In order to more closely examine sound generated by the continuous mining machine, sound power levels were measured in a reverberation chamber at the Pittsburgh Research Laboratory (PRL). Different chain types and configurations were installed on the conveyor system, and the resulting sound power level ranged from 118 dB(A) to 108 dB(A). Noise generated by the dust collection system was also examined and found to be 107 dB(A).

1. INTRODUCTION AND BACKGROUND

Due to the relatively large size of underground mining equipment, noise induced hearing loss is common in the mining community. Despite over 30 years of regulation, this health hazard is still prevalent among underground mine workers. Past studies indicate that 80% of underground coal miners have a hearing impairment by the time they reach retirement age.[1] Comparing equipment used in underground coal mining operations, the continuous mining machine accounts for the most noise overexposures. According to the Mine Safety and Health Administration (MSHA) Coal Noise Data taken from 2000 to 2006, the overall number of noise overexposures has declined while the number of overexposures caused by continuous mining machines has slightly increased, shown in Figure 1.[2]

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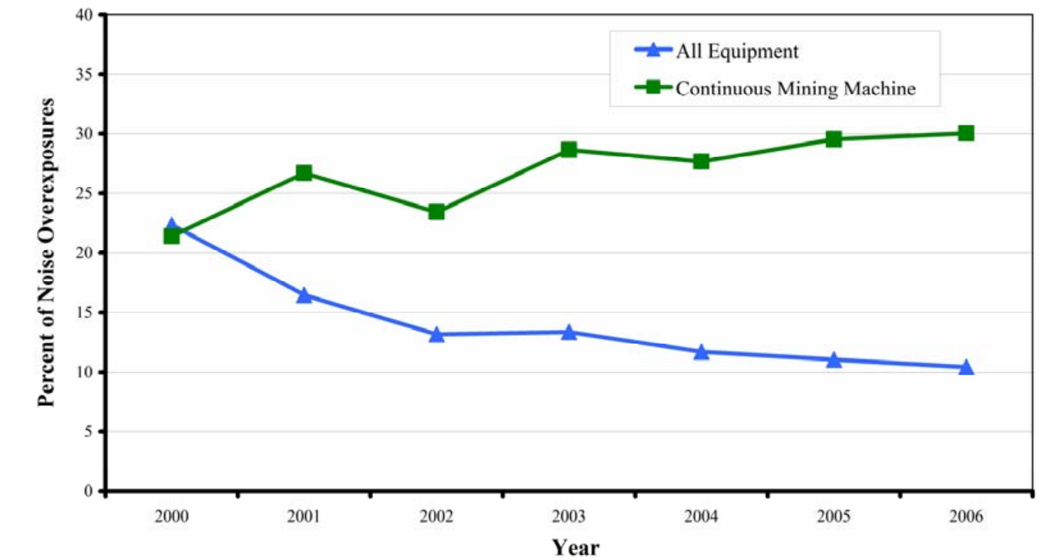

Figure 1: MSHA coal noise sample data - Percentage of equipment operators that exceeded 100% noise dose

There are two conventional types of mining approaches that are employed in underground coal mining: the longwall mining method and the continuous mining method. The longwall mining method utilizes a mechanized rotating shearer that moves back and forth across the coal face, which can be over 300 m wide. The continuous mining method divides the mine into a series of 6-to-9 m "rooms" where work areas are cut into the coal bed and "pillars" are left behind for roof support. Longwall mining is a more efficient means to extract coal, but is not applicable in all geological situations. The room and pillar method of mining remains one of the fundamental methods to extract coal during mining operations, and the continuous mining machine is one of the primary pieces of equipment used for this type of mining. Continuous mining machines accounted for 175 million tons of coal mined in the United States in 2006, just under half of the total underground coal produced.[3] There are over 9000 continuous mining machine operators employed in the United States, and approximately half work in underground coal mines.[4]

Overall noise generated by the continuous mining machine is a result of several operational system mechanisms. The cutting, dust collection, and conveying systems can be operated independently, but are often all running simultaneously during operation. The cutting system noise is a result of a rotating drum cutting bit, used to cut the coal seam, and the coal/rock interface. The dust collection system noise is the result of a vane axial fan used to collect fine particulate during cutting, which is located opposite of the manual controls. The conveying system noise is caused by impacts that occur between the conveyor deck and flight bars, used to move mined coal to the discharge end of the machine. Noise generated by the vane-axial fan in the dust collection system has been examined by previous research and proposed treatments showed promise.[5,6,7] Past studies conducted by the Bureau of Mines concentrated on the importance of noise associated with the cutting system.[5] However, this assumed that the operator controlled the continuous mining machine via on board controls, unlike the remote machine controls used by industry today. By using remote controls operators are more directly exposed to the noise generated by the conveying system, which has been the focus of recent investigations.[6,8]

In order to reduce operator overexposure, noise generated by the continuous mining machine conveyor system must be abated. Noise produced by this system is due to the interaction between the conveyor flight bars and machine components during chain travel. Two noise controls have been developed to address these interactions: urethane coated flight bars and urethane treated tail roller.[8,9,10] The urethane coated flight bars addresses noise generated at the gear sprocket drives at the front of the machine and the impacts that occur along the conveyor deck. The urethane treated tail roller specifically focuses on the flight bar / tail roller interaction by isolating impacts that occur as the chain changes direction at the discharge end. Tail roller component treatments have been further examined but has not shown as much promise in reducing conveyor system noise as the urethane coated tail roller.[10] In order to effectively evaluate noise reductions, these treatments need to be examined in combination.

2. EXPERIMENTAL SETUP

Acoustic measurements were taken at the Pittsburgh Research Laboratory (PRL) large reverberation chamber.[11] Given the geometric and acoustic variations that are encountered in underground mining, sound power levels were used to evaluate noise treatments applied to the continuous mining machine. The chamber is a 1286 m^3 room with treated hard walls and controlled humidity to ensure a highly diffuse sound field. Microphones were placed in a parallelepiped configuration to ensure that no microphone was placed less than one major machine dimension from the continuous mining machine. The approach outlined by ISO 3743-2 using the comparison method was used for all tests. Data from the 16 microphone locations were acquired using a Bruel & Kjaer Pulse system. Collected one-third octave band sound pressure levels were logarithmically averaged during data post processing.

To accurately compare different test parameters the same machine was used for all sound power measurements. Tests were performed on a Joy 14CM-9 continuous mining machine equipped with a 76 cm wide conveyor system. The conveyor was continuously driven by a sprocket gear at a measured speed of 2.5 m/s. Water was continuously applied to the conveyor tail section to simulate wet conditions that occur during the coal cutting process. The tail section of the continuous mining machine can be swung 30 degrees off center to strategically place the mined product. The chain flight bars impact the side flex plates that guide the conveyor when the tail section is swung. Thus, conveyor orientation to each extreme (left and right) was examined as shown in Figure 2.

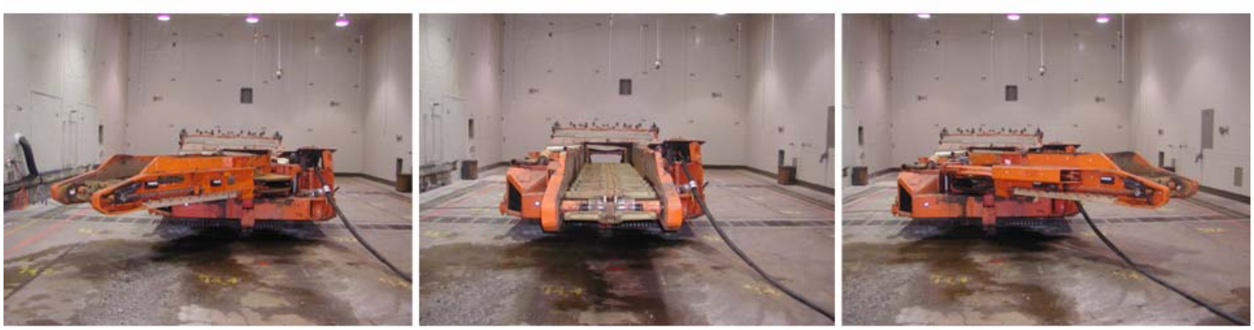

Figure 2: Continuous Mining Machine in PRL reverberation chamber with conveyor swung left, straight, and right

In order to quantify the acoustic performance of the continuous mining machine conveyor system, many operating variables were examined. As stated above, continuous mining machine noise can be categorized by operational components. For this study only the conveying and dust collection systems were examined. The gear and hydraulic pumps were examined to quantify machine background noise. Two different manufactured chains were installed on the continuous mining machine: Joy Mining Machinery and Cincinnati Mine Machine[*]. Chain tension was made constant for both chains using methods described in previous studies.[6] Also, noise treatments previously demonstrated were applied to the Joy Mining Machinery chain.[6,8,9] The continuous mining machine was also tested under loaded conditions by using a synthetic coal mixture (coalcrete) to fill the conveyor deck shown in Figure 3. Coalcrete is a mixture of: 8 parts coal, 8 parts ash, and 3 parts cement.[12] This was achieved by manually placing aggregate on the conveyor deck, and collecting data for 10 seconds.

Figure 3: Continuous mining machine with noise treatments installed and loaded with synthetic coal mixture

3. RESULTS AND DISCUSSION

The noise generated by the hydraulic pump and dust collection fan were examined first. The Cincinnati Mine Machine chain was installed on the conveyor system and resulting sound power levels can be seen in Figure 4. The machine hydraulics pumps (light blue line) were turned on alone. The dust collection system was then switched on (dashed line), followed by the conveyor system (dark blue line). The hydraulic pumps produced an overall A-weighted sound power level of 87 dB, while the dust collection system and conveying systems generated levels of 107 dB(A) and 119 dB(A), respectively. The conveyor system noise is at least 10 dB louder than the

[*] Product(s) mentioned are not endorsed by NIOSH or authors

dust collection system noise in all frequency bands shown in Figure 4, and therefore has little contribution to noise caused by the chain conveyor. Thus, future tests conducted during this research concentrated on conveyor noise, and dust collection system noise is not present. It should also be noted that 93% of the A-weighted sound power level generated by the conveyor system shown in Figure 4, is a result of the 400 Hz - 4 kHz one-third octave bands. For noise treatments on the conveyor system to be effective, these frequency bands must be targeted.

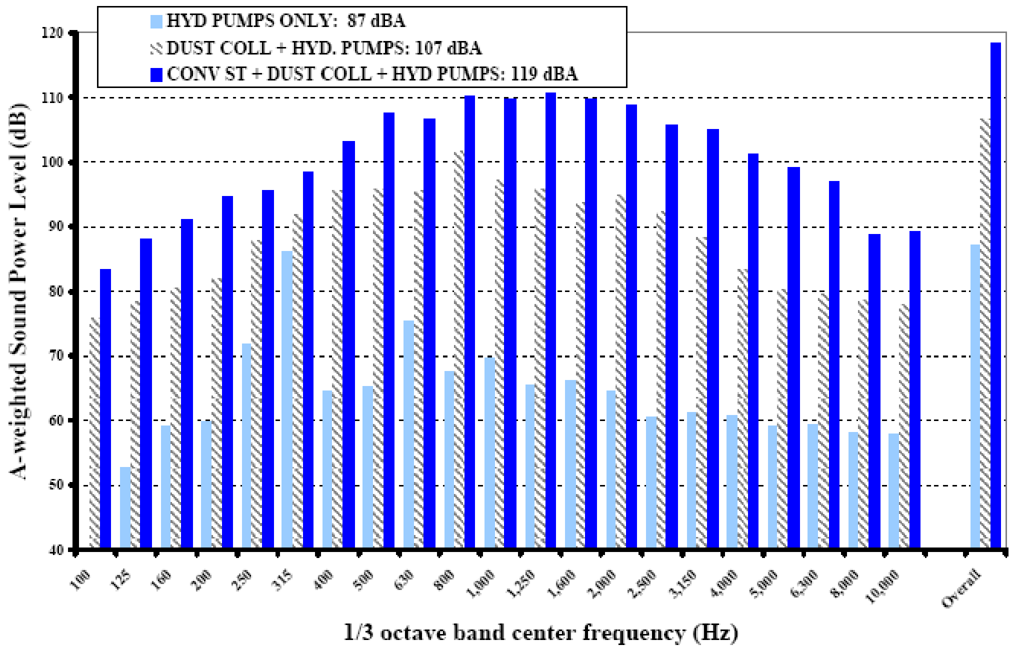

Figure 4: Sound power level of the hydraulic pumps, dust collector, and Cincinnati Mining Machine Chain

The sound power levels of continuous mining machine conveyor chains from different manufacturers were the next test parameter that was examined. The sound power level of the Joy Mining Machine chain installed in the conveyor system is shown in Figure 5. Sound power levels were observed at the conveyor tail section positions shown in Figure 2 for the conveyor swung: straight (orange line), left (dashed line), and right (light green). With the tail section straight, the continuous mining machine conveyor system generated A-weighted sound power levels of 117 dB. The conveyor system produced levels of 120 dB(A) when the conveyor was swung to the left or right. The Cincinnati Mine Machine chain was also tested with the same configurations, and the results showed similar results (not shown for redundancy). When the conveyor was straight the Cincinnati Mining Machine chain produced a level of 119 dB(A), and 120 dB(A) with the tail section swung left or right. In comparing these results there seems to be no acoustic advantage in using the Joy Mining Machinery over the Cincinnati Mining Machine chain, because they produced A-weighted sound power levels that were within 1 dB of each other.

Previously developed engineering noise controls were installed on the continuous mining machine using the Joy Mining Machinery chain.[6,8,9] A sound power level comparison of these applied treatments is shown in Figure 6. The standard 76 cm Joy Mining Machinery chain (orange line) flight bars were machined and accommodated with a urethane coating (checkered line). A reduction in sound power level of 5 dB is observed with the urethane coated chain installed and the conveyor tail section oriented straight. The continuous mining machine was then fitted with the urethane coated tail roller (light grey line) and the coated flight bar simultaneously. A reduction of 9 dB in sound power was achieved when both noise treatments were used concurrently. Similar reductions were observed when the conveyor tail section was articulated left and right (not shown).

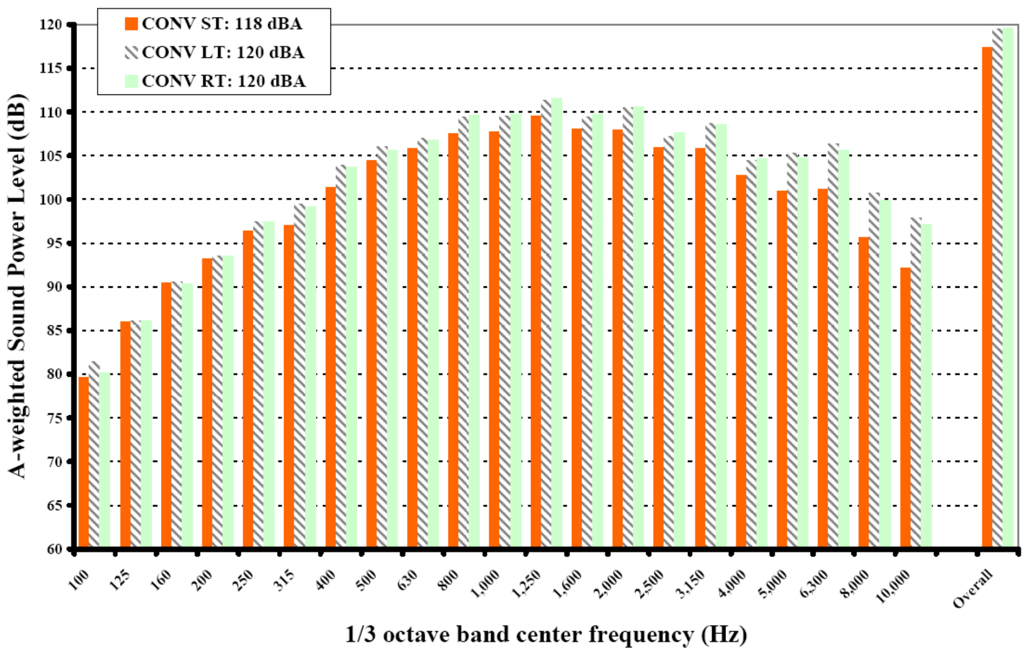

Figure 5: Sound power level of the Joy Mining Machinery chain

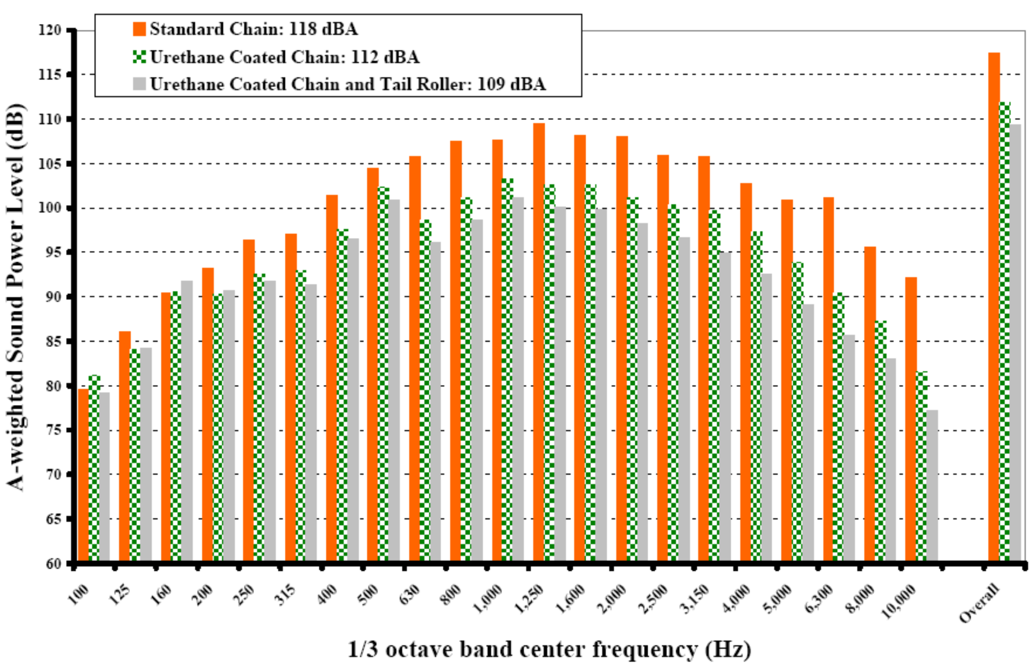

Figure 6: Sound power level of noise controls installed on the continuous mining machine

Finally, the continuous mining machine with noise treatments installed was tested with the conveyor fully loaded. The ability of mined coal aggregate to suppress noise caused by the conveyor system was examined by loading the conveyor with a synthetic coal mixture known as "coalcrete". A continuous mining machine conveyor system will typically accumulate a 20 cm thick layer of coal during operation. It was believed that this layer would dampen impacts that occur between the conveyor flight bars, deck, and transition points. Figure 7 shows the sound power level comparison between the conveyor unloaded (grey line) and loaded with coalcrete (dashed line). Engineering noise controls described above (urethane coated flight bar and tail roller) were implemented with the tail section positioned straight. Although there are some differences in the high and low frequency bands, the resulting overall A-weighted sound power level was found to be 108 dB for both cases. It should be noted that there is a 1 dB discrepancy in overall levels between the unloaded conveyor in Fig. 7 and the standard chain in Fig. 6. This was most likely due to a bottom plate that was removed from the conveyor underside. The plate was interacting adversely with the coalcrete, and was removed for both data sets shown in Fig.7.

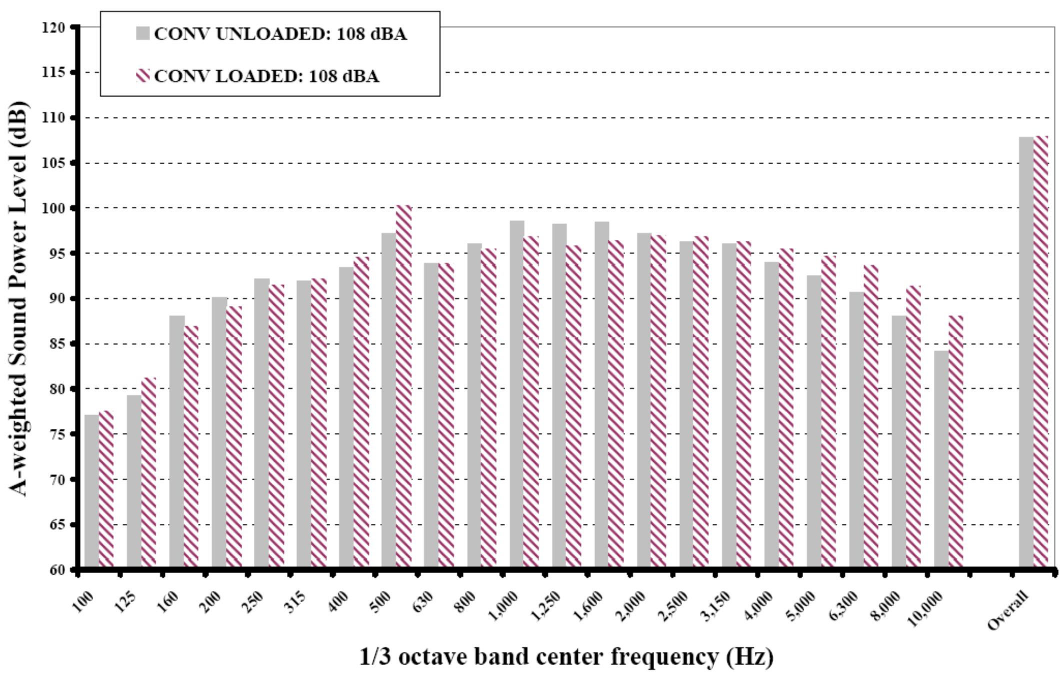

Figure 7: Sound power level of continuous mining machine with noise controls installed under loaded conditions.

4. CONCLUSIONS

The sound power levels of several continuous mining machine configurations were tested at the PRL reverberation chamber. Conveyor chains made by different manufacturers were installed on the conveyor and the results showed similar sound power levels. Neither chain manufacturer showed promise in reducing underground operator noise overexposure. The conveyor tail section orientation was also examined, and showed slightly higher sound power levels at the higher frequencies when swung to the left or right. The Joy Mining Machinery chain had a durable urethane coating applied to the conveyor flight bars. The urethane coated chain was examined simultaneously with a coated tail roller using the same urethane material. An overall A-weighted sound power level reduction of 9 dB was observed with these treatments implemented. These noise controls were examined with and without conveyor loading, which showed no difference in the overall sound power levels. The hydraulic pump and dust collection fan noise was investigated in relation to conveyor system noise. The dust collection system noise seems to have little effect on the overall observed conveyor system sound power level. However, with the above mentioned noise controls applied the dust collection system becomes a dominant noise source. Future investigations should also concentrate on reducing noise generated by the vane-axial fan in the continuous mining machine dust collection system.

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