Modified tail section reduces noise
on a continuous mining machine

by A. K. Smith, J. J. Zimmerman, R. Michael and P. G. Kovalchik

Abstract ■ Overexposure to noise remains a widespread, serious health hazard in the U.S. mining industry. Most other categories of illnesses and injuries associated with mining have improved, with the exception of hearing loss. U.S. Mine Safety and Health Administration (MSHA) coal noise data from 2000-2004 show that the continuous mining machine (CMM) is first among all equipment, accounting for 35% of noise overexposures. Joy Mining Machinery, in collaboration with the National Institute for Occupational Safety and Health (NIOSH), is conducting research to reduce noise generated by continuous mining machines. This paper describes a "JOY-Designed for Noise Reduction" (JOY-DNR; patent pending) tail section as a noise control for reducing the noise overexposures of CMM operators. Underground testing shows a 45% to 65% noise exposure reduction for the operator when comparing the JOY-DNR tail section results to those for a standard machine. Utilizing this newly developed noise control, along with previously proven controls, will provide CMM operators an opportunity to be within the MSHA permissible exposure limit (MSHA-PEL).

Introduction

Exposure to industrial noise continues to be an extensive health issue for mine workers in the United States. Noise can also be an indirect safety hazard because it can "mask" important sounds, such as backup alarms. Although noise-induced hearing loss (NIHL) is preventable, studies suggest that more than half of the nation's mine workers will retire with a hearing impairment (Franks, 1996). NIHL is particularly severe among underground mine workers, due to the operation of large industrial equipment in confined spaces. Of particular concern is the continuous mining machine (CMM) used in room-and-pillar mining.

The CMM is one of the principal machines used in underground coal mining and is also one of the loudest. Analysis of noise samples collected by the U.S. Mine Safety and Health Administration (MSHA) in 2006 show that 30% of CMM operators exceeded the permissible exposure level (PEL), as stated by Title 30 of the Code of Federal Regulations (MSHA, 2008). This constitutes the largest group of underground equipment operators that are overexposed to noise. Furthermore, underground sound levels can range from 78 to 109 dB (A) during typical CMM operation (Bauer et al., 2006). Operation of the onboard conveyor system has also been identified as a dominant noise source that significantly contributes to operator exposure. Sound power generated by the conveyor system can range from 118 to 120 dB (A), depending on how the tail section is swung (Smith et al., 2008).

Effective CMM noise reduction strategies have concentrated on addressing the dominant noise sources. Acoustic beamforming has been used to identify components on the CMM conveyor system that are significant radiators of noise (Camargo et al., 2008). Interaction between the steel flight bar chain and conveyor deck excites the machine structure and produces most of the noise. Also, forces are transmitted at the tail roller and sprocket transition points, where the conveyor chain transverses its path. Several engineering noise controls have been developed to address these noise-generating mechanisms (Smith et al., 2009; Camargo et al., 2008; Smith et al., 2008; Smith et al., 2007).

Recently, Joy Mining Machinery has made several design improvements in the CMM tail section to reduce noise and improve performance. This paper examines these improvements to test their impact on CMM noise reduction.

Approach

Several modifications were made on the tail section of a Joy Mining Machinery 14CM15 CMM to reduce noise generated by the conveyor system. The machine utilized a dual-sprocket chain

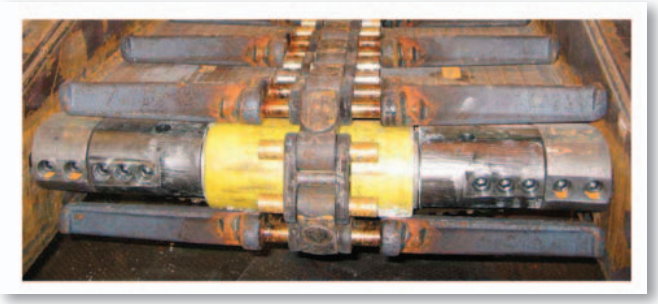
Table 1

MSHA permissible exposure level dosimeter settings.

Parameters	Settings
Weighting	A
Threshold level	90 dB
Exchange rate	5 dB
Criteria level	90 dB
Response	Slow
Upper limit	140 dB

Figure 1

Joy-DNR tail section with isolated tail roller installed.



conveyor system. Improvements were also made to the conveyor chain tensioning and take-up systems, as well as the tail roller component. The automatic hydraulic tensioning systems removed chain slack, which influences the noise generated by the conveyor system. Tail roller components were constructed with various compliant materials to reduce the vibration transmitted to the rest of the machine. These design changes were combined with a Joy Mining Machinery dual-sprocket conveyor chain, which has previously demonstrated the ability to reduce noise (Smith et al., 2009).

The modified CMM was put into service at an underground coal mine to assess performance. Success of any acoustic treatment on underground mining equipment is determined by its ability to reduce noise and maintain durability in the work environment. To evaluate the noise reduction capability of the JOY-DNR tail section, noise exposure and task observation data were collected. Durability was assessed by the ability of noise treatments to survive in a mining environment for an extended period of time.

CMM operator noise exposure data were collected using a personal noise dosimeter. The dosimeter settings were set to the MSHA PEL, as shown in Table 1. Dosimeters were attached to workers on the surface before the shift started, and were removed after the shift was complete. Noise exposure data were collected over three days for three separate work shifts. Dosimeters were placed on the two CMM operators working in a multiple-entry, split-air section. Both of the CMMs were Joy Mining Machinery 14CM15; one was a standard build machine and the other included the JOY-DNR tail section. A standard tail roller was used on the JOY-DNR tail section for day 1, and different isolated tail rollers were installed for days 2 and 3 on the same machine. Task observations and production data were also collected to give context to the results.

Figure 2

CMM operator noise exposure comparison of Joy-DNR tail section with standard tail roller (red line) and standard tail section machine (gray line).

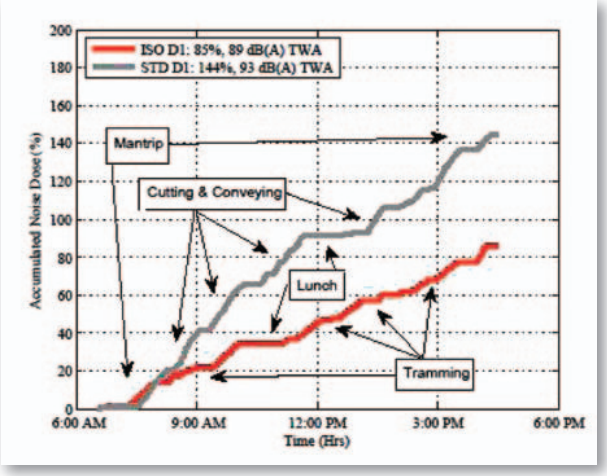
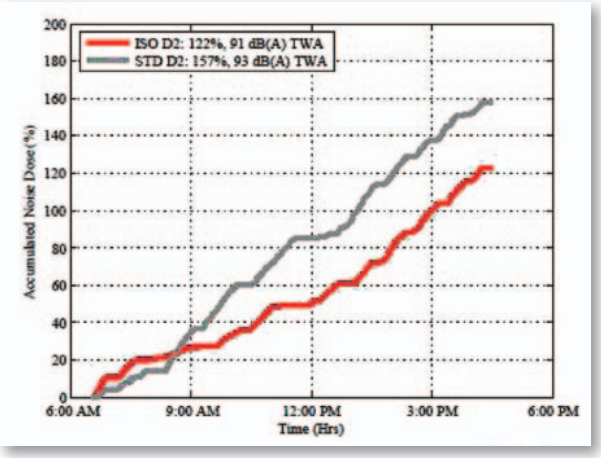


Figure 3

CMM operator noise exposure comparison of Joy-DNR tail section with tail roller #1 (red line) and standard tail section machine (gray line).



To achieve further noise reduction, vibration-isolated tail rollers were developed for the JOY-DNR tail section. The tail rollers had a hard plastic outer shell for wear protection with a compliant material core to absorb chain impacts. Two different materials for the core were examined: heavily damped butyl rubber and high strength natural rubber. An isolated tail roller installed on the JOY-DNR tail section is shown in Fig. 1.

Results and discussion

Operator noise exposure data were used to evaluate a JOY-DNR tail section on a CMM in a working environment. Accumulated operator noise doses for the standard and JOY-DNR tail section machines were computed for each shift. The operator noise dose for the JOY-DNR tail section machine (red line) is compared to that for the standard machine (gray line) in Figs. 2 - 4. The total accumulated noise dose and time-weighted average for an eight-hour work shift ($TWA_{(8\ Hr)}$) are shown in the legend of each figure. An example of the general task observations for both machines is also shown in Fig. 2. Task observation data were collected for the other shifts, but are not shown for purposes of brevity. Production

Table 2

Noise exposure results and production.

	Day 1		Day 2		Day 3	
	STD	JOY-DNR (REG TR)	STD	JOY-DNR (TR #1)	STD	JOY-DNR (TR #2)
Shift dose	144%	85%	157%	122%	155%	90%
$TWA_{(8\ Hrs)}$	93 dB(A)	89 dB(A)	93 dB(A)	91 dB(A)	93 dB(A)	89 dB(A)
Production	245 ft	280 ft	240 ft	290 ft	255 ft	200 ft

numbers were also collected for each machine during the work shift.

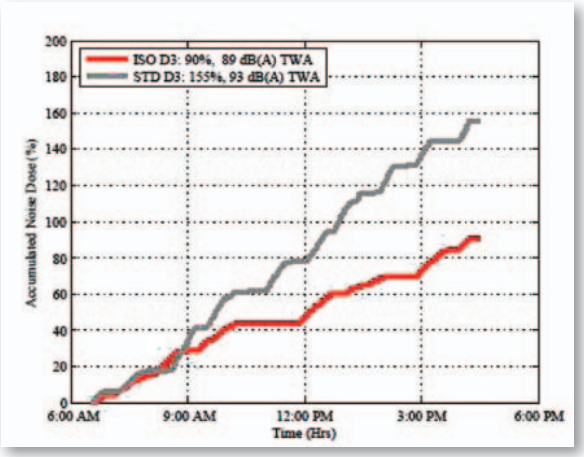
Different tail rollers were installed on the JOY-DNR tail section machine in an attempt to further reduce noise and vibration transmitted to the rest of the machine. On the first day of data collection, a standard tail roller was installed on the JOY-DNR tail section machine. For days 2 and 3, the JOY-DNR tail section machine had different tail roller designs installed. The results of CMM operator exposure data are summarized along with production numbers in Table 2. The tail rollers of different compliant materials are labeled TR #1 and TR #2.

There were no observed changes to the standard CMM noise exposure results during data collection during the three work shifts. In contrast, for the JOY-DNR tail section machine, several observations can be made by comparing the accumulated operator noise exposure results. Noise exposure levels were consistently lower for the operator using the JOY-DNR tail section machine. $TWA_{(8\ Hrs)}$ reductions of 4 dB (A) are observed on day 1 and day 3, while a modest $TWA_{(8\ Hrs)}$ reduction of 2 dB (A) is seen on day 2. These findings reflect a 45% and 65% noise exposure reduction for the CMM operator when the JOY-DNR tail section results are compared to those for a standard machine. Daily production remained relatively consistent for all shifts where data were collected.

Several variables must be considered when examining these underground mining worker noise exposure results. Although both CMMs were used on the same working section of the mine, geological composition and machine operation were not exactly the same. Also, the operator position for the standard CMM was on the same side as the exhaust of the dust collection system of the standard machine. Although the conveyor system is a dominant noise source, noise generated by the axial-vane fan at this location could contribute to operator noise exposure for the standard machine operator.

Figure 4

CMM operator noise exposure comparison of Joy-DNR tail section with tail roller #2 (red line) and standard tail section machine (gray line).



Conclusions

A JOY-DNR tail section, developed for a 14CM15 CMM, is the latest effort by Joy Mining Machinery to address equipment noise generation that affects mine workers. Several different JOY-DNR tail rollers were examined in this study. Modifications to their design showed promise in reducing worker noise exposure. Further tests are needed to confirm promising results that were observed during this underground evaluation. The JOY-DNR tail section machine should be examined acoustically in a laboratory environment to prove repeatability of the test results and reduce variance. Also, material properties of the compliant materials used in the JOY-DNR tail rollers should be further investigated. Implementation of this technology, along with other proven noise controls for CMMs, should help lessen the occurrence of NIHL in the underground mining industry. ■

Disclosure

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health. Mention of any company or product does not constitute endorsement by NIOSH.

References

Bauer, E.R., Babich, D.R., and Vipperman, J.R., 2006, *Equipment Noise and Worker Exposure in the Coal Mining Industry*, Information Circular 9492, National Institute for Occupational Safety and Health, Pittsburgh, PA.

Camargo, H.E., Smith, A.K., Kovalchik, P.G., and Matetic, R.J., 2008, "Noise source identification on a continuous mining machine," *Proceedings of Noise Con 2008*, Dearborn, MI: INCE.

Franks, J.R., 1996, *Analysis of Audiograms for a Large Cohort of Noise-Exposed Miners*, Unpublished technical report. National Institute for Occupational Safety and Health, Cincinnati, OH.

MSHA, 2008, *MSHA Standardized Information System, Number of Noise Samples @90PELDose(computed)>=100 by Machine Code*, 2006, Denver, CO: U.S. Department of Labor, Mine Safety and Health Administration, Office of Injury and Employment Information. Date accessed: March 20, 2008.

Smith, A.K., Yantek, D.S., and Peterson, J.S., 2007, "Development and evaluation of a urethane jacketed tail roller for continuous mining machines," *International Mechanical Engineering Congress & Exposition*. Seattle, WA: ASME.

Smith, A.K., Peterson, J.S., and Kovalchik, P.G., 2008, "Continuous mining machine conveyor system sound power levels," *Proceeding of Noise Con 2008*, Detroit, MI: INCE.

Smith, A.K, Kovalchik, P.G., Matetic, R.J., and Alcorn, L.A., 2009, "A dual sprocket chain as a noise control for a continuous mining machine," *Noise Control Engineering Journal*, Vol. 57, No. 5, pp 413-419.

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