A dual sprocket chain as a noise control for a continuous mining machine

Pete G. Kovalchik
Adam K. Smith
Rudy J. Matetic
Lynn A. Alcorn
National Institute for Occupational Safety and Health
626 Cochrans Mill Road
PO Box 18070
Pittsburgh, Pa. 15236

ABSTRACT

Over-exposure to noise remains a widespread, serious health hazard in the U.S. mining industries despite 25 years of regulation. Most other categories of illnesses and injuries associated with mining have improved, with the exception of hearing loss. Mine Safety and Health Administration (MSHA) coal noise sample data collected from 2000 to 2002 show that 65% of the equipment whose operators exceeded 100% noise dosage is comprised of seven different types of machines. The continuous mining machine is first among all the equipment with 35% of the noise overexposures. The ational Institute for Occupational Safety and Health (NIOSH) is conducting research to reduce excessive exposure for operators of continuous mining machines and preventing additional cases of oise Induced Hearing Loss (NIHL) by developing low-cost retrofit noise controls for mining equipment. This paper describes a noise control for reducing the noise overexposures of continuous mining machine operators. Underground results show a 26.4% and 27.4% noise exposure reduction for the continuous mining machine operator. This research is providing the mining community with an additional noise control to be utilized on continuous mining machines, therefore reducing operator noise overexposure. Utilizing this newly developed noise control, along with previously proven controls for the continuous mining machine chain conveyor, will provide operators of these machines an opportunity to be within the MSHA-Permissible Exposure Limit (MSHA-PEL).

1. INTRODUCTION

One of the more serious noise problems in underground coal mining is related to the operation of continuous mining machines. The continuous mining method accounted for 48% of all underground coal extraction for 2005. [1] There are approximately 1400 mines with over 4,000 continuous mining machine operators. [2,3] Figure 1 shows the percentage of continuous mining machine operators that exceed 100% noise dose from 2000 to 2005 according to the MSHA database.

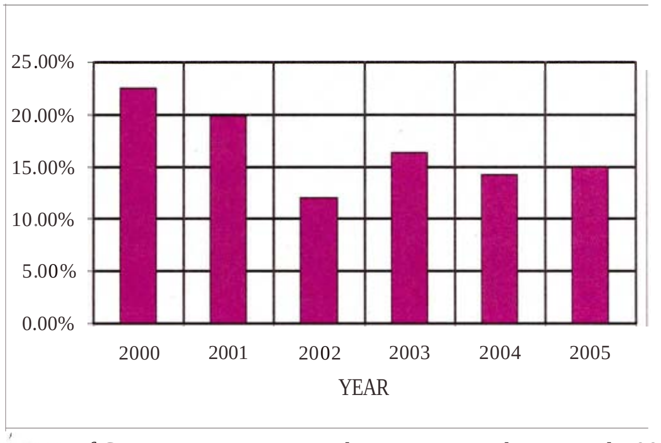

Figure 1 Percentage of Continuous mining machine operators that exceed 100% noise dose

The continuous mining machine is ranked first as a noise source of underground noise at the face. The dominate noise sources from the continuous mining machine are the conveyor and cutting systems.[5,6] Continuous mining machines are large underground coal cutting machines which cut the coal at the working faces, gather up the cut coal, and transport it via an onboard conveyor to the back of the machine where it is loaded onto either another conveyor or a piece of mining equipment designed to carry the coal away from the working face. One of the major noise sources on a continuous mining machine is the onboard conveyor which consists of a chain with flight bars which drags the coal along the base of the conveyor system. The metal chain and flight bars in contact with the metal base and the coal itself are a significant noise source and contribute a great deal to the noise exposure of workers at the face. Continuous miner operators stand near the chain conveyor, especially at the back of the machine, and receive a significant portion of their dosage from the noise coming from the conveyor.

This paper presents results from a project related to the latest effort by NIOSH's Pittsburgh Research Laboratory (PRL) to control noise exposure on continuous mining machines in coal mining environments. Specifically, this paper concentrates on the noise emissions from the conveyor of a Joy Mining Machinery continuous mining machine. Joy Mining Machinery continuous mining machines are representative of industry usage.

The successful control of the conveyor noise will be a major contributor for reducing the noise overexposures of operators using continuous mining machines.

2. BACKGROUND

The continuous mining machine has several noise sources which may be considered worthy of examination. These include the chain conveyor, cutting head, pumps, and dust collector or scrubber (essentially fan noise). Joy Mining Machinery has a significant portion of the market for continuous mining machines used in underground coal mines, and typically uses the same components. In 2001 tests were conducted at PRL confirming the chain conveyor was a major noise source.[7] In 2002 NIOSH addressed this issue by developing a chain conveyor with coated flights as a noise control for reducing the sound power emissions of continuous mining machines. By coating the flight bars with a heavy duty, highly-durable urethane, the metal to metal and metal to coal contact is reduced with a resulting reduction in noise levels. NIOSH designed, developed, and has been lab tested this control in a partnership effort with labor

(United Mine Workers of America), industry (National Mining Association, Bituminous Coal Operators Association), manufacturers (Joy Manufacturing), and MSHA stakeholders. [8] However, the effectiveness of this engineering noise control, coated flight bars, in reducing the noise exposure of continuous mining machine operators in an underground coal mine environment still needed to be conducted. In 2005 an underground case study was conducted to confirm the effectiveness. The case study showed the accumulated dose of the operator using the coated conveyor chain was reduced from 178% to 114%. [9] This corresponds to a 3 dB exposure in a full shift TWA using the MSHA exposure criteria. This research is providing the mining community with a dual sprocket chain as a noise control to be utilized with the coated conveyor chain for the continuous mining machine. This will provide operators of these machines an opportunity to be within the MSHA-Permissible Exposure Limit (MSHA-PEL).

3. DUAL SPROCKET CHAIN

The continuous mining machine chain conveyor typically consists of an 83mm pitch chain with 433mm length flights bars and a four tooth sprocket. The chain conveyor speed runs at 475 ft per minute. Illustration 1 shows a typical chain conveyor.

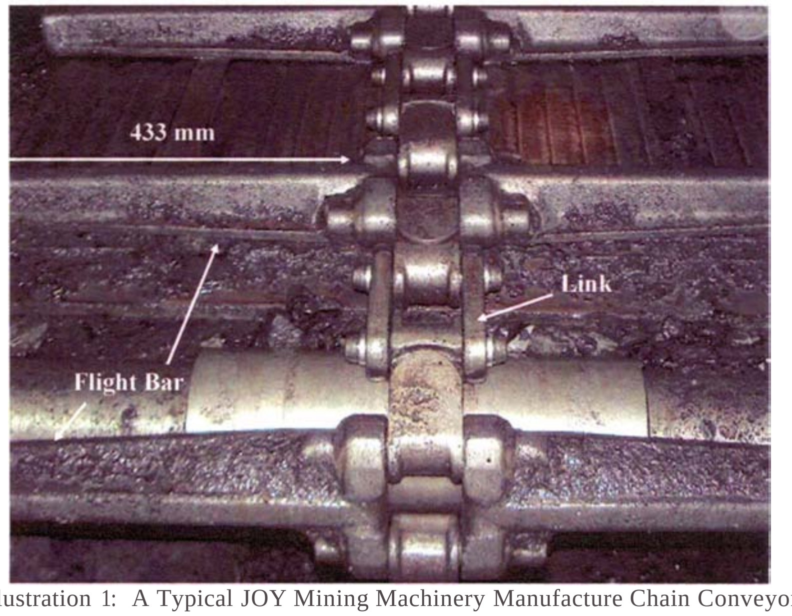

Illustration 1: A Typical JOY Mining Machinery Manufacture Chain Conveyor

The dual sprocket chain has the same chain pitch of 83mm and runs at the same speed. Therefore, the sprocket design consists of two sprockets with 8 teeth on each sprocket. So the dual sprocket has 16 teeth instead of 4 teeth. This sprocket was designed for to minimized fluctuation of chain tension, which should reduce the amount of noise created by the chain conveyor and increase the life of the chain. Past research conducted by NIOSH showed that the noise level due to the conveyor was also affected by the tension in the chain with higher tensions resulted in higher noise levels. [7] Another difference in the chain is the flight bar length is 370mm which is a reduction of 63mm in length of the flight bars. This is because the chain now has two sets of links instead of one. Illustration 2 shows the newly designed dual sprocket chain by JOY Mining Machinery Manufacturer.

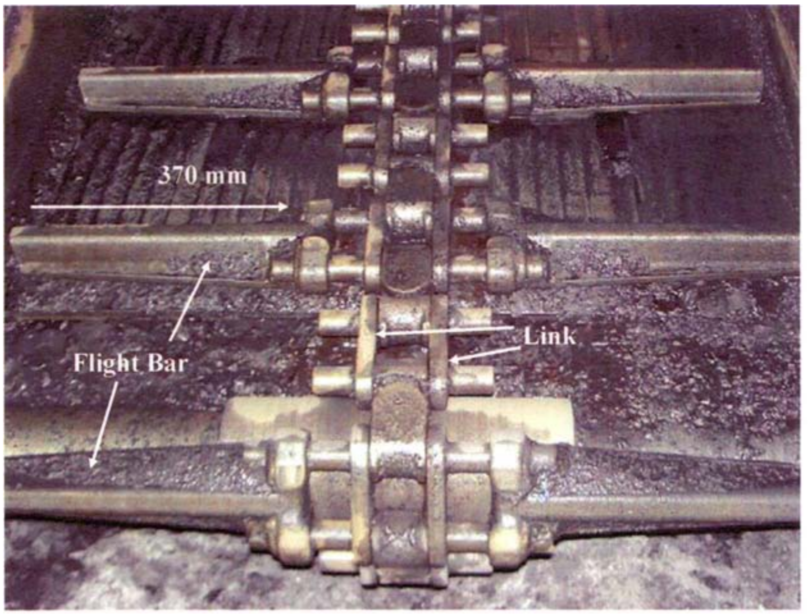

Illustration 2: The newly designed dual sprocket chain by JOY Mining Machinery Manufacture.

4. APPROACH

The Pittsburgb Research Laboratory NVLAP accredited reverberation chamber was used for determining sound power levels for the chain conveyor. The PRL reverberation chamber (Illustration 3) was designed for sound power testing of large equipment in conformance with ISO 3741.[10] It meets ISO 3741 in the frequency range of 100Hz to 6300 Hz.

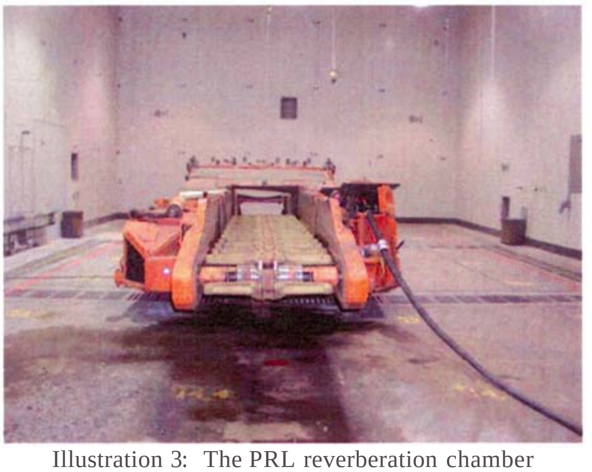

Illustration 3: The PRL reverberation chamber

Baseline sound power levels were collected for a typical Joy Mining Machinery chain, which consisted of an 83mm pitch chain with 433mm length flights bars and a four tooth sprocket running at 475 ft per minute. The chain tension was set according to the manufacturer's recommendation. A set of three tests were conducted with the typical conveyor chain. The first test consisted of running only the conveyor in the straight position. (Illustration 3) The second test consisted of running only the conveyor extended fully to the right. (Illustration 4)

Illustration 4: The conveyor extended fully to the right.

The third test consisted of running only the conveyor extended fully to the left. (Illustration 5)

Illustration 5: The conveyor extended fully to the left.

After the lab baseline data was collected, sound power levels were then collected for the dual sprocket chain. The same test configurations were used for testing the dual sprocket chain (straight, fully right, and fully left).

Comparison of the results was then conducted to see the effectiveness or ineffectiveness of the dual sprocket chain in the laboratory conditions. If the dual sprocket displayed promise in the laboratory then the next step would be to conduct an underground field evaluation. The underground field evaluation would be determined by using dosimeters to determine the amount of acoustic noise that an operator is exposed to during a work shift. The dosimeters parameters were set according to MSHA specifications (Table!). Baseline dosimetry had to be collected first on a typical chain conveyor to determine the amount of acoustic noise that the operator was exposed to during a work shift. Then the dual sprocket chain dosimeter would be collected on the same operator and same machine to determine the amount of acoustic noise that the operator was exposed to during a work shift using a dual sprocket chain.

Table 1: The dosimeters parameters according to MSHA

Parameters	Setting	Designation
Weighting	A	MSHA Permissible Exposure Level (PEL)
Threshold Level	90 dB	
Exchange Rate	5dB	
Criterion Level	90 dB	
Response	Slow	
Upper Limit	140 dB	

5. RESULTS

Measurements were conducted in both the laboratory and at an underground coal mine. The laboratory testing consisted of sound power levels measurements conducted in the PRL reverberation chamber. Table 2 shows the results of the sound power generated by the standard Joy chain, the Joy dual sprocket chain, and the coated conveyor chain. Comparison of the two chains showed the sound power generated by the dual sprocket to be 3 dB(A) less then the standard chain when the conveyor was in the straight position. However, when the conveyor was extended fully right the dual sprocket displayed a 5 dB(A) reduction and only 2 dB(A) when extended fully left. From these laboratory results the dual sprocket chain was believed to be a potential noise control and that underground field evaluation should be conducted.

Table 2' Sound Power Levels Measurements in the PRL Reverberation Chamber

Conveyor Orientation	Standard Chain	Dual Sprocket Chain	Coated Conveyor Chain
Conveyor Straight	118.5 dB(A)	115.5 dB(A)	111.5 dB(A)
Conveyor Right	121 dB(A)	116 dB(A)	112 dB(A)
Conveyor Left	119 dB(A)	117 dB(A)	112 dB(A)

The underground field evaluation was conducted in a coal mine in western Kentucky. Two trips consisted of collecting two days of dosimetry data. On one day, dosimetry data was collected on the standard chain and on the other day dosimetry data was collected on the dual sprocket chain. All measurements were performed with dosimeters set to MSHA parameters (Table 1). The same type of continuous mining machine, a 14CM15, was used for all underground measurements. However, different operators were used because the underground tests were conducted over two days and the same operators were not available. Time motion studies were also conducted each day. Figure 2 shows the amount of acoustic noise that the continuous mining operators were exposed to during trip 1 with the standard chain and the dual sprocket chain during each work shift.

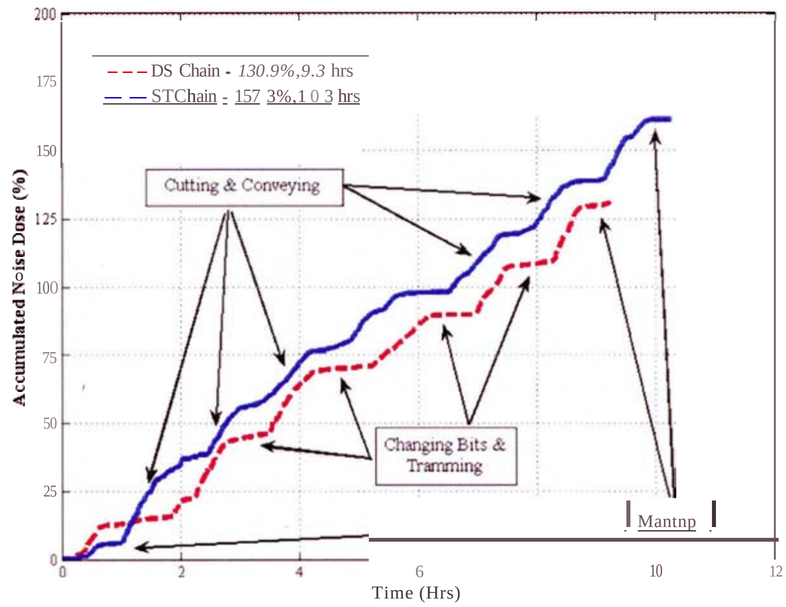

Figure 2: Trip 1

Figure 3 shows the amount of acoustic noise that the operators were exposed to during trip 2 with the standard chain and the dual sprocket chain during each work shift.

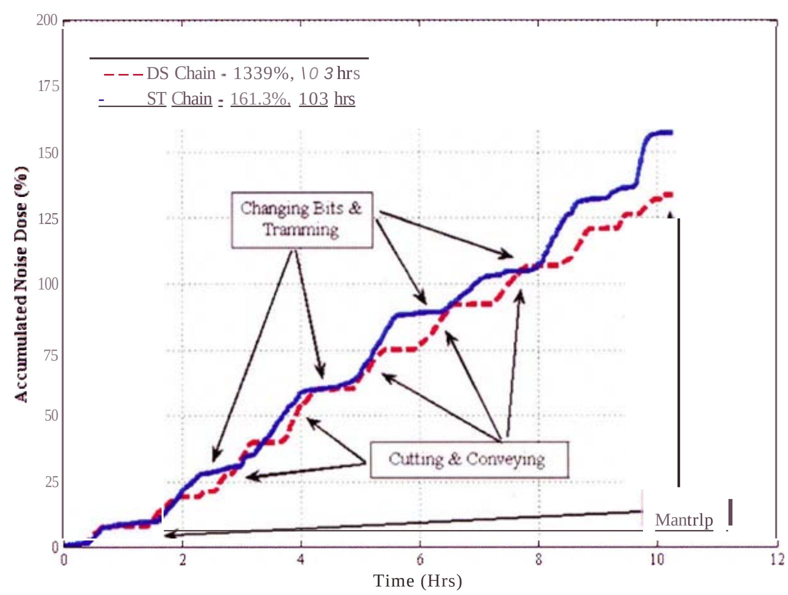

Figure 3: Trip 2

When comparing both chains it can be seen from the plots that the continuous mining machine operator experienced a generally uniform dose accumulation throughout the shift with occasional periods of low dose as shown by the flat slopes of the cumulative dose line. These low dose periods occurred when the worker was changing the bits or when the continuous mining machine was tramming. This was consistent for both trips. Other observations have shown less dose accumulation occurred when the worker was in the man trip. High dose periods occurred when the continuous mining machine was cutting and conveying. It should also be noted that the conveyor was continuously running during all the high dose periods. The exposure levels with the standard chain were relatively consistent with levels of 157.3% for trip one and 161.3% for trip two. When using the dual sprocket chain the exposure levels were also relatively consistent , but consistently lower. These levels were 130.9% for trip one and 133.9% for trip two. When comparing the differences, trip one was 26.4% less when using the dual sprocket chain and 27.4% less for trip two.

However, it should be noted that the underground operation of the continuous mmmg machine is subject to many variables that can affect the noise emissions. Some of these variables, such as the acoustic environment, geometry and composition of the surfaces, mine geometry, and compressive strength of the face medium, cannot be controlled. The acoustic environment that the continuous mining machines operate in is a critical factor in influencing sound pressure levels to which workers are exposed. Underground mines are enclosed areas with reverberant sound fields. The geometry and the composition of the surfaces influence the overall sound level by reflecting or absorbing the incident sound energy. The compressive strength of the face media being cut affects the acoustic absorption properties of the mine environment. Harder media, with compressive strengths above 20,000 psi, reflect more acoustic energy than softer media, i.e. less than 10,000 psi compressive strength.

The operator who is responsible for controlling the continuous mining machine can also influence the overall noise level generated while cutting coal. Variations of the chain conveyor tension will also affect the sound power level emissions, which the operator should check and set according to the manufacturer specifications.

All of these variables need to be considered when conducting underground field evaluations. Eliminating as many variables as possible or keeping these variables consistent for each test are significant and could affect the results.

From the time study it was noted that there were several variables that could have influenced the results. Some of these were difficult to control such as the face media when cutting (different compressive strength), different operators, chain tension on the standard chain, and different sections of the mine. However, researchers believe that the dual sprocket chain could be an effective noise control if used with another noise control such as the coated flight bars. This was based on the testing conducted in the laboratory at PRL where the environment and the chain tension were controlled and the results were promising.

6. CONCLUSION

NIOSH laboratory results show that the dual sprocket chain has a significant influence on lowering the sound power emissions of the chain conveyor of a continuous mining machine when compared to a standard chain. The underground results weren't as significant for the dual sprocket chain as the laboratory, but did show a 26.4% and 27.4 % reduction in noise exposure to the operator.

In general, experimental results show the dual sprocket chain has potential and if used with another noise control, such as the coated flight bars could be an effective noise control. This research will provide the mining community with an additional noise control to be utilized on continuous mining machines, therefore reducing operator noise overexposure. Utilizing this newly developed noise control, along with previously proven controls for the continuous mining machine chain conveyor, will provide operators of these machines an opportunity to be within the MSHA-Permissible Exposure Limit (MSHA-PEL).

7. REFERENCES

1 Energy Information Administration Form EIA-7A, "Coal Production Report," and U.S. Department of Labor, Mine Safety and Health Administration Form 7000-2, "Quarterly Mine Employment and Coal Production Report.", 2005, web site http://www.eia.doe.gov/cneaf/coal/page/acr/table3.html

2. U.S. Department of Labor, Mine Safety and Health Administration, Form 7000-2, "Quarterly Mine Employment and Coal Production Report", 2005, web site http://www.eia.doe.gov/cneaf/coal/page/acr/tablel.htm I

3. U.S. Department of Labor Bureau of Labor Statistics, May 2006, web site http://www.bls.gov/oes/current/oes475041.htm

4. Title 30 CFR Part 56 and 57, 2000-2005, U.S. Department of Labor, Mine Safety and Health Administration, Information Resource Center, Denver Co.

5. oise Reduction of Chain Conveyors - Volume II, Bolt Beranek and Newman Inc., Contract HO155113, page 13, February 1983.

6. Measuring Noise From a Continuous Mining Machine, Bureau of Mines Information Circular 8922, Roy Bartholomae, John Kovac, and John Robertson, page 2, 1983.

7A oise Control for Continuous Miners, Peter Kovalchik, Marty Johnson, Ricardo Burdisso, Frank Duda, and Mike Durr, Proceedings from the 10th International Meeting on Low Frequency oise and Vibration and its Control, York England, page 302, September 11-13, 2002.

8. M.T. Durr, P.G. Kovalchik, and E. Kwait, "Evaluation of Engineering loise Controls for a 7. Continuous Miner Conveyer System," *Proceedings of Noise-Con 03*. Cleveland, Ohio, June 2003, pp. I-II.

9. Smith AK, Spencer ER, Kovalchik PG, Alcorn LA [2006]. Underground Evaluation of Coated Flight Bars for a Continuous Mining Machine. Proceedings of lNTER-NOISE December 2006.," pp. 1-8.

iD ISO 3741 entitled "Acoustics --- Determination of sound power levels of noise sources using sound pressure --- Engineering method in an essentially free field over a reflecting plane", 31 pages, Second edition 1994-05-00I.