CDC Workplace Safety and Health
NIOSH OMSHR
Technology News
No. 552 Milestones in Mining Safety and Health Technology August 2013

A New Visual Warning System to Reduce Struck-by and Pinning Accidents

Objective

The objective of this technology is to provide an intervention that reduces the risk of underground mine workers being struck-by or pinned by mobile mining equipment such as the continuous mining machine (CMM).

Background

Mobile mining equipment poses a significant safety risk to workers who can be accidentally struck-by or pinned by the equipment, resulting in worker injury or death. Because of their severity and frequency, these machine-related accidents are at the forefront of the stakeholder concerns of the National Institute for Occupational Safety and Health (NIOSH). Mine Safety and Health Administration (MSHA) accident data from 2002–2011 indicates that 44 fatalities and 4,754 nonfatal days lost (NFDL) occurred in the underground coal mining industry and were described as struck-against or struck-by and caught or pinned in-under-between. An MSHA report [MSHA 2011] indicates that 33 fatalities involving a CMM occurred from 1984 through March 2011. The operators controlling the CMMs were identified as the workers with the highest accident frequency in these incidents; the most dangerous activity identified was moving the CMM to a new location. Performing maintenance was the second most dangerous activity. Most of the fatalities occurred at the right rear of the CMM. In all accidents described by the MSHA report, poor work practices were contributing factors given that the accidents occurred when miners were positioned within the turning radius of an active CMM.

One mitigation strategy to address struck-by or pinning accidents is to provide guidance to help CMM operators to understand and avoid potentially dangerous areas near mobile mining equipment. During 2004, a "red zone" pictorial was developed from real-life experiences by MSHA and the Virginia Department of Mines, Minerals and Energy [MSHA 2004]. This red zone pictorial depicts hazardous zones to avoid during various CMM operations. Another mitigation strategy is to use a proximity detection system (PDS) that would alert miners if they are too close to the CMM, or potentially shut down the machine if they are within an unacceptable distance from the machine. Some PDS's use both an audible and a visual alert.

Figure 1. The new Visual Warning System (VWS) installed on a continuous mining machine (CMM). The LED warning light (see arrow) indicates that the conveyor is going to swing to the right.

Each of the mitigation strategies has its own strengths and limitations. For instance, PDS's hold much promise but require complex technology, and performance issues can result from magnetic interference.

A simpler alternative to these strategies was developed by NIOSH researchers and named the Visual Warning System (VWS), which visually alerts miners of impending machine movements and conveys the type and direction of machine movement. Although visual alerts are used in PDS's, they do not convey the type and direction of machine movement because the visual alerts are limited to small indicator lights.

Approach

To verify the practicality (viability) of the new VWS, NIOSH researchers conducted human subject testing in a controlled, laboratory environment [Sammarco et al. 2012] with a CMM as the test machine. The VWS mounts to the CMM and electrically interfaces to the CMM's control subsystem. The VWS has its own control subsystem and eight luminaires with each using a red, 1-W light-emitting diode (LED) to illuminate a 0.6-m-long, 14-mm-diameter side-emitting optical fiber (Figure 1). Due to safety concerns during testing, researchers used a

high-definition, video-based CMM simulator developed by NIOSH. Additionally, the CMM simulator enabled consistent rates of movements to be presented for every test. Actual CMM movement rates often vary due to machine control variations and floor conditions, which can confound the data. Video scenes of a CMM with a VWS installed were recorded. These scenes included 30 combinations of machine movements and various VWS lighting conditions. Five visual warning conditions were studied: (1) None: no visual warning is given at any time; (2) Static: the luminaires for a given machine movement will turn on and stay on as long as the machine function is actuated; (3) Flashing: the luminaires for a given machine movement will flash at 4 Hz as long as the machine function for movement is actuated; (4) Directional: the luminaires for a given machine function will provide a directional warning (4-Hz direction sequence), as long as the machine function is actuated; (5) Progressive: each luminaire turns on sequentially and stays on until the last luminaire in the sequence is on. The simulator also included a data acquisition and control system that enabled the collection of the test subjects' reaction times in detecting various machine movements.

Of the 36 test subjects, there were 27 males and 9 females who took part in the testing. There were 12 participants each in three age groups. The mean ages for each group were 21.6 years, 47.3 years, and 56.5 years. Subjects that had radial keratotomy, monocular vision, glaucoma, or macular degeneration were excluded. Only the volunteers that passed vision tests for distance visual acuity of 20/40 or better, log contrast sensitivity values of 1.72 to 1.92, the absence of color vision deficiency, and peripheral vision of at least 80° for each eye were accepted for the study.

Reported Findings

The differences between the no-lighting condition and any VWS lighting condition were dramatic. For instance, for the forward and reverse CMM movements, the average detection time for the no-lighting condition was 1.96 s, but the average time using the VWS flashing condition was 0.49 s. During this 1.47-s difference, or 75% improvement, the CMM travels 0.485 m given the fast speed of 19.8 m/min. This distance traveled is significant especially when considering the tightly confined spaces of a mine. The most dramatic time difference results were with the machine pivots, where the average detection time for the no-lighting condition was 2.23 s, but the average for the flashing and directional conditions was 0.47 s. During this 1.76-s difference, the CMM would pivot 5.63° given the pivot rate of 3.2°/s, and the end of the CMM conveyor would move about 0.6 m. Our analysis of the 33 fatalities documented by MSHA [2011] indicated that 30 fatalities involved machine forward, reverse, or pivot movements.

The visual warning system research, which began in late 2010, had the interest of RSL Fiber Systems. During 2012, RSL Fiber Systems licensed the VWS, and a commercial product is now available. Most recently, a NIOSH research project for a proximity warning system is using the VWS for identification of proximity detection events [Jobes et al., forthcoming] given that the VWS can be used as a standalone system or with a proximity detection system.

Summary

The test results clearly demonstrate that the new VWS, as installed on a CMM, vastly improves an individual's ability to detect hazardous machine movements. Results of this experiment suggest that dynamic lighting conditions (directional, flashing, and progressive conditions) enhance movement detection time to a greater extent than a simple static light. The use of the VWS appears to be an important tool in alerting underground miners to impending or active machine movements and may help prevent the incidence of struck-by or pinning accidents. The VWS has application to other moving machinery used in mining or other industries where moving machinery poses struck-by or pinning hazards.

References

Jobes C, Carr J, Reyes M [forthcoming]. A visual warning system for the identification of proximity detection events around a continuous mining machine. HFES 2013 International Annual Meeting. San Diego, CA . Sept. 30–Oct. 4, 2013.

MSHA [2004]. Red zones are no zones for mining with remote control continuous miners. Arlington, VA: U.S. Department of Labor, Mine Safety and Health Administration.

MSHA [2011]. Remote control fatal accidents analysis report of victims physical location with respect to the mining machine. By: Dransite J and Huntley C. Arlington, VA: U.S. Department of Labor, Mine Safety and Health Administration.

Sammarco JJ, Gallagher S, Mayton A, Srednicki J [2012]. A visual warning system to reduce struck-by or pinning accidents involving mobile mining equipment. Appl Ergon *43*(6): 1058–65. April 2012.

For More Information

For more information on the new Visual Warning System (VWS), contact John J. Sammarco (jsammarco@cdc.gov), RSL Fiber Systems (http://rslfibersystems.com), or the Health Communications Coordinator (OMSHR@cdc.gov), NIOSH Office of Mine Safety and Health Research, P.O. Box 18070, Pittsburgh, PA 15236-0070. Technical details concerning the VWS are described by Sammarco et al. [2012].

DHHS (NIOSH) Publication No. 2013–151