Technology
TO REDUCE MINE HOISTING ACCIDENTS

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Researchers at the Spokane Research Laboratory (SRC) of the National Institute for Occupational Safety and Health (NIOSH) are studying methods and technology to improve safety in underground metal/nonmetal mining. One particular project goal is to reduce the number of accidents and injuries associated with hoisting personnel and materials. Each year, several miners are killed or seriously injured while operating equipment associated with hoisting and ore transfer operations. Other accidents occur while loading, unloading, or riding the cage.

The following article describes the development of new sensors, data transmission methods, and operator interfaces that can convey critical information to hoist operators and inspection personnel.

The Problem

In most underground mines, the hoist operator has very little information about what is happening at the conveyance. The most common type of position indicator, the dial on a Lilly controller, really only indicates the position of the hoist drum and presumes that the conveyance is moving at the same speed and is at the indicated location. Without accurate position information, accidents can occur, which has happened several times when the conveyance was pulled into the headframe.

Communication between a hoist operator and workers on the conveyance are often nonexistent when the hoist is moving. Only when the conveyance creeps or stops can the workers signal the operator using a bell system.

Another critical piece of information that the hoist operator lacks is an indication of rope load. This information is most important when a tight or slack rope condition exists while the conveyance is moving. Such conditions indicate shaft guide misalignment or obstructions in the shaft. Workers riding the conveyance when it moves through a tight spot in the guides can be injured during abrupt deceleration. In one incident, a skip came to a complete stop when it became jammed at the ore pocket, but the hoist operator, unaware of the situation bellow, continued to lower the hoist. The rope piled on top of the skip until the weight of the accumulated rope caused the skip to release. When the skip fell and the slack was taken up, the rope broke.

Many hoisting accidents could be avoided if the operator were aware of certain critical parameters, such as conveyance position, rope load, and shaft guide alignment. However, not many commercially available sensors that could be used to monitor these parameters are effective in a mine environment. Those that do exist are too expensive for industry-wide use. Another problem is that of transferring information from sensors on a moving conveyance to the hoist room.

Researchers at NIOSH are working to solve these problems. New sensors are being developed to monitor shaft guide alignment, conveyance position, and rope load. Radio transmission technology is showing promise as a method of transmitting sensor data to the hoist room. This work is being aided by the construction of a scale-model shaft and hoist room, which provides the necessary test bed for sensor development and operator interface designs.

Test Facility

Testing sensors for hoists in an active mine is extremely difficult because this work requires an excessive amount of downtime for the lifeline of the mining operation—the hoist. NIOSH engineers designed a scaled-down mine shaft and hoist facility to allow researchers to develop, test, and debug new sensor designs and computer-based operator interfaces in an environment that simulates a mine shaft.

This facility is located at a test site near the Spokane Research Laboratory and consists of a mine shaft, a 500-kg-capacity ore skip, a closed-loop ore pass system, and a hoist room.

The mine shaft and headframe are simulated by a steel frame that extends approximately 18 m above and 5 m below ground. The one-fifth-scale skip travels on guides within this frame, and the ore skip dumps ore at the top of the frame into a simulated ore pass, which is constructed of steel tubing. The ore then falls down the tubing and then fills an underground loading pocket, after which the skip returns to bottom of the shaft, where it is refilled at the loading pocket.

The hoist room houses a 50-hp dc motor that drives a 1-m-dia wire rope winding drum. A dc motor controller and a programmable controller enable either manual or automatic control of the hoist and ore pocket gates. In the automatic mode, the ore loading and unloading cycle can be repeated as often as needed as a result of the closed-loop design of the ore haulage circuit. A PC-based interface conveys graphical information about hoisting parameters to the operator.

Conveyance Monitoring

The development of a shaft conveyance monitoring system has focused on conveyance position and velocity, wire rope load, and guide displacement. The approach has been to mount the sensors on the conveyance itself to minimize the need for any additional setup in the shaft and to measure load as close to the conveyance as possible. These considerations require some type of data transmission method to transfer the data to the surface.

A position sensor on the conveyance indicates the true position of the conveyance instead of how much rope has been laid out. Researchers are currently testing a method that uses an encoder wheel that runs along the shaft guide (shown on the bottom left of the skip in Figure A) and provides pulses that can be counted to determine velocity and position; one drawback to this system is the potential for wheel slippage.

Other types of sensors are also being tested, including radar and ultrasonic-based ground speed sensors like those that are used in the agriculture industry.

A sensor that measures guide displacement every time the conveyance travels the shaft can provide a warning if the shaft guides are becoming misaligned. In this system, guide alignment is measured by a string potentiometer attached to the bottom of the conveyance and held between the guides.

The potentiometer is tensioned by wheels that are pushed against the guides with springs and is protected by steel tubing (the horizontal bar at the bottom of the skip in Figure A). As the distance between the guides fluctuates, the potentiometer varies its signal proportionately. A linear potentiometer is in the process of being tested to replace the string unit in order to improve the operating life of the sensor.

Conveyance load monitoring enables the operator to watch for slack and tight rope conditions and overloading. A newly developed rope load sensor has a unique design feature that allows conveyance weight and rope tension to be measured independently of

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the wire rope load path. Rope tension is determined by measuring beam-bending strains resulting from the normal load component of a slight bend in the rope.

As the wire rope tension increases, normal force components increase, resulting in corresponding bending strains at the midpoint of the sensor's body. This strain is indicated by strain gauges in a full bridge configuration that generate an electrical signal. The curvature at either end of the rope is realigned with the initial unflexed rope to eliminate stress concentrations that may develop at entry and exit points.

The design principle is based on the theory of elasticity for a distributed line load across and normal to the transverse center of a beam supported at each end. Crosby clips—commonly used at wire rope terminations—clamp the rope load sensor to the wire rope at one end, provide the required offset at midpoint, and allow slip at the other end.

This design minimizes flexural strain in the wire rope during loading and unloading cycles so as not to compromise the rope's ultimate strength and working life, yet generates enough flex to provide the required output.

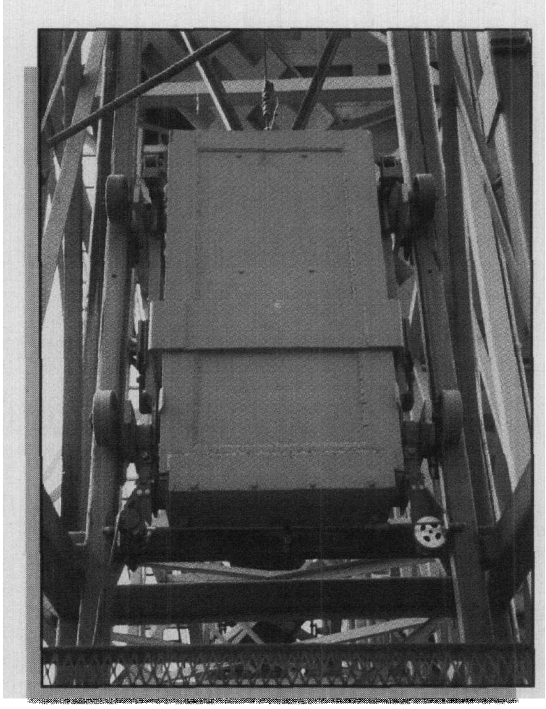

Fig. A.: NIOSH's scale-model 500-kg-capacity ore skip.

The rope load sensor is packaged to withstand the rigors of long-term, unattended underground operation and to survive the unusually hazardous conditions of underground hoisting operations. It is protected from electromagnetic interference and repeated hoisting cycle temperature extremes, which may range anywhere between -47°C (-50°F) and +53°C (+120°F).

It is simple and fast to install and relatively maintenance-free. The packaging provides electrical insulation, high-impact and mechanical-shock resistance, and only minimal sensitivity to thermal extremes.

The rope load sensor and the other sensors described above have been packaged into a system called the hoist and shaft conveyance monitoring system (HASCOMS). The second module of the system provides the method of getting data from these sensors to the hoist room.

Data Transmission

A custom-designed data acquisition and transmission package used in conjunction with the HASCOMS includes a battery-operated microcomputer-controlled signal processing board (SPB), a spread-spectrum radio modem, and a 12-V battery. The SPB was custom-designed to meet the requirements of this specific application.

The package dynamically monitors and processes data from six analog channels and one digital channel, and provides optically isolated serial data output. The SPB is linked to a radio modem for data telemetry from the moving conveyance to the hoist machinery room. The data acquisition rate is 100 ms or 10 scans/sec. For a conveyance traveling at 180 m/min or 3 m/sec, this particular sampling rate provides load and position data for every 30 cm of conveyance travel.

The latest tests on an actual mine conveyance in a deep shaft show that the effective transmitting distance of the current system is around 600 m. Modifications are continuing so the transmitting distance can be increased to at least 2,000 m.

A secondary RS232 serial port on the SPB transfers data to a portable computer or terminal on the conveyance itself. The SPB, the rope load sensor, and the remaining sensors on the hoist conveyance or elevator car are designed for ease of installation and maintenance and minimal interference with hoisting functions.

Different methods of recharging the batteries of the system are being studied, including using a generator on one of the conveyance guide wheels or using the wind generated by conveyance movement.

Operator Interface

The best way to convey sensor information to the operator is to provide a graphical representation that can be understood and acted upon easily. Two approaches were taken in the development of the operator interface. In the case where the HASCOMS is retrofitted in a facility that uses computer-based control and human machine interface (HMI) software to monitor the hoisting functions, the HASCOMS data can be imported into the existing HMI and displayed.

For installations that do not have any type of existing HMI, a stand-alone system is being developed.

The hoisting test facility described above uses a General Electric (GE) Series 90-30 programmable logic controller to control the hoisting functions. SRC researchers developed process graphics screens in Windows using Wonderware's Intouch HMI software, which is included in GE Fanuc's Cimplicity package. The HMI allows dynamic data exchange to access data from other Windows programs. A data import routine is currently being written to collect the serial data from HASCOMS and import it into the HMI software where it can be presented graphically.

For installations that do not have existing HMI capabilities, a second approach was taken for presenting the data to the operator. A stand-alone software package has been developed to run on a PC to collect and present the data from the sensors in a graphical format. The data are collected directly from HASCOMS via a serial port and displayed with the software.

This second system can also be applied during hoist inspections. A portable computer can be connected to a HASCOMS to provide a means of collecting and storing shaft and hoist operational data either from the hoist room or while riding the cage.

Conclusions

The development of these new monitoring systems has focused on providing hoist operators with pertinent information on hoisting functions. At the same time, the cost of these systems must be kept to a minimum so smaller operations can afford to use them.

After all, the safety of mine hoisting operations can only be improved if the needed technology is available and affordable. The objective of NIOSH researchers is to assure that the best solution is available for solving hoisting safety problems by applying the latest in sensing and monitoring technology.

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