Safer Mine Hoisting With Conveyance Position and Load Monitoring

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BACKGROUND

A mine shaft is the lifeline to underground mines. Mine operators depend on safe, uninterrupted, and efficient movement of workers and materials. The shaft and hoisting system provides access to the network of openings used to recover the underground resource, provides vertical transport of miners and materials, and serves as an escapeway in case of an emergency. Accidents involving hoisting can be catastrophic. Such was the case in 1973 at the Markham Colliery in Derbyshire, UK when the conveyance overwound and fell to the shaft bottom, resulting in 17 deaths.

Hoist and elevator machinery must meet the requirements specified in the Code of Federal Regulations (CFR), Parts 57 and 75. According to the Mine Safety and Health Administration (MSHA) data, many shaft-related accidents in the United States are associated with the hoisting cycle. MSHA statistics show that there were about 1500 shaft-related accidents in the 5-year period between 1992–1996. Most of these accidents resulted from the action, motion, or failure of the hoisting equipment or mechanism and involved movement of the conveyance which includes cages, skips, ore buckets, and elevators.

A hoisting hazard may be characterized as an "unsafe hoist operating condition caused by insufficient or inaccurate information available to the hoist operator" (authors' quote). Earlier investigators have defined safety features and operating and maintenance standards for hoists, and reported on monitoring and control systems and sensors for hoists and conveyances [Farley, 1983; Ward, 1993]. However, despite the considerable technological progress and hoisting control improvements in recent years, safety-related issues that require further investigation still remain.

The hoist operator must constantly be aware of two important hoist-operating conditions: the position of the conveyance and the tension in the hoist rope. If this information is not available or is inaccurate, the hoist becomes unsafe. Current technology provides this information indirectly from sensors and indicators in the hoist room. However, unlike a building elevator hoistway, mine shaft hoistway problems often include:

1. poor ground conditions and excessive shaft wall and guide displacement;
2. rock bursts in deep mines (resulting in large rock movements and fragments blocking the hoist way);
3. water, ice, and salt buildup (impeding the smooth flow of the conveyance);
4. severe vibration from hoisting (resulting in loose guide support brackets, broken welds, or other alignment and conveyance mechanism malfunctions).

The second issue relates to dynamic rope loads applied during normal winding, particularly during loading, acceleration, and stopping. Safety factors on wire rope are based on static load. They are artificially high to account for all cases of dynamic loads, even though the total load history on the rope (static and dynamic) during service is unknown. Therefore the tension, and thus the compliance with wire rope load safety factors, is unknown to the hoistman.

RESEARCH METHODS

The approach to this research is to simulate hoisting hazards with a reduced scale hoisting test facility, and to

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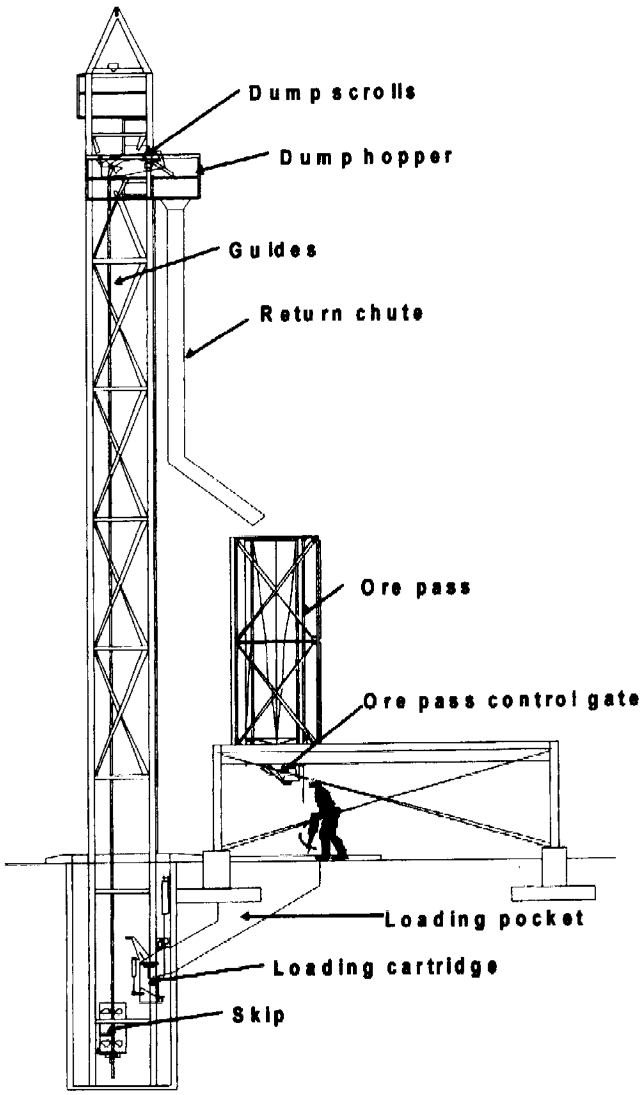

FIGURE 1. Layout of closed-loop mine shaft and hoisting test facility located in Spokane, WA.

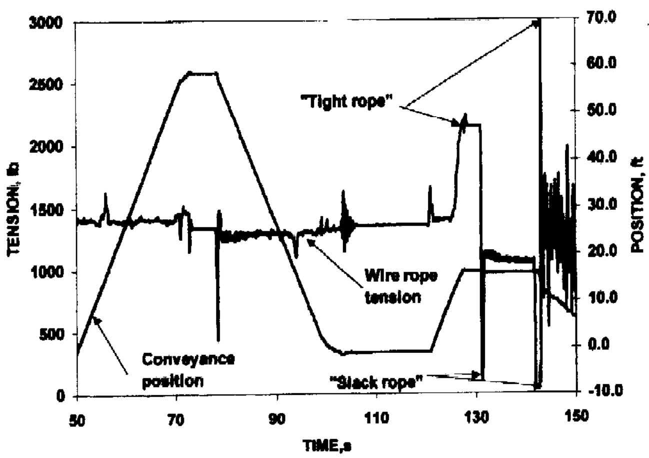

FIGURE 2. Results from one hoisting test showing slack and tight rope conditions caused by an induced guide displacement.

develop and test engineering controls to minimize or eliminate the hazards. A reduced scale shaft and hoisting research facility was designed and constructed to simulate mine-hoisting operations. Figure 1 shows the layout of the closed-loop mine shaft and hoisting test facility. Ore or waste material is initially loaded through a ground-level grizzly into a gated, below-ground discharge chute and loading cartridge, and then into the skip. The skip hoists the ore to the top of the headframe where it is dumped into a hopper. The ore is gravity-fed through an ore pass chute and gate system. The material is then dumped into the below ground hopper and loading pocket, completing the loop.

Engineering controls have evolved in the development of a shaft conveyance monitoring system that determines conveyance position, wire rope tension, and guide displacement. The system provides hoist operators and maintenance and inspection personnel with a real-time indication of the operational status of a mine shaft hoist conveyance. The conveyance-mounted system consists of sensors, signal processing electronics and data transmission to the surface. The receiving end of the data link, located at the collar of the shaft, provides sensor data to the serial port of a desktop PC in the hoist control room. The same information is also transmitted to a laptop computer or handheld device on the conveyance for inspection or maintenance purposes.

A sensor developed at SRC is attached to the wire rope in a manner that completely isolates it from the wire rope load path; and therefore, produces no effect on the wire rope safety factor. Use of an industry standard wire rope clip and hardened surface contact points ensure that the wire rope is not subjected to excessive wear and abrasion. A conveyance-mounted position sensor eliminates the need to correct the position of the conveyance because of rope stretch. Measurement of guide displacement warns of impending slack and tight rope conditions caused by shaft wall movement or guide misalignment. A custom-designed data acquisition package was developed for processing the sensor signals and converts data to a format suitable for computer input [Beus and McCoy, 1995]. An in-house developed computer program using the LabView programming language displays the data.

RESULTS

The most hazardous condition that can occur during hoisting is the conveyance becoming stuck and the wire rope going slack. Test results validated the functional performance of the engineering controls and the ability to detect slack rope and other abnormal hoisting cycles. Figure 2 shows a simulated slack and tight rope condition resulting from an induced guide displacement. The normal hoisting cycle is followed by a cycle in which the conveyance became stuck between the guides due to excessive guide displacement. When the deformed guides stopped the conveyance, tight rope conditions resulted in rope tensions of about 60% of the conveyance weight. As the winding drum was reversed, a slack rope condition developed when the conveyance remained stuck. The conveyance then dropped about 1 m (3 ft), suddenly taking up the slack in the rope and causing another tight rope condition that exceeded conveyance weight by 120%. Results of several tests that were conducted during normal inspection activities at an escape shaft of a deep mine in northern Idaho verified that reliable data transmission from unlimited depth of approximately 630 m (1,900 ft) was possible with the use of radio repeaters.

CONCLUSIONS

A state-of-the-art hoisting research facility was constructed to test new engineering controls developed by SRL. Results indicate that monitoring of conveyance position, wire rope tension, guide displacement, and voice from the moving conveyance can eliminate hazardous conditions of underground hoisting operations. Field tests revealed that the conveyance monitoring system functioned as intended. Reliable data transmission has been achieved from depths of 1,333 m (4,000 ft) in a deep mine shaft, which is sufficient for all but the deepest shafts in the United States.

The major benefit arising from this research will be the prevention of injuries and fatalities related to hoisting operations. Improved hoist monitoring technology will improve the safety of the workplace.

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