OVERVIEW OF BUREAU RESEARCH DIRECTED TOWARDS SURFACE POWERED HAULAGE SAFETY

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ABSTRACT

Surface mining operations, including mills and preparation plants, employ over 260,000 people. This represents a significant contribution to our nation's economy and an important source of skilled and well-paying jobs. As mine production has shifted from underground to surface, and with continuing advances in underground mine safety, surface mining has unfortunately become the leader in mine fatalities. In 1994 surface mining accidents accounted for 49% of all mine fatalities, followed by underground mining with 37% and mills and preparation plants with 14%. The U.S. Bureau of Mines (USBM) has targeted surface mining as an important research priority to reduce the social and economic costs associated with fatalities and lost-work-time injuries. USBM safety research focuses on the development of technologies that can enhance productivity and reduce mining costs through a reduction in the number and severity of mining accidents. This report summarizes a number of completed and ongoing research programs directed towards surface powered haulage--the single largest category of fatalities in surface mining and a major cause of lost workdays. Research products designed for industry are highlighted and future USBM surface mining safety research is discussed.

INTRODUCTION

Accidents involving powered haulage equipment in surface mines are among the most severe. They represent a disproportionate share of the total number of fatalities and lost workdays (Aldinger and Keran, 1994). In surface mines, which produce over 90% of the mined tonnage in the United States, 116 fatalities resulted from powered haulage accidents from 1990 to 1994. Powered haulage was the leading cause of fatal accidents, accounting for 22% of the mine fatalities and 39% of the surface mine fatalities. Haulage trucks were involved in 65% of these fatal accidents, making them the number one source of death at surface mines and the primary focus of much of the USBM's past and present research. The dynamic environment of surface mining mobile equipment operation, the complexity and variety of the equipment, and the nature of the job is responsible for the greater potential for a hazardous situation to develop and a serious injury to occur.

This report highlights some of the past, present and future safety research projects dealing with surface mine powered haulage equipment conducted by the USBM. The USBM publications referenced in this paper can be obtained from:

National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4600

Additional information regarding the research presented in this paper is available from:

Technology Transfer Officer
Pittsburgh Research Center
U.S. Bureau of Mines
P.O. Box 18070
Cochrans Mill Road
Pittsburgh, PA 15236

PAST RESEARCH

The USBM has a long history of research activity in the area of surface powered haulage. This section highlights past safety research dating back to the mid 1970s. The following discussion is chronological beginning with the earliest research.

Haul Road Design and Construction

Throughout the 1960s and 1970s as the size and speed of mining equipment increased, the design of haulroads became critical in regards to safety and productivity (figure 1). Guidelines were not available that could assist mine operators with the design, construction, and maintenance of mine haulroads. The USBM responded with the development of a mine haulage road design manual (Kaufman and Ault, 1977). The manual considers haulroad design based primarily upon haulage truck size and addresses the following aspects of haul road design:

- Road alignment (both vertical and horizontal)
- Construction materials
- Cross slope and drainage provisions
- Traffic control
- Lane widths
- Road and vehicle maintenance; and
- Runaway vehicle safety provisions (escape lanes and center safety berms)

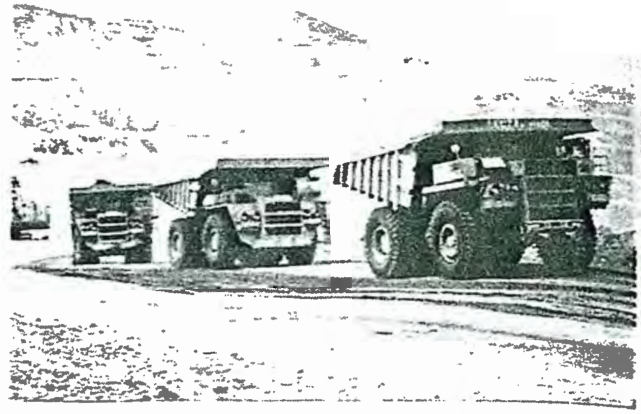

Figure 1. Haulroad design and construction was addressed by the USBM in the 1970s

The manual "Design of Surface Mine Haulage Roads" Information Circular (IC) 8758 has excellent illustrations, tables, and graphs to assist the mine operator and represents a complete manual of recommended practices that promote safer, more efficient road construction.

Fire Suppression for Mobile Mining Equipment

Research on automatic fire suppression systems for mobile mining equipment was in part necessitated by the increasing size of equipment throughout the '60s and '70s. With smaller vehicles, the operator could more easily get out when a fire started, but with larger equipment the operator was often injured while trying to escape. In addition, it was more difficult to gain access to and extinguish a fire on the larger equipment (figure 2). In the late '70s, the USBM developed and tested automatic fire suppression systems for use on large mobile mining equipment (Johnson and Forshey, 1975). In-mine testing included starting small fires in the engine compartment of equipment or heating the sensors until the automatic fire suppression system activated. As a result of this research, there are now many different commercial fire suppression systems available to the mining industry (Pomroy and Bickel, 1980). A typical automatic fire suppression system consists of suppressant tanks, an automatic actuator, sensors, a manual actuator

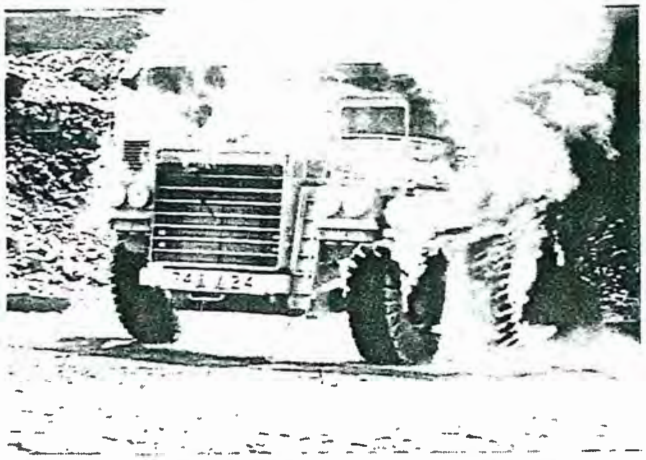

Figure 2. The USBM performed research on automatic fire suppression systems to prevent mobile equipment fires.

in the cab and also at ground level, and a hose and nozzle system. These systems have now been used successfully for over 20 years.

Berm Design and Runaway Vehicle Protection

In 1989, the Mine Safety and Health Administration (MSHA) mandated that roadside berms should be constructed to mid-axle height of the largest mobile vehicle using the road. This is a good rule of thumb for all areas of potential overtravel and contributes to worker safety. Generally, roadside berms are used to prevent an operator from inadvertently driving over an edge. They provide moderate resistance to prevent the equipment from going over the edge, assist the operator in maintaining control of the equipment, and provide a visible indication of the edge of the roadway. However, roadside berms cannot be expected to stop a runaway truck. In order for a roadside berm to prevent a run-away truck from leaving the roadway, the berm would need to be well compacted and 3 times the axle height for trucks less than 85 tons and 4 times the axle height for trucks greater than 85 tons (Stecklein and Labra, 1981 and Miller et al., 1983). Obviously the construction of berms this size is not realistic.

In the early '80s, work was performed by the USBM on berm designs required to stop a runaway vehicle which could be practically implemented. Several techniques were evaluated including edge of road berms, guardrails, boulders, concrete barriers, center safety berms, and escape lanes.

To safely stop a runaway truck on long down hill hauls, two techniques are normally used, center safety berms or escape lanes. Center safety berms were evaluated by the USBM (Hays, 1983) when they were still a novel approach and not widely recognized throughout the mining industry. The safety berms are constructed in the middle of the haulage road. The berm stops a runaway truck when the operator straddles the truck over the berm center line. Center safety berms are currently being used successfully within the United States. The evaluation of center safety berms identified some of the following points:

- Significant operator training is required
- Since they are spaced closer together than escape lanes, the operator has greater control of the truck speed at impact
- There is less dependency on topography for construction
- An increased road width is required
- They are more suitable for conventional rear dump trucks
- They need to be constructed from unconsolidated material, which needs to be protected from moisture and freezing
- There is a greater potential for rollover that can be substantially reduced by compacting material and constructing the berm narrower than the rear duals

Information regarding these studies and recommended construction techniques for center safety berms are available from the USBM.

Powered Safety Steps for Large Surface Mining Equipment

In 1975, a powered safety step was invented by Ted Rivinius from Bismarck, North Dakota. The purpose of the powered safety step was to eliminate the access problems associated with large tracked mining equipment such as dozers and shovels. Consisting of a hydraulic boom and a man basket, the simple but clever design proved to be a reliable and an effective means for reducing accidents associated with getting on and off the equipment. It provided a way for getting both men and materials on the large machines and made it unnecessary to climb on irregular surfaces often made slippery by mud, ice, rain, and snow. The powered safety step can be adapted to any type or model of large equipment (Long, 1984). The USBM's role was limited and consisted of in-mine testing and evaluation of the unit. The powered safety step is available commercially with additional information available from the USBM.

Operator Training and Training Simulators

The USBM has played a significant role in the development of training materials for the mining industry. As training materials are developed, they are given to MSHA for distribution through the MSHA Academy. For a full listing of all training products available from MSHA, including those developed by the USBM, the "Catalogue of Training Products for the Mining Industry" should be requested from the National Mine Health and Safety Academy, P.O. Box 1166, Beckley, West Virginia 25802-1166, telephone number (304) 256-3257.

A partial listing of training material developed by the USBM related to surface powered haulage includes:

- Open Pit Mining Hazards, 1967
- Conveyor Belts - Be Careful (Metal/Nonmetal), 1969
- Supervisory Training Series, 1969
- Preshift Inspection Program (most mobile equipment types), 1977
- Front-End Loader Training System, 1982
- Haultruck Training System, 1982
- Rubber-Tire Dozer Training System, 1984
- Scraper Training System, 1984
- Excavation Training, 1984
- Stockpile Safety Manual No. 30, 1993

Many of the training programs include tapes or slides and handbooks to assist the mine trainer. Additionally, Woodward Associates, Inc. under contract with the USBM developed an On-Board Simulator of Abnormal Conditions (Krupp and Applegate, 1983). This simulator was capable of providing the trainee with simulated emergency situations on a haulage truck at the mine site. The trainee could then be evaluated by the trainer under a controlled environment. This simulator taught inexperienced haulage truck drivers how to properly react in an emergency situation. Information regarding the development and evaluation of the simulator is available from the USBM, however, the unit is not currently being manufactured.

Roll-Over-Protection Research and ROPS Inspection Guide

Rollover protective structures (ROPS) are required on all self propelled surface mining equipment, except haul trucks, manufactured on or after July 1, 1969 (Code of Federal Regulations, Title 30, Parts 56/57.14130 and 77.403.a). The protective capability of ROPS can be greatly reduced by accidents, unauthorized repairs, or normal use. The USBM developed a guide to help maintenance personnel to properly maintain and inspect ROPS (Swan, 1985). The manual "Rollover Protection Structures Inspection and Maintenance Guide" IC 9009 describes the types of defects to look for and provides a complete inspection checklist. Some of the more common defects include cracks, bulges, kinks and dents. Cracks near welded joints are the most common major defect. A second cause for concern are unauthorized field repairs or modifications, such as welds, bolting on accessories and drilling holes, all of which may void the manufacturer's warranty.

As part of this research, the USBM sponsored a rollover test on a front-end loader over 200,000 lbs, which had never been done before (Dahle and Gavan, 1985). The loaders were instrumented to determine the accelerations, loads and deflections exerted on the ROPS. A mannequin was placed in the operator's seat and instrumented to measure forces on seat belts, vest restraints, and head accelerations. Each test consisted of at least two complete rollovers. After testing was completed recommendations were made for changing the ROPS standard for front-end loaders larger than 240,000 lb. gross vehicle weight.

Collision Avoidance

As the size of surface mining equipment increased, the number of collisions resulting from large blind areas also increased (figure 3). The USBM addressed different aspects of this problem throughout the '80s, looking first at mirrors and visibility aids for haul trucks, then discriminating backup alarms for front-end loaders, and finally radio collision avoidance systems for haul trucks.

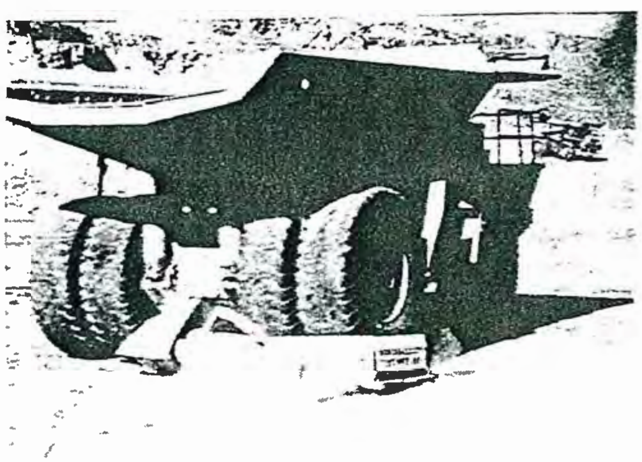

Figure 3. The blind areas around large mobile mining equipment represent a significant surface mining hazard.

While defining the blind area of large haulage trucks, it became apparent that mirrors were often mounted incorrectly or were simply inadequately designed. An improved driver's side mirror was designed to be longer, providing a larger field of view. The mirror was designed for fabrication on the mine site, and ease of installation. An improved convex rectangular mirror for installation on the side opposite the operator's compartment was also designed and is currently available commercially. The mirrors were tested in several mines on haul trucks and front-end loaders. A handbook on mirror design, mounting, and use is available from the NTIS (Eirls et al., 1982).

A different kind of collision hazard exists involving front-end loaders. Workers were becoming desensitized to the continuous sound of backup alarms during normal loader operation (Johnson et al., 1986) and accident rates were high even though the alarms were functioning correctly. To address this problem, the USBM tested, evaluated, and developed systems that would only alarm when a collision hazard existed and the vehicle was in reverse gear. This resulted in a more effective warning for pedestrians located behind the loader and also permitted a warning for the equipment operator inside the operator compartment. Several technologies were evaluated including infrared, ultrasonic, and microwave doppler radar. The research was successful and the concept was proven to be viable. MSHA has since modified its regulations (CFR Title 30, Parts 56/57.14132 and 77.4101) to permit use of discriminating backup alarms. Several units are currently available commercially and a list of manufacturers is available from the USBM.

In the late 1980s, the USBM contracted with Motorola and Dynascan Corporation for the development of an active collision avoidance system for large haulage trucks (Griffin, 1988). The purpose of this work was to allow the driver of a parked haulage truck to detect a small vehicle (i.e., pick-up truck) in the blind spots to the front, side, or rear of the truck. The system utilized a continuous transmitter on the small vehicle with a range of approximately 30 ft. Receivers on the haul truck detect the vehicle and issue an alarm to the haul truck operator. The systems developed were shown to be dependable, however, they are currently not available commercially. The problem of blind areas around mobile mining equipment and resulting collisions continues to be a concern and further cooperative efforts between industry and the USBM may be required.

Shiftwork and Extended Workdays

The USBM evaluated the effect of irregular shift schedules on workers' health and safety, including the effects of rotating shifts, extended shifts and weekend shifts. To address the effects of irregular shiftwork, the USBM collected and analyzed data from miners working a variety of schedules. In addition to surveys, physiological and performance measurements were also taken. This allowed the direct measurement of performance changes for an individual based on rotating shifts, shift lengths, number of consecutive days worked, etc.

Results from the shift work studies indicated that: (1) rotating shifts are less acceptable than are fixed, nonrotating shifts;
(2) backward rotation of the shift schedule (night-evening-day) does not necessarily have more adverse safety and health effects than does forward rotation (day-evening-night);
(3) workers adopt two distinctly different sleep strategies to cope with night shift work, namely early sleep (in the morning) or delayed sleep (in the afternoon/evening), with more health complaints but less on the job fatigue reported by delayed sleepers; (4) adjustment to night shift work appears more complete for a 2-week shift rotation schedule, than for a 1-week rotation; and (5) older mine workers have more difficulty adjusting to shift work, compared to younger workers (Duchon et al., 1989).

The second major area of shiftwork research dealt with extended workdays, defined as those workdays exceeding 8 hours. Two studies of extended workday schedules introduced into underground hard rock mining operations were completed. The findings from these studies are summarized: (1) workers on both 8- and 12-hour night shifts consistently report feeling more sleepy and less alert by the end of the shift, compared with workers on other shifts; (2) self-reports of feelings (using a number of different scales) by 12-hour night shift workers were consistently more negative by the end of the shift, compared to workers on all other shifts; and (3) in terms of changes in either behavior fatigue (as assessed by behavioral testing) or physical fatigue (as assessed by submaximal exercise testing) across the shift, there appears to be no significant differences between the 8- and 12-hour shifts. The extended workday study concluded that: (1) because of its acceptance and beneficial operational effects, coupled with no strong evidence of adverse performance effects, the 12-hour shift should be retained; and (2) continued research and surveillance of the possible long term effects on safety and health are justified (Duchon and Smith, 1993).

Maintenance Safety

Maintenance activities associated with powered haulage equipment are responsible for a large percentage of powered haulage-related accidents. Several research tasks related to equipment maintenance were completed throughout the '80s. Aspects of maintenance safety addressed by USBM research included training, tools, mobile equipment design, tires, the work environment, and slips and falls (Kuenzi and Nelson, 1995).

One of the research tasks identified haulage truck systems which are the most hazardous to work on (Albin, 1990). These included the cooling system, suspension, and tires, with a significant portion of the accidents involving poor access, inadequate footing, falls from ladders, and falling parts and tools. Improvements in equipment access, platforms, and training would aid in the reduction of these accidents. A detailed discussion of these findings and recommendations for improved safety can be found in USBM IC 9246 "Assessment of Accident Risk During Haulage Truck and Power Shovel Maintenance and Recommendations for Improved Safety."

Stockpile and Waste Dump Safety

As part of its continuing effort to reduce hazards associated with haulage truck operation, the USBM has recently completed a project oriented towards the safe operation of mobile equipment on stockpiles and waste dumps (May, 1990). The results of this work include development of the computer code "INSLOPE3," based on the kinematic method of limit analysis, which determines an admissible truck weight for varying distances from a slope edge. The program, which is designed to run on a personal computer, considers the material strength parameters, slope geometry, and inertial forces induced by vehicle braking. The program can be used to assist in the determination of safe operating distances for a haulage truck from a slope edge and the development of safe operating procedures. The software has been designed for use by mining engineers and others with a soil or slope stability background (May, 1991). The software and accompanying user's manual are available from the USBM.

In cooperation with MSHA, the USBM also developed a stockpiling safety manual (May et al., 1992). This manual discusses the hazards associated with stockpiles and reviews the procedures that can be used to minimize the occurrence of accidents (figure 4). Some of the topics covered include: safe stockpiling techniques; signs of slope instability; inspection procedures; and recommended operating techniques for haulage trucks, front-end loaders, dozers, and scrapers. Providing clear, concise, and practical information for the mine operator, the safety manual can be obtained from the National Mine Health and Safety Academy, Beckley, West Virginia by requesting Safety Manual No. 30

Bin and Hopper Design to
Insure Material Flowability

The mining industry continues to experience a major problem with material bridging in bins, hoppers, and stockpile feeders. The problem results in the interruption of material flow in process activities which are predominantly designed for a continuous flow of material. Because of the urgency of reinstating the material flow after a plug has occurred, mine personnel often place themselves in precarious positions over the feeders or within the bins and hoppers while trying to clear the plug. Although these activities involving bins, hoppers, and feeders are closely regulated by MSHA, the inherent hazards associated with these devices continue to present a major safety problem. The majority of accidents involve trying to clear bridged material although some occurred from material sliding down the inside of a bin or hopper that was not operating.

The USBM has addressed this problem by developing a fundamental understanding of bulk material flow properties and the cause of material arching (Drescher, 1995). This

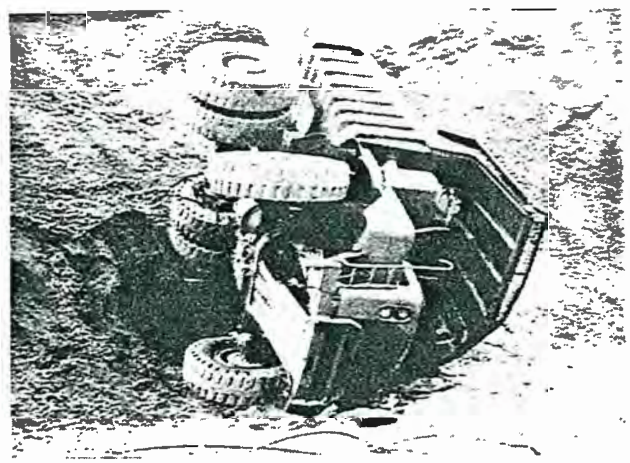

Figure 4. Severe injuries and fatalities often result from accidents on or around stockpiles and wastedumps.

understanding permitted the development of tools that will assist mining operations in the design of bins and hoppers to insure material flowability. The software package HOPP and accompanying users manual "Users Guide to HOPP: A Software Program to Design Bins and Hoppers" will soon be available. The software package examines material parameters and their relation to critical outlet size and hopper wall angle. The software requires that a set of direct shear tests on the bulk material be conducted and the results from these tests input into the program. Other input parameters including bulk unit weight, wall friction angle and hopper half-included angle are also required and described in the user's manual. Based on these data, the program provides recommended outlet sizes and wall angles required to insure material mass flow.

Several additional publications documenting material test procedures, construction of a shear test apparatus, and a theoretical discussion of the design techniques are currently in the publication process and should be available soon.

CURRENT RESEARCH

This section highlights ongoing research projects which are in different stages of completion.

Shock Isolation for Mobile Equipment Operators

A successful reduction of powered haulage accidents and injuries requires that the operator of haul trucks, front-end loaders, dozers, and scrapers be protected from severe shock loadings. The single largest number of lost workdays in surface powered haulage result from acute shock forces imparted to the equipment operator. These shock forces result from collisions, rollovers and tipovers, and the jarring, bumps, and impacts occurring during routine equipment operation.

The USBM is addressing this problem by determining the magnitude and orientation of the forces imparted to the equipment operators. This information will then permit the conceptualization, development, and testing of operator restraint and shock isolation techniques. Shock isolation might, for example, consist of relatively minor modifications to seat or cab mountings. Other than the frequency and severity of the injuries occurring to the head, neck, and back, the significance of the shock loadings is that they are vertical or sideways (or a combination of both) in addition to the front-to-rear impacts normally associated with an automobile.

Efforts are currently underway to measure the shock environment of haul trucks and front-end loaders. Shock recorders are being placed on equipment operating in an assortment of mines and under varying operating conditions. The instrumentation which is small and unobtrusive permits both short-term controlled testing and long-term data gathering. Equipment is being instrumented for periods up to a month to insure that the peak shock forces are being detected and recorded. Very preliminary data from 35-ton conventional rear dump haul trucks operating in crushed stone operations have identified shock forces up to 11 g's, with durations of up to 33 milliseconds. These forces occurred in all three orientations, front-to-rear, sideways, and vertical. Upon completion of the field measurements, a publication summarizing the shock forces an operator is subjected to during equipment operation will be developed. The project will then proceed to the development of engineering solutions.

Vehicle Position Monitoring and Warning System

As part of its effort to reduce hazards associated with the operation of haulage trucks, the USBM has undertaken the development of technologies capable of monitoring the position of a vehicle in relation to a potential hazard. An accurate real-time position monitoring and warning system could notify equipment operators when they deviate from a known safe course and are approaching a potential hazard such as a road edge, highwall, dump point, or other mining equipment. This technology could enhance the operator's control of the vehicle during periods of inclement weather and low visibility. It might also permit monitoring of operator alertness, preventing accidents that occur when the operator has become fatigued or otherwise inattentive to the task of equipment operation.

Based upon required system operating specifications and a preliminary screening of twelve viable approaches, two concepts for a position monitoring and warning system were selected for evaluation: a radar positioning system combined with dead reckoning and a differential global position system (DGPS) combined with dead reckoning. Field testing and evaluation of the radar system at a test track set up by the USBM demonstrated that, although a promising technology, it could not provide the required position accuracy and timeliness required. Research is now concentrating on the utilization of DGPS technology. A cooperative research and testing program between the State of Minnesota, the iron industry in northern Minnesota, and the USBM has just recently been completed. This research and testing program evaluated DGPS for mining applications. The results of these tests have been very promising and the USBM is proceeding with further development of the monitoring system. A computer simulation of a haulage truck and position monitoring system has been developed to aid in the design and analysis of potential system configurations. Publications describing research progress to date are under development and will soon be available.

Seat Design and Vibration Isolation for Mobile Equipment Operators

Although difficult to quantify, it is known that whole-body vibration contributes to the occurrence of accidents and the severity of the injuries resulting during equipment operation. Excessive vibration levels can inhibit the operator's ability to safely control the equipment. Whole-body vibration increases eye blur, disequilibrium and physical exhaustion, increasing the potential for an accident and a resulting operator injury. Long-term health problems due to cumulative vibration exposure are an additional concern. A heavy equipment operator working for 30 years would be exposed to approximately 45,000 hours of whole-body vibration in a seated position which increases the load on the posterior portion of the intervertebral disc in the lower lumbar spine.

The USBM is currently addressing this problem through the development of techniques that will permit the optimal design of seat suspensions. This work is being accomplished under a contract awarded to Marquette University in Milwaukee, Wisconsin. The primary goal of this project is the development of a design approach for equipment and seat manufacturers that will assist them in the design of seats for mobile mining equipment. Specifically, the software under development will allow designers to evaluate seat designs considering the effects of whole-body vibration. This will permit designs based upon vibration measurements taken on the cab floor of the particular piece of equipment under consideration. It will provide performance recommendations for the mechanical components of the seat suspension for a piece of mobile equipment based upon its size, design and construction, duty cycles, and operating environment. Seats with enhanced vibration isolation will reduce the amount of whole-body vibration that an equipment operator is subjected to over the long term. This will result in a safer and healthier working environment for the equipment operator and an anticipated improvement in productivity.

This work, which is currently focusing on the vibration environment encountered on haulage trucks, involves the development of a model which considers a coupled system (human-seat). The selection of a model-based measure of human sensitivity to whole-body vibration and the development of a simple model that captures the essential dynamics of a seated human exposed to whole-body vibration have been completed. Development and evaluation of the design software is near completion. The design software and full supporting documentation will be available from the USBM.

Selection and Application Criteria for Flow Aids

The USBM has recently initiated a project which is concerned with the selection and application of flow aids for bins and hoppers. As already discussed (previous research concerned with bin and hopper design), mine personnel often place themselves in precarious positions over feeders or within bins and hoppers while trying to restore material flow. The primary industry approach to the problem of material bridging is the installation of a flow aid such as a mechanical vibrator. Because of a lack of understanding of the effects of flow-aid devices on material bridging, the devices are often incorrectly chosen or installed and have only a limited effect in eliminating the problem. Discussions with flow-aid manufacturers have revealed that improvements in these devices has been prevented by a lack of understanding of their effects on the strength of material bridging. This lack of understanding also prevents the establishment of proper recommendations for their selection and use.

It is hoped that USBM research on flow-aid devices will result in technologies and procedures of immediate benefit to the entire mining industry, with an emphasis on techniques that can be applied to existing bins and hoppers. The evaluation of flow-aid technology and the development of recommended procedures for their use and installation will involve a study of the propagation of vibration through granular material and the response to stress fields within material in the hoppers. This will enable the development of improved flow-aid devices and improved recommendations for their selection and application.

The project is progressing well with the completion of an experimental test hopper and initiation of preliminary testing. A critical concern regarding the progression of the project has been solved. This involved the development of a technique for measuring vibration signals within the granular material in a bin without affecting the material flow properties. A successful technique has been developed which utilizes the placement of thin film piezoelectric transducers with the material. As products are developed they will be made available to industry.

FUTURE RESEARCH

In early 1995, the USBM assembled a team to determine the future of research directed towards surface powered haulage. The USBM team compiled a list of critical research areas based upon their knowledge of the surface mining industry, a review of accident statistics, discussions with mine safety directors, the United Mine Workers, MSHA training specialists, and a mine safety consultant. In addition, two representatives from MSHA technical support with an expertise in surface powered haulage were asked to participate on the team. The team considered the fatalities and lost workdays that would be impacted by the research, the potential for industry cooperation, the potential of success, customer (mining industry) interest, cost, duration, and the potential for industry use and acceptance.

Based on this assessment, a priority for further research was developed as follows:

- Seat Belt Utilization
- Updated Haul Road Design and Maintenance Guidelines
- Novel Emergency Braking
- Reduction of Jarring and Shock Injuries (ongoing)
- Updated Analysis of Accident Trends
- Operator Alertness and Monitoring
- Emergency Procedure Training
- Automated Haulage Technology
- Novel Collision Avoidance Technologies
- Vehicle Overtravel Prevention
- Preventive Maintenance
- Reducing Ingress-Egress Accidents

The USBM is continually evaluating its current and planned research to insure that it makes the most effective use of resources. Industry input is welcomed and encouraged to insure that research remains responsive to industry needs.

SUMMARY

This paper has highlighted USBM safety research directed towards powered haulage in surface mines. Past research products available for the mining industry were presented. Current research is emphasizing accident categories where the greatest impact remains to be made and where current technology may offer potential solutions. Future research will continue to be guided by industry needs and the potential of successfully solving real world problems.

Industry input is encouraged and sought. Close liaison and cooperation with industry is required to insure that USBM research meets the needs of America's miners.

REFERENCES

Albin, T.J. 1990 "Assessment of Accident Risk During Haulage Truck and Power Shovel Maintenance and Recommendations for Improved Safety" USBM IC 9246, 7 pp.

Aldinger, J.A. and C.M. Keran. 1994 "A Review of Accidents During Surface Mine Mobile Equipment Operations" Paper in Proceedings of 25th Annual Institute on Mining Health, Safety and Research, pp. 99-108.

Dahle, J.L. and G.R. Gavan. 1985 "Development of Rollover Protective Structures (ROPS) Performance Criteria for Large Mobile Mining Equipment" (contract no. H0292020, Woodward Associates, Inc.). USBM OFR 57-86, NTIS PB 86-216066, 254 pp.

Drescher, A. 1995 "Arching In Hoppers; I. Arching Theories and Bulk Material Flow Properties" 12 pp. and "Arching In Hoppers: II. Arching Theories and Critical Outlet Size" Powder Technology, Vol. 84, n. 2., 7 pp.

Duchon, J.C., J. Wagner, and C.M. Keran. 1989 "Forward Versus Backward Shift Rotation" Paper in Proceedings of the Human Factors Society 33rd Annual Meeting, Denver, CO, pp. 806-810.

Duchon, J.C. and T.J. Smith. 1993 "Extended Workdays and Safety" International Journal of Industrial Ergonomics, Vol. 11 No. 1, pp. 37-49.

Eirls, J.L., S.F. Hulbert, and A.L. Foster. 1982 "Improved Visibility Systems for Large Haulage Vehicles: Handbook of Mirror Technology for Large Haulage Trucks" (contract no. H0262022). USBM OFR 127-82, NTIS PB 82-251927, 120 pp.

Griffin, R.E. 1988 "Anticollision Systems for Large Mine Haulage Trucks" USBM IC 9212, NTIS PB 90-266602, 14 pp.

Hays R.M. 1983 "Applicability of Center Safety Berms in Surface Mines" USBM Contract Report (P.O. No. P3330440, Ronald M. Hays and Assoc.), 31 pp.

Johnson, G.A. and D.R. Forshey. 1975 "Automatic Fire Protection Systems for Large Haulage Vehicles, Prototype Development and In-mine Testing" USBM IC 8683, NTIS PB 246 704, 16 pp.

Johnson, G.A., R.E. Griffin, and L.W. Laage. 1986 "Improved Backup Alarm Technology for Mobile Mining Equipment" USBM IC 9079, NTIS PB 86-229747, 19 pp.

Kaufman, W.W. and J.C. Ault. 1977 "Design of Surface Mine Haulage Roads - A Manual" USBM IC 8758, NTIS PB 277 251, 68 pp.

Krupp, K. and J. Applegate. 1983 Haulage Truck Training System (contract no. J0387221, Woodward Associates, Inc.). USBM OFR 61-85, NTIS PB 85-215-762, 209 pp.

Kuenzi, J.K. and B.C. Nelson. 1995 "Mobile Mine Equipment Maintenance Safety: A Review of U.S. Bureau of Mines Research" USBM IC 9424, 19 pp.

Long, D.A. 1984 "Improved Personnel Access For Surface Mining Equipment" USBM IC 8983, NTIS PB 84-226059, 20 pp.

May, J.P. 1990 "Analysis of Dump Point Accidents Involving Mobile Mining Equipment" USBM IC 9250, NTIS PB 91-105791, 19 pp.

May, J.P. 1991 "User's Guide for Inslope3: A Computer Code to Analyze the Effect of Haulage Truck Operation on Dump Point Stability" USBM IC 9291, NTIS PB 92-111020, 20 pp.

May, J. P., J. Fredland and J. Jansky. 1992 MSHA Safety Manual #30, U.S. Department of Labor, Mines Safety and Health Administration, 59 pp.

Miller, G.G., G.L. Stecklein, and J.J. Labra. 1983 "Improved Haul Road Berm Design" Paper in Proceedings, Safety in the Use and Maintenance of Large Mobile Surface Mining Equipment. USBM IC 8947, pp. 87-97.

Pomroy, W.H. and K.L. Bickel. 1980 "Automatic Fire Protection Systems for Surface Mining Equipment" USBM IC 8832, NTIS PB 81-156937, 39 pp.

Stecklein, G.L. and J. Labra. 1981 "Haulroad Berm and Guardrail Design Study and Demonstration" Volume I, (contract HO282-28, Southwest Res. Inst.). USBM OFR 188-82, NTIS PB 83-137091, 186 pp.

Swan, S.A., D.C. Jones and K. Niziol. 1985 "Rollover Protective Structures (ROPS) Inspection and Maintenance Guide" USBM IC 9009, NTIS PB 85-235786, 15 pp.

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AUGUST 28-30, 1995

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Published by the Department of Mining and Minerals Engineering
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061-0239
540/231-6671