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EQUIPMENT DEVELOPMENT TRENDS: CANMET'S PAST AND PRESENT INVOLVEMENT

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by

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ABSTRACT

The presentation reviews the evolution of mining methods over the past several decades; defines their impact on equipment development; places their present status in historical perspective; and prognosticates future evolution with respect to big and small mines. The successful development and introduction of new mining equipment in the eighties was made possible by bulk mining methods developed in the sixties and seventies.

The shift from selective mining to bulk mining methods has increased the equipment dependency of all phases of mining: drilling, explosives handling and blasting, ground control and ore handling. These individual mining operations will be considered and discussed in the presentation. CANMET's role will be highlighted and underlined with respect to promoting new equipment development.

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KEY WORDS: Mine equipment evolution, mechanization, automation, robotics, communications, CANMET/MRL.

TENDANCES DANS LA MISE AU POINT DU MATÉRIEL: IMPLICATION PASSÉE ET ACTUELLE DU CANMET

par

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RÉSUMÉ

L'exposé passe en revue l'évolution des méthodes d'exploitation au cours des dernières décennies. Il définit comment ces méthodes ont influencé la mise au point du matériel et les situe dans un contexte historique. Il fournit des prédictions sur l'évolution de ces méthodes dans les mines de grande et petite taille. Les méthodes d'exploitation en vrac mises en oeuvre au cours des années soixante et soixante-dix ont permis la mise au point et l'introduction de nouveau matériel d'exploitation minière durant les années quatre-vingts.

Étant donnéque les méthodes d'exploitation sélective ont été remplacées par celles d'exploitation en vrac, les exploitants de mines dépendent davantage du matériel à toutes les étapes de l'exploitation, c'est-à-dire le forage, la manutention des explosifs et l'abattage, le contrôle des terrains et la manutention du minerai. Ces différentes étapes de l'exploitation minière seront examinées et discutées lors de l'exposé. On soulignera et mettra en valeur le rôle du CANMET dans la promotion et la mise au point de nouveau matériel d'exploitation.

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INTRODUCTION

To outsiders, the sixties and seventies are generally perceived as a period when Canadian mines underwent few major technological innovations. However, to insiders, it was a period of rapid technological changes with the introduction of continuous coal mining methods, and increased mechanization in underground hardrock mines. In the latter case, the shift from selective to bulk operations was significant.

The past decade has seen the development of mining machinery with automation potential, slowly at first but with accelerating strides since the 1982 recession. The move towards automation oriented equipment is more evident at major mines where the benefits of its use are easier to realize. Such equipment is also evident at many smaller mines where modified working methods are in use.

Mr. R. Woodbridge, President of Canadian Advanced Technology Association, recently stated that the Canadian mining industry, the third most important mining industry in the world, had indicated a desire to automate virtually all operations before the end of the century. An important component in meeting the target is suitable mining equipment.

The mining industry has adopted a policy of borrowing as much high tech developments as possible from parallel sectors to improve productivity. While certain transfers are from areas related to mining, many transfers, with sophisticated electronic and/or mechanical equipment suitable for upgrading mining equipment or operations, are from unrelated areas. As an example, remote control systems used in underwater vehicle or space shuttle automation might be adapted to mining needs with relatively minor modifications. While failure from breakdown is probably the most critical factor in space or underwater systems, cost effectiveness is a primary consideration in mining applications. Manufacturers as well have considerable problems in designing and constructing equipment which will function satisfactorily in a mining environment.

The presentation will highlight innovative trends in the industry related to each part of the mining cycle (drill, blast, support, muck). Foreseeable achievements will have an important social impacts on Canadian economy. Recent mechanical and electronical technology developments applied to mining will have to meet one of the world's most demanding work environments.

MINING METHODS

Past achievements

A major recent development in Canadian mining has been, without doubt, the increased use of bulk methods in underground operations. Over the past fifteen years, significant productivity improvement has taken place through innovations. Some of these innovations, however, could not have been successfully introduced without parallel innovations in heavy equipment to suit the mining environment. A good example is the down-the-hole drill (DTH) developed for use in medium sized quarries and adapted to underground conditions by Sudbury operators.

As well, the introduction of load-haul-dump (LHD) equipment in underground mines has reduced mine development time, by eliminating the need for slusher drifts. With such innovations, Canadian mines have maintained and sometimes increased their share of the world markets in a free trade environment, in spite of competition from mines located in non market economies. Further productivity improvements are essential to maintain Canadian mining viability in this environment.

In the past two decades, open pit cost reductions were the consequence of increases in equipment and operations size. Such innovations, however, have reached their practical limit, with the exception of coal, bauxite and phosphate mining, for the following reasons: the limited dimension of most orebodies which do not permit higher extraction rates, and the need for operational flexibility and selectivity between ore and waste. The latter is very important where product quality is a factor in securing markets. Recent advances in hydraulic technology have increased the productivity achievable with smaller equipment size, and thus the financial status of mines that use such equipment.

Perspectives

Previous innovations have been mainly related to medium and large sized operations. In the lenticular orebodies typical of North-Western Québec and North-Eastern Ontario gold producing mines, these innovations are slowly being adapted after appropriate modifications. Shrinkage stoping can be replaced by sub-level stoping, a bulk mining method. Often, sub-levels cannot be eliminated with these orebodies, because of a lack of continuity in lense orientation. Dome and Opemiska have successfully mined 1.3m wide lenses dipping as much as 50° using 51mm diameter parallel upholes and downholes. As a result of the reduced dilution achieved, veins uneconomic to mine by shrinkage stoping can be mined using sub-level stoping.

DRILLING

Past achievements

Drilling has two primary functions in mining: the direct creation of openings to access ore, and the provision of drill holes to load explosives for ore fragmentation. The past twenty years have seen considerable evolution in the equipment available to create horizontal access to deposits. Wheel, rail or caterpillar mounted Jumbo drills, which have almost completely replaced stopers and jacklegs, have speeded up drift advance. Initially, Jumbo drills exclusively used compressed air as an energy source. Electric energy was later introduced as an alternate energy source, and hydraulics used for thrust control. These modifications have permitted the achievement of better drilling accuracy and longer breasts. The introduction of multiple booms has speeded up the opening of large cross-section drifts.

The National Research Council (NRC) funded the development of a large full-face tunnel boring machine (TBM) that was successfully used at Donken-Morien to access underwater coal reserves. The builder of the unit has subsequently sold similar units in Sweden and Germany, countries which are noted for their innovations in the field of mining equipment. Comparative studies of the ground response to conventional and machine tunnel development were also carried out under contract to CANMET, and showed a definite stability advantage of TBM over conventional drifting.

Related to the above project, CANMET and NRC subsidized the design and development of a tunnel borer dismantling machine by Beaver Construction. The Erector-Transporter was designed to dismantle the TBM used at Donken-Morien at the face without the need for withdrawal. The machine was successfully used to dismantle the TBM in one week instead of the conventional three weeks. The same machine can also be used to erect a TBM at a new job site at a substantial savings in cost as no special site preparation is required.

Vertical access work (raises) has also evolved from traditional drill and blast methods to either drop raising (raises drilled from the upper level and retreat blasted in consecutive horizontal slices) or boring (vertical boring machines, VBM) in longer raises. VBM have become sophisticated machines with controls to optimize drilling speed and minimize drilling costs in relation to the rock formations encountered. These improvements in VBM performance have reduced the vertical raising distance needed to overcome setup costs, when compared with the cost of other raising techniques.

With regard to stope mining, broken rock occupies approximately 50% more space than intact rock. As a result, bulk methods require a progressive build-up of blast size, so primary openings can accomodate blasted muck. Drop raising is a very popular method to develop a primary opening. Its major handicap is the development time required, up to six weeks. There certainly is a need to develop a replacement for drop raising which must at the moment be used to drive short raises.

Perspectives

To speed up drilling, various hydraulic drill functions are already regulated. Ongoing development is in part directed at developing automation, which will permit the remote control of several machines by a single operator. Such a development necessitates advances to be made in face pattern recognition methods and in surveying techniques to locate drill holes. Successful development of an automated drill, in addition to providing productivity gains, would reduce drill operator exposure to noise, dust, diesel fumes, oil droplets and high humidity at the drilling face. Reduced labor skills also mean a wider potential population to draw from.

A Val d'Or mine recently carried out a field trial with a full face TBM. The trial indicated the machine would be useful in accessing ore zones/deposits which are at a great distance from a shaft. The trial results also indicated that the time is approaching when tunnelling machines will compete with conventional drifting techniques in long hardrock drives. One benefit of their use would be a reduction in the time between resource discovery and exploitation.

An interesting recent development, as a result of the financial support of CRM (Centre de Recherches minérales) and CRIQ (Centre de Recherches industrielles du Québec), is the Foreuse Roger. In its raise boring configuration, the Foreuse Roger could provide an alternative to drop raising. The Foreuse Roger drill is designed to be used with a down-the-hole (DTH) production drill which initially drills the pilot hole for the Foreuse Roger. The DTH rod assembly then pulls the Foreuse Roger head up from the undercut to drill the raise. Instead of requiring more than a month, as in the case of drop raising, this simple apparatus can provide a vertical relief opening for the stope in less than a week. Moreover, in difficult ground conditions, the method prevents overbreak and the development of unsafe situations for workers in the drilling drift. It is claimed that the Foreuse Roger will be equally effective when used for drifting, although no horizontal trials have been carried out to date.

Wall control, and therefore blasthole drill deviation, are critical in large stopes because of the possible dilution of ore with waste. CANMET recognized the problem of drill hole deviation with respect to large blasthole stoping because of the consequent productivity losses entailed. Through Supply and Services Canada, a contract was awarded to Mining Resource Engineering Ltd. of Kingston to develop a software package with graphics, available on IBM-PC and mainframes, to design bulk stope blast patterns taking into consideration hole deviations, required fragmentation and vibration limits. Although quite inefficient on small machines, the software, nevertheless, provides mine site access to a sophisticated package to check blast loading and sequencing, and to predict the size distribution of blasted materials.

Under contract, Vadiko International Ltd. has developed a prototype add-on package for use with DTH drills to locate and orient drill holes to specifications and to establish actual bit location at rod changes. The use of this unit will permit more rapid decisions to be made on the need for additional holes and their location, and hole abandonment when deviation is excessive.

The next logical drill package advance is the development of a continuous monitoring rod/hammer trajectory control unit. Such a unit would improve hole location, minimize or reduce ore loss, waste dilution and wall vibration levels. Larger distances between sub-levels would become practical in continuous orebodies. Tis new drilling technology would reduce mining cost per tonne of ore mined and increase the competitiveness of Canadian mines.

To summarize, drilling automation has not yet reached its achievable limits. Improved productivity and a better working environment will result from the introduction and use of automated drills in Canadian mines.

EXPLOSIVES

In the past decade, mine blasting practices have become very sophisticated. Explosive loading machines, first introduced 20 years ago, are now standard equipment in open pit mines. Explosive loading machines are now being introduced progressively in underground mines and are contributing to faster loading and a reduction in the hazards associated with bulk explosives loading.

The present principal technology thrust is to increase efficiency while reducing blast vibration structural damage in both open pit and underground operations. Instruments are now regularly used to assure delays and vibration levels are being respected. A study by INCO suggests that production blast damage can be more extensive than originally believed. In one of their mines, a virgin zone, separated by a pillar from active stopes, would appear to be sufficiently damaged to be in a post-failure state.

Developing new blasting technology to effectively control and/or reduce damage would be a significant contribution to the stability of many underground openings.

GROUND CONTROL

Past achievements

The sixties and seventies combined constituted a period where rapid advances were made in the development of numerical structural models to study the stability of mine openings. The companion geotechnical instrumentation required to effectively use such models in rock mechanics studies related to mine design was also fully developed during this period. Modelling concepts have since been refined. During this period, techniques and machinery have been borrowed and modified, when necessary, to meet rock bolting and cementation requirements. Open pit wall bolting is more commonly used today when rock masses with low internal cohesive strength are encountered. Installation of such support systems, however, is slow, and automation and mechanization are required to increase productivity.

Scaling is one of the most potentially hazardous operations in underground mining. CANMET has supported, through a Supplies & Services Canada contract, the development of a mechanical mini-scaler (Teledyne) that reduces the hazards associated with this operation while improving scaling efficiency. Mechanization, as represented by the Teledyne scaler, is the natural prerequisite to automation and remote control of scaling operations. Rock falls, man falls, and back injuries are major sources of lost time accidents in underground mines. INCO, under Canada-Manitoba Mineral Development Agreement (MDA), is developing a new scaling bar to reduce the hazards associated with unassisted hand scaling.

Perspectives

Backfill plays a very important ground support role in many Canadian underground mines. Within the Canada-Ontario MDA, two research projects are concerned with the use of dense backfills and potential fill liquefaction. Dense fills are placed at 88+% solids; hydraulic fills are placed at 60-70% solids. Water and fines in underground drifts, high humidity and rehandling of water and sludge are problems associated with the use of low density fills. Dense fills have the added advantage of returning more of the fines to the stopes and of requiring less cement. This new technology will require the development of more sophisticated and more automated surface and underground plants for economic acceptance by the Canadian mining industry. Another MDA project is concerned with the control of violent pillar failure in the Elliot Lake area by backfilling stopes. Microseismic sensors have been installed and backfilling has started. There is every indication from USBM studies that 7% of vertical pressure in horizontal confinement is enough to prevent violent failures.

SPAR Aerospace is developing, under contract to INCO, a machine to simultaneously screen and rockbolt walls and backs. Such a machine has the potential to considerably reduce the time required to carry out these operations, and shorten the overall mining cycle with consequent savings in costs. Better support should be provided because of the reduced time for rock pressure release to take place. The machine is also amenable to remote control, which would result in greater worker safety. Not all mines screen systematically all openings like INCO, but many screen 'permanent' openings, to reduce maintenance and increase safety.

HAULAGE

Past achievements

Ore handling is the major mining cost in both open pit and underground metal mines. The past 25 years have seen increasing use in underground mines of Load-Haul-Dump (LHD) units, and loaders and trucks to increase productivity. Over the same period, the load capacity of open pit mine trucks has increased considerably; at present, some open pit mines are using 300 tonne capacity trucks.

The increased efficiency of open pit operations, due in part to the use of larger equipment, has permitted the economic exploitation of low grade deposits. The size of open pit mine equipment, however, now seems to have reached its practical limits. Innovations in other areas are being introduced to further reduce mining costs. As an example, many larger operations have introduced, during the last decade, truck dispatching systems to maximize production by reducing truck waiting times and haul distances. Such dispatching systems are at present too expensive for use by medium size mining operations (between 10-20 trucks). It is the view at CANMET that suitable technology and software should be developed for their economic use by the smaller mines. Personal information sources indicate that steps are under way to develop suitable small mine dispatching systems.

Safer and more efficient ore handling equipment and systems have been introduced in underground mines in the last decade. For example, the Atlas Copco Häggloader has been used to considerably improve the loading phase of muck haulage in drift development and stoping operations. Suitably combined with Jumbo drills, they have speeded up mine development. The present technological emphasis with respect to these two units is to devise methods of optimizing their use in combination, and thus improve mine development planning and scheduling.

Until true expert systems become available for haulage equipment scheduling, human judgement will play a major role in the assignment of equipment for handling ore and waste materials in open pit mines. Recently, however, a methodology and software have been developed which can assist an operator in making decision on equipment assignment related to ore loading and haulage in open pit mines. The interactive software requires the operator to feed it with specific information on the operation. On the basis of this information and using linear analysis, the operator is provided with solutions to problems that arise. If the solution is not acceptable, the operator can ask for additional solutions by modifying input data until a satisfactory one is provided. As an example, the software can be used to establish the optimal reallocation of trucks as a result of a loader breakdown. The innovation in this case is the making available to mine dispatchers linear analysis/programming methodology to help them solve their problems.

Perspectives

Mine equipment could be used more efficiently if equipment requirements were given greater consideration in the design and location of shafts and ramps. Often in the past, levels and bench heights have not been selected with due consideration of the impact on equipment performance. Mining efficiency will only be optimized if the optimal equipment is used for the mine configuration selected.

No data bank is available to assess equipment and its characteristics in terms of operational settings. Such a data bank would be useful in optimizing equipment selection based on a mine's specific configuration. It must be remembered that equipment not suitable for use at one mine because of site specific conditions might admirably suit the needs of a neighbouring mine. Such a data bank is a prerequisite to the development of mine expert systems. It is needed for optimal technical planning of mining operations.

Not enough is presently known about equipment availability and rock product size to assess equipment performance. Greater use of equipment sensors is required to record equipment availability if productivity improvements are to be realized. Present industrial monitoring systems are not adequate for open pit and underground mining operations, because they are limited to monitoring engine performance. The use of comprehensive monitoring systems would permit timely preventive maintenance to be carried out and a reduction of the number of equipment units used.

Two innovations are presently being introduced to open pit mining: crawlers, and steep angle conveyors to reduce the amount of pit wall roads. Their introduction is expected to modify material handling techniques by allowing moveable in-pit crushers to be used with steep angle conveyors to provide rock to waste dumps or plant. The successful use of these innovations should reduce overall open pit haulage costs.

Diesel engines do not contribute positively to the underground work environment. The recent shift to electrical equipment not only reduces ventilation requirements, but reduces worker's exposure to diesel combustion gaseous and particulate products. As well, electric power coupled with hydraulic systems provides the positive machine control required for equipment automation.

The recently developed "Oscilloader" by INCO has significantly increased the output from draw points when compared to other available methods and equipment. The higher output has considerable economic consequence in terms of the development required to meet a mine's ore production requirements. The unit is used as part of INCO's continuous mine system which consists of a loader, portable crusher, belt bender and extensive conveyor. The system can supply up to a few thousand tonnes a day to the main mine transportation network for hoisting to surface. This permits concentration of underground operations, with increased supervision potential. Such systems are amenable to automation, and should provide better lighting and reduced ventilation requirements.

Many mines in Canada develop and economically mine narrow vein orebodies. The special small sized mine equipment requirements of these underground operations are being investigated at several mines. Electrical LHD units have been successfully used in several narrow vein mines across the country. When bulk mining is being used to mine narrow vein orebodies, mini-LHDs are being used at draw points and replace slushers for loading train cars on levels. Adaptation of existing technology is the present trend with respect to mining narrow ore lenses. Some mines are purchasing multi-purpose equipment to carry out the following operations by simply changing the tool head: drill, scale, rockbolt and handle ore in stopes.

COMMUNICATIONS

Past achievements

In the past, underground mine communication stations were limited to a few locations, mainly shaft level stations and lunch rooms. An exception: Cominco Sullivan Mine already had voice communication links between all areas of the mine and to surface in the early seventies. The increased mechanization of some mines has since created the need for the development of an upgraded communication system to determine the work status and to locate individual units of mechanized equipment. It is now an essential system for increased coordination of operations. The main problem with most systems is maintenance of lines and phone units in a water-saturated, gas- and dust-laden, and corrosive atmosphere.

Perspectives

CANMET recognizes the need for the development of a radio system specifically designed to meet the requirements of Canadian underground mines. Better coatings are now available to insulate lines and boxes for reliable underground use. Under the Canada-Manitoba Mineral Development Agreement, a Montan-Forshung system is being installed and tested at Sherritt Gordon's Ruttan mine in northern Manitoba. The system is being evaluated in terms of providing a voice communication link to remotely located miners for safety and as a data communication link for operations.

This system is not the only mine radio system being tested in Canada. Selbaie Mines, north of Joutel, have installed the National Coal Board system; Quirke Mine of Rio Algom have installed and Lac Minerals Bousquet Mine is in the process of installing the french Charbonnages de France Silec system; Montan-Forshung systems have been installed at Falconbridge's Lockerby Mine, INCO's South and Frood Mines, and Kiena Mine. Evidently, there is a growing commitment to underground communications by mines with equipment fleets of some importance. Such developments leed to the essential data communications systems needed to further automate underground equipment.

CONCLUSION

As is evident, the Canadian mining industry has not been technologically conservative and static over the last few decades. To the contrary, there has been a continuous series of technological innovations of which the general public is not aware. Most mining towns and villages are located a considerable distance from centers of learning and high technology. Thus, additional problems are faced by the mining industry when upgrading employees to use new technology not shared with other industries.

The recent emphasis in mine equipment development has been with respect to: monitoring, telemetry, data acquisition and analytical systems to assess the status of mining equipment. The primary objective is to improve equipment reliability through timely servicing. Other areas where there is considerable interest in new equipment technology development are: drill hole wander control; blast vibration measurement; breast orientation and face drilling pattern recognition; remote controlled scaling and rockbolting; and haulage automation.

The Mining Research Laboratories (MRL) is in a unique position to appraise, on a National basis, the industry's existing and developing technology needs. CANMET/MRL has limited funds to directly support industry research initiatives to develop new technology for the mining industry. It has, however, the important additional role of promoting to other Federal agencies with the financial resources and mandate, mine equipment technology research deemed of importance to the industry.