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CANMET'S ROLE IN MINE EQUIPMENT DEVELOPMENT

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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.

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 change with the introduction of continuous coal mining methods, and increased mechanization in many underground hardrock mines. In the latter case, the shift from selective to bulk operations was significant.

The past decade has seen the development, slowly at first but with accelerating strides since the 1982 recession, of mining machinery with automation potential. 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 evident at many smaller mines where

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modified work methods are being used.

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, has 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 many high technology developments as possible from parallel sectors to improve productivity. While certain transfers are from areas related to mining, many transfers are from unrelated areas in other sectors. As an example, adaptation of remote control systems used in space or underwater transport might meet mining needs with relatively minor modifications. While failure from breakdown is probably the most critical consideration in outer space or underwater systems, cost effectiveness would be the primary consideration in a mining system. Historically, manufacturers have considerable difficulty in designing and constructing equipment which functions satisfactorily in a mining environment.

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 as a result of their use. Some of these methods and modified methods, however, could not have been successfully introduced without the occurrence of innovations in heavy equipment that could be modified to suit the mining environment. A good example is the down-the-hole drill (DTH) originally developed for use in medium sized quarries and adapted for use in underground mines by Sudbury operators.

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, Canadians 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. Because of such competition, continued productivity improvements are essential to maintain Canadian mining viability.

In the past two decades, open pit cost reductions were the consequence of increases in equipment size and operations. Such modifications, however, have reached their practical limit, with the exception of such commodities as coal, bauxite and phosphate, 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 improvements in hydraulics technology have increased the productivity achievable with smaller size equipment, and thus the financial status of mines that use such equipment.

Perspectives

Until recently, mine technology innovation has been mainly concerned with medium to large sized operations. These innovations are now slowly being adapted, after appropriate modifications, to the lenticular orebodies typical of North-Western Québec and North-Eastern Ontario gold mines. Shrinkage stoping can be replaced by sub-level stoping, a bulk method. Often, sub-levels cannot be eliminated with these orebodies, because of a lack of continuity in lense orientation. With this method, Dome and Opemiska have successfully mined 1.3m thick 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 are being economically 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. In the past twenty years, considerable evolution has occurred in the equipment available to create horizontal access to a deposit. 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 for thrust control. These latter modifications have permitted the achievement of more precise drilling 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 that was successfully used at Dunken-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.

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 full face boring machine used at Dunken-Morien at the face. The machine was successfully used to dismantle the boring machine in one week instead of the conventional three weeks. The same machine can also be used to erect a borer at a new job site at a substantial savings in site preparation costs.

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

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 developed muck. Drop raising is a very popular method to develop a primary opening. Its major handicap is the development time required is long, up to six weeks. There is a need to develop a replacement for drop raising for use in the development of short raises.

Perspectives

To speed up drilling, various hydraulic drill functions are already regulated. Present technology research is, in part, directed at developing automation which would 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.

A Val d'Or mine recently carried out a field trial with a full face tunnelling machine. The trial indicated the machine has potential to access ore zones/deposits at great distance from a shaft. The trial results also indicated that the time is approaching when tunnelling machines will compete with conventional drifting techniques for the driving of 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 has the potential to provide an alternative to drop raising. The Foreuse Roger drill is designed to be used with a down-the-hole (DTH) production drill which also drills the pilot hole for the machine. The DTH rod assembly pulls the Roger head up from the undercut as it drills 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 a conventional 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 because of the possible dilution of waste with ore in blasthole stoping. 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, to design bulk stope blast patterns taking into consideration hole deviations, required fragmentation and vibration limits.

Under contract, Vadiko International Ltd. has developed a prototype add-on package for use with DTH drills to locate and orient drill holes and 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 reduce ore loss and waste dilution. Large distances between sub-levels would become possible. This 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 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 vibrations structural damage in both open pit and underground operations. Instruments are now regularly used to assure that delays and vibrations levels are respected. In this regard, a study report 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 that damage would be a significant contribution to the stability of many underground opening.

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 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 now more commonly used when rock masses with minimal internal cohesive strength are encountered.

Scaling is one of the most potentially hazardous operations in underground mining. CANMET has supported 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 the scaling operation. Rock falls and back injuries are the major sources of lost time accidents in underground mines. INCO, under the Canada-Manitoba Mineral Development Agreement (MDA), is also 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. Under the Canada-Ontario MDA, two research projects are being carried out to investigate the use of dense backfills and potential fill liquefaction. Dense fills are normally placed at 88+% solids; normal 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 containing more of the fines in 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 project is concerned with the control of violent pillar failure in the Elliot Lake area by the use of fill.

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 mining cycle time with consequent savings in costs. As well, better support should be achieved because of the reduced time required for support placement. Not all mines screen all openings as is the case with INCO Sudbury operations. However, many mines screen 'permanent' openings, to reduce maintenance and increase safety.

HAULAGE

Past achievements

Ore handling is the major mining cost in both underground and open pit 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 lower 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, in 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 operations (between 10-20 trucks). It is the view at CANMET that suitable technology and software could be developed for their economic use by the smaller mines. Personal information sources indicate that steps are under way to develop suitable dispatching systems for small mines.

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 and access to ore. The present technological emphasis with respect to these two units is to devise methods of optimizing their use in combination.

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 has been developed which can assist an operator in making decisions on equipment assignment related to ore loading and haulage in open pit mines. The interactive software, however, 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 a possible solution. If the solution is not reasonable, 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 technology is the making available to mine dispatchers linear programming methodology to solve problems that develop.

Perspectives

Mine equipment could be used more efficiently if equipment capabilities 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 their characteristics in terms of operational settings. Such a data bank would be useful in optimizing equipment selection based on a mine's specific conditions. 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 and 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 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 in the number of equipment units used by the mine.

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

The use of diesel engines in underground mines is not a positive contributor to the work environment. The recent shift to electrical equipment not only reduces ventilation requirements, but reduces worker's exposure to diesel combustion, gases 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 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 extendable conveyor. The system can supply up to a few thousand tonnes a day to the main mine transportation system for hoisting to surface. The system will permit a reduction in the number of working places needed to meet production requirements and permit increased supervision. Such systems are amenable to automation, and permit reduced ventilation and increased lighting.

A large number of mines in Canada economically mine narrow vein orebodies. The special small sized mine equipment requirements of these operations are being investigated at several mines. Electrical Load-Haul-Dump (LHD) units have been successfully used in narrow vein mines across the country. In several mines where bulk mining is being used in narrow vein orebodies, mini-LHDs are being used at draw points, replacing slushers to load train cars on levels. Adaptation of existing technology is the present trend with respect to the mining of 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

In the past, underground mine communication stations were limited to a few locations, mainly shaft level stations and lunch rooms. The increased mechanization of some mines has created a need for the development of an upgraded communication system to determine the working status and location of individual units of mechanized equipment. It is essential in such mines for the coordination of operations.

CANMET recognizes the need for the development of a radio system specifically designed to meet the requirements of Canadian underground mines. 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. New communications systems are also needed to further automate underground equipment.

CONCLUSION

As is evident, the Canadian mining industry has not been technologically conservative and static over the past 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 at considerable distance from centers of higher learning and high technology. Thus, mines often face an additional problem compared to other industries when advanced training for their employees is required related to the introduction of new technology.

The recent emphasis in mine equipment development has been on: monitoring, telemetry, data acquisition and analytical systems to assess the status of mining equipment, the primary objective being 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 also has the additional important roles of promoting to other Federal agencies with the financial resources and mandate for mine equipment technology development, new research initiatives.