# Considerations for Development of Hard Rock Roadheaders

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ABSTRACT

The ability of roadheader style machines to operate and cut effectively in hard rock has been limited by system stiffness, the inability of radial and point attact cutting tools to withstand high normal forces, and premature carbide insert failure as a result of high impact loads and heat generated during excavation of high silica rocks. Several roadheader manufacturers have recently developed high horsepower, large mass machines in an effort to enhance the performance capabilities and to broaden the application base of traditional roadheader technology into the excavation of harder and more abrasive rock formations. Recent improvements in bit designs and materials coupled with the introduction of high torque drive systems and significantly increased machine stifness have resulted in some success in extending the cutting ability of roadheaders to rocks harder than previously considered suitable for roadheader use. The current and future anticipated development trends indicate additional performance improvements in the ability of roadheaders to effectively tackle harder rocks. A promising approach appears to be the adaptation of disc cutting technology in place of the drag type cutting tools currently utilized on roadheaders. In particular, new developments in small diameter, high thrust capacity disc cutters show great potential for use on roadheaders to allow economic excavation of hard rock formations.

INTRODUCTION

Roadheaders have traditionally operated in rocks with unconfined compressive strengths of less than 15,000 psi. Occasionally, harder rock formations have been succesfully excavated where the presence of joints, bedding planes, fractures or foliation have created a considerably weakened rock mass. In these rocks, the primary excavation process is the removal of blocks of rock from the face by the ripping action of the roadheader. Without any existing rock internal weaknesses however, the performance of roadheaders drops off drastically as the rock hardness and the silica content increase. In particular, the high bit wear and the requirement for frequent bit replacements can make up a substantial portion of the overall excavation costs. The current roadheader technology suffers from several major shortcomings when applied to hard rock cutting. Chief among these is the inability of drag bits to withstand the high thrust and shock loads which are required and encountered in hard rock excavation. When used in hard rock, the bits either experience premature structural failure or suffer extensive abrasion wear with unacceptably high replacement costs. Second, the current machines lack the mass and the rigidity to generate and react to the high cutting forces required for efficient excavation of hard rocks. Finally, there still exists a lack of a full understanding of rock property effects on machine performance and bit wear. This limits the effectiveness of design efforts aimed at optimizing machine performance through improvements in bit geometry and lacing pattern.

Roadheaders provide a highly flexible and versatile rock excavation system due to their mobility and the capability to cut any desired profile. Especially with recent developments in automated profile control systems, the opening size and shape can be precisely programmed and maintained. This results in less overbreak and reduced support requirements. Owing to these features, the hard rock mining industry is showing considerable interest in the use of roadheaders both for mine development and production purposes. It is believed that roadheaders capable of effectively cutting hard rock can provide significant cost savings, in particular for rapid development of mine entries,ventilation drifts, haulageways, etc.

## RECENT DEVELOPMENTS IN ROADHEADERS

Extensive rock cutting research conducted with drag bits at the Colorado School of Mines and elsewhere have clearly shown that deep bit penetrations coupled with slow cutting speeds are required for efficient excavation of hard rocks both in terms of machine performance and bit wear. Deep penetrations create more efficient fragmentation while taking greater advantage of any internal rock weaknesses resulting from the presence of microfractures, joints, bedding, foliation, or grain alignment. Deep penetrations also mean bit spacing can be made larger, reducing the total number of bits utilized on the machine and therefore, lower bit costs. A side benefit of deep penetration cutting is the reduced dust production. Slow cutting speeds also contribute to improved bit life by reducing the heat buildup on the bit during the excavation process. This helps retard the potential thermal degradation of the carbide tip due to high cutting temperatures usually generated in cutting high silica rocks.

To achieve deep penetration cutting, the roadheader needs to be equipped with the required torque, sumping and the slewing force capacities. Also, the machine needs to incorparate sufficient weight to react to these forces or employ some other means of generating gripping forces, for example by using stelling jacks.

Until recently, the cutterhead speed reduction on roadheaders was accomplished by utilizing a two-speed gear box or by changing the drive motor. Both of these techniques had certain drawbacks. The motor change reduced the horsepower available for cutting, thus adversely affecting machine productivity. In cases where a gear reduction was used, the high input horsepower could only be applied for a short duration of time without causing gear box failure.

The modern roadheaders have now been incorporated with pole switchable motors or variable frequency AC-drive motors to allow changing of head rotational speed to match rock hardness and ground conditions. Other recent developments include the new hydraulic drive system developed by the Voest-Alpine Company. This features a planetary gear system which converts the electric drive into a high power hydraulic drive for operation at about 25% of the speed of standard electric drive while providing a higher torque capacity. As shown in Figures 1 and 2, this new drive system provides for higher rates of advance with reduced bit costs in harder materials.

The new roadheaders also incorporate lower slewing speeds to accomodate the slower bit traverse speed and the deeper bit penetration requirements. To enable effective sumping in harder rocks, the machines are also fitted with a longitudinal slide of two to three feet so that the reaction forces are directed to the mass of the machine and not lost in tractive inefficiencies of the system. This feature becomes particularly effective on machines equipped with transverse cutting drums. In addition, the cutterhead power on some of the larger, high production roadheaders have been increased to as much as 500 kW.

One of the current roadblocks to economic use of roadheaders in hard rock is the lack of bit technology to withstand the high loads required for excavating hard materials while providing an acceptable bit life. The drag bits presently utilized on roadheaders suffer extensive abrasive wear or premature

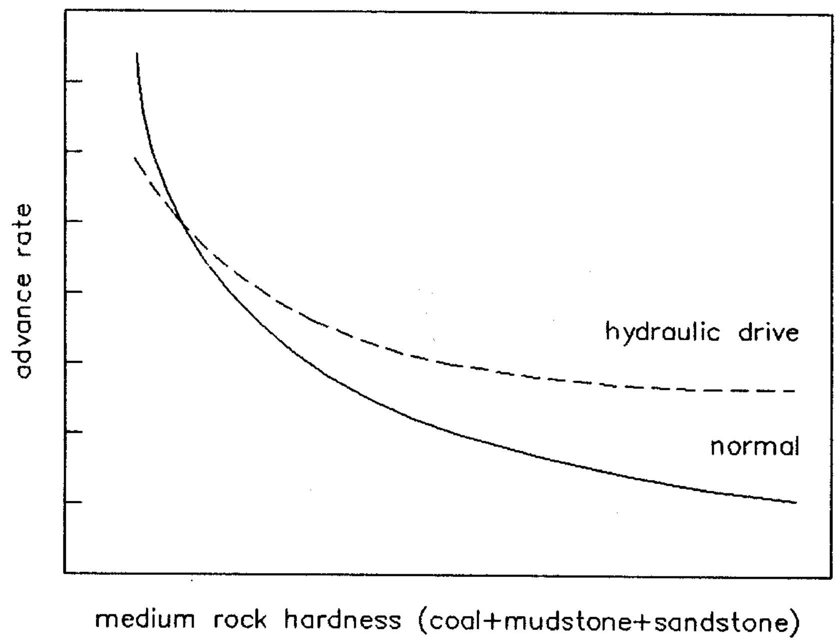


FIGURE 1

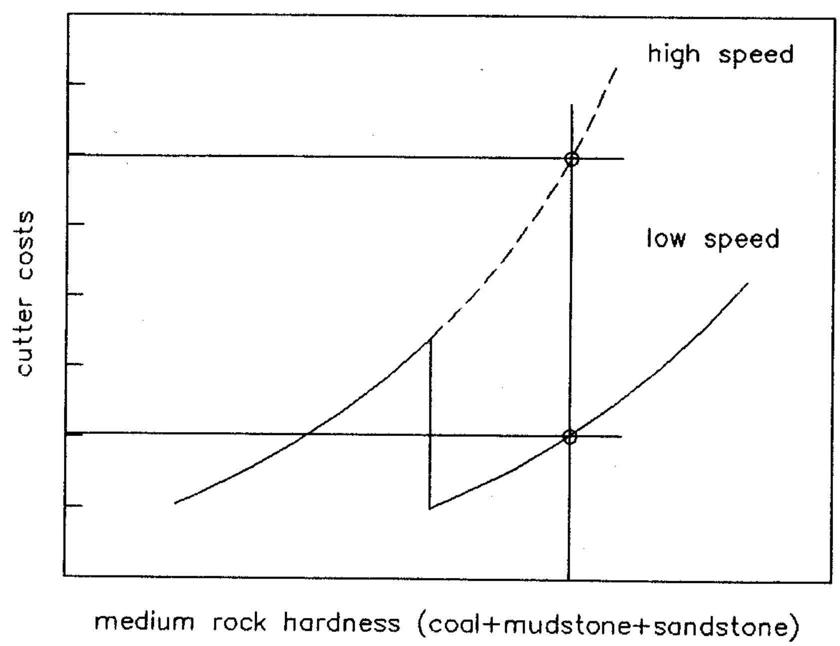


FIGURE 2

structural failure when applied to cutting of harder rocks. The resultant high bit costs and extensive machine downtime to replace bits result in very poor economics compared other conventional excavation techniques. Recognizing this shortcoming, intensive efforts have been directed in recent years to developing more wear resistant and longer lasting drag bits. These efforts have resulted on tougher and more heat-resistant tungsten-carbide cutting tips. In particular, introduction of layered carbide tips and shaped polycrystalline diamonds has provided for the extended capability to efficiently excavate harder materials with roadheaders. These developments coupled with more efficient bit designs and lacing patterns allowed economic roadheader application in harder and more abrasive rock formations than previously possible.

Unless a revolutionary breakthrough in drag bit technology is achieved, it is not believed that drag bits will ever evolve to a point where they will be capable of economically excavating the rock types typically encountered in most hard rock mining operations. A promising solution is the use of roller cutters, in particular the disc cutters which can effectively cut hard rocks, as has been demonstrated from many successfull applications of tunnel boring machines (TBMs) in rock types ranging from soft to very hard and abrasive. At present several manufacturers and research establishments are vigorously investigating the technical and economic feasibility of equipping heavy-duty roadheaders with disc cutters for excavating hard rock.

The main obstacle preventing the use of disc cutters on roadheaders so far has been the high thrust requirements of disc cutters to effectively penetrate the rock. In addition, disc cutters need a stiff cutting system in order to deliver high performance and long bit life. TBMs fully meet these these conditions by providing a rigid cutting system and being able to generate and apply the relatively high thrust loads required for efficient disc cutter operation. Naturally, being a mobile type excavator without the type of gripping system used on TBMs, roadheaders can not be expected to satisfy the thrust and stiffness requirements of disc cutters. Moreover, the presently available disc cutters can not be installed on roadheaders on a reasonable layout pattern simply because of size restrictions. For disc cutters to be given serious consideration for use on roadheaders, it is imperative that cutter size and thrust requirements are reduced substantially. In fact, several ongoing research and development efforts are addressing this issue, attempting to develop small diameter, high thrust capacity disc cutters with long wear life in hard, abrasive materials. These new designs incorporate "plain" bearings rather than the roller bearings which the current disc cutters utilize. Several types of plain bearings are being evaluated, including the diamond inpregnated teflon and ceramic coated surfaces. The primary advantage of a plain bearing over the conventional roller bearings is that the cutter size can be reduced drastically without a major decrease in the cutter load capacity. It is believed that this new technology will produce disc cutters as small as 6 in. in diameter with a load capacity approaching 20,000 lbs. Disc cutters of this size can be easily fitted on a roadheader drum in practically any desired lacing pattern. Further, the small disc cutters with plain bearings can have a full-carbide cutting ring with a relatively sharp cutting edge to provide high penetration capability. It is estimated that for a 20,000 psi rock, a 6 in. disc cutter with a V-profile, sharp cutting edge can achieve a penetration of about 0.5 inches at a thrust requirement not exceeding 5,000 lbs, which is well within the capabilities of current heavy-duty roadheaders. Thus, the small disc cutters can achieve the same rates of production as drag bits when used on roadheaders. This means a significant reduction in bit costs while maintaining the same production potential of the machine.

As stated earlier, disc cutters require a relatively stiff cutting system to be most effective. Otherwise, cutter wear is bound to occur at an accelerated rate with a rapid decline in machine performance. For roadheader application of disc cutters, this means the machine will have to incorporate a rigid cutting boom with longitidunal sumping action in conjunction with some auxiliary stelling jack arrangement for increased stabilization and boom force reaction.

## CONCLUSIONS

A roadheader capable of effectively cutting hard rocks up to 25,000 psi in compressive strength is needed by the mining and the tunnelling industry. A great deal of work is currently underway by the machine manufacturers and various research organizations to develop the bit and cutting technology necessary to extend the application of roadheaders to excavation of materials stronger and more abrasive than what is considered economically feasible today. An approach which shows great promise is the use of small, sharp disc cutters on the cutting boom to take advantage of the proven capability of disc cutters in hard rock excavation. The new, plain bearing disc cutters under development offer high potential for extending the application of roadheaders to harder rocks. This coupled with improved machine design and more cuttingboom power should enable roadheaders to excavate harder rock formations.

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