Roof bolting machines for high speed drivages

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High speed driving of the in-seam headings is imperative to meet the high production targets stipulated from underground coal mines. Supporting the roof (sometimes sides or even the floors) of these headings, many a times, is the bottleneck of the operation in such high speed drivage. The technology of roof bolting appears to be the fast, safe and reliable method of support. New roof bolting machines have mechanised the roof bolting technology and the roof bolters are becoming increasingly popular, globally, to provide immediate support to the mine roof. The paper, highlights a few important aspects of construction and application of various types of roof bolting machines, which are available in the international market.

The current impetus, with respect to Indian Coal, is on higher level of mechanization for increased productivity, so as to cater to the exponentially hiking demands for coal. Keeping this end in view, fast panel development, for enhanced productivity levels, is necessitated, which, in turn, essentially banks on fast drivage of headings.

Roadheaders have now been widely introduced for fast drivages of the development headings. With the deployment of these fast drivage machines, drivage rates have increased significantly and rates in excess of 100 m per week are no longer exceptional, internationally. The main drawback, with introduction of roadheaders, in Indian context, has been the lack of full capacity utilisation of these capital intensive machines (costing approximately Rs. 2.5 crores). This can largely be attributed to the slow existing roof supporting operation. As such, the major share of operational time is diverted in supporting the headings, thus, keeping the expensive roadheaders unutilized for substantially long periods.

It is thus imperative to devise fast, safe and reliable supporting cycle in the headings. In this light, roof bolters are growing increasingly popular to provide immediate and permanent support in the roadways. It is appropriate to state here that when bolting is used as a means of primary support, the cost of materials for bolted drivages is substantially less than for those supported by conventional steel arched supports. If transport and labour costs for material handling are included, the total cost can be reduced by 50%. In the USA, the application of roof bolting machines has been successfully practised for last 10-15 years. Also, in Australia, roof bolting, through the bolting machines has become the sole method of roadway stabilisation. Roof bolting by the use of roof bolting machines is, therefore, internationally acclaimed for increased drivage rates alongwith improved roadway condition. Passive supports offer constraints to high speed drivages. Also, it is pertinent to mention here that besides enhancing the drivage rates, the American and the U.K. experience have proved that combined use of roof bolting machines and free steered vehicles definitely increases the efficiency of face salvage operations too. In this view, the paper highlights a few pertinent details of various types of roof bolting machines currently available in global market for application in underground coal mines.

Essential Design Requisites in a Roof Bolting Machine

Roof bolting machine is primarily a drilling machine designed for drilling as well as bolting operations. Its application is widely extended in the roadways, galleries, gateroads etc. The main requirements of a bolted roadway are that it should be capable of being driven rapidly as well as safely. Safety is important in bolting operations because roof bolting is generally considered one of the most dangerous activities in mining cycle. In a series of studies it has been pointed out that roof bolters ranked first in the number of fatal accidents. The machine is capable of drilling holes ranging from 28 to 45 mm dia. The drilled holes are bolted by means.
of bolting adaptor which pushes the bolt into the hole, after having finished the essential preparations, for instance, pushing the resin cartridges into the hole. The bolt is thus grouted at place. Since the machine operates in the underground atmosphere, the following design requisites in the machine must essentially be looked into before deciding on the type of machine to be procured for specific application\textsuperscript{4}\textsuperscript{,}\textsuperscript{6}\textsuperscript{,}\textsuperscript{7}.

(i) The machine must be light in weight.

(ii) The machine must be able to readily move in the most confined areas in underground (u/g) mines and must be safe in operation.

(iii) The machine must be provided with an excellent combination of manoeuvrability, rotation and thrust for drilling and bolting operations.

(iv) The machine, while at operation, must have rapid drilling capabilities in order to provide immediate support in the exposed roof areas.

(v) The components of machine must be corrosion and impact resistant.

(vi) The machine must have a simple but compact design with ready accessibility to all components for quick maintenance with minimum downtime.

(vii) The machine must have low noise emission levels.

Types of Roof Bolting Machines

The roof bolting machines are available in wide varieties in order to suit the varied applications in underground working climate. These machines come in all sizes, with a comparable price range\textsuperscript{6}.

On the basis of the type of mounting and the type of energy transmission media deployed to power the machines, the entire spectrum of the currently available machines in the global markets, can be put into four types, viz., (i) Portable, pneumatically powered machines, (ii) Portable, hydraulically powered machines, (iii) Wheel mounted, hydraulically powered machines and (iv) Crawler mounted, hydraulically powered machines.

Constructional and Technical Details

The following section pertains to the constructional and technical details of each type of roof bolting machine.

Portable pneumatically powered machine

This machine is basically a pneumatic powered rotary drilling machine configured for vertical hole drilling with added provision of oscillation in vertical plane up to $\pm 15^\circ$. The machine has rapid positioning and setting capabilities. Extensive use of such portable machines is important from the viewpoint of expanding roof bolting techniques more extensively in the underground\textsuperscript{8}. A general arrangement of this type of machine is illustrated in Fig. 1.

Following are the essential sub-systems of the machine.

Stingers

Stingers are vertical supporting columns which lock the machine between roof and floor, while in operation. They are made up of carbon fibre material.

![Fig. 1—Portable pneumatically powered roof bolting machine.](image-url)
Rod holders
Rod holder, which holds the drill rod, has automatic holding/releasing capabilities. It is equipped with tungsten carbide jaws which automatically release the rod when forward rotation starts. In the event of loosing air pressure and also when the rotation is stopped, the rod holder regrips the rod.

Rotation unit
The rotation unit comprises air motor designed for high torque, compact size robust and light weight configuration so as to perform efficiently in the underground settings.

Feed
Pneumatically operated feed mechanisms are capable of exerting thrust of 10 to 11 KN on the drill bit.

Control console
Remote operated ergonomically designed control console is seat mounted to ensure operator’s comfort while operating.

Other relevant details
The machine, being light weight is readily portable in u/g mines. Two persons are required for easy portability of the machine. The current range of such machines is composed of advanced composite materials and high-tech plastic to provide an adequately good performance to weight ratio. The application of one such machine in Frickley Colliery (U.K.) was on trial and it performed more consistently and better than its hydraulic counterpart. Such bolters have been extensively used under Australian Geo-mining conditions also.

The tungsten drill bit gives a penetration rate varying from 1 m/min to 1.5 m/min in rock of compressive strengths up to 130 MPa.

Table 1 gives salient technical specifications of one such machine being manufactured by CRAM, Australia.

**Portable hydraulically powered machine**

This type of roof bolting machine is basically a hydraulically powered rotary drill fitted with double acting telescopic leg, as depicted in Fig. 2. This machine, which is very light in weight, takes its hydraulic power from the power take off points of underground mining equipment like roadheader, Side Discharge Loaders (SDL); Load Haul Dump Machines (LHD); powered supports in longwall faces etc. With such facility of conveniently drawing the hydraulic power from the face equipment, the combined roadway heading and bolting machine concept appears attractive to extensively use these machines in the most confined settings. In the USA a continuous miner mounted with such bolting machine has averaged linear advances of 45 m per shift when used in a modified place changing system. One such satellite bolter (as it is called) F-525 manufactured by the Fairchild, USA, has machine mounted integrated feed and retraction mechanism.
roof bolters that operate independently of the mining function, allowing simultaneous bolting and mining. The Alpine bolter miner, in Australia, also deploys this concept successfully.

In mines where the hydraulic power from the mining equipment is not readily available, a compact hydraulic power pack mounted on a trolley is used for providing hydraulic power to the bolting machine.

The essential sub systems, of this machine, are discussed below:

**Drilling motor**

Drilling motor is a hydraulic motor rigidly fitted to the hydraulic telescopic leg. The operating pressure of the motor lies between 200 to 220 bar. However, peak pressure for a short duration can be up to 350 bar.

**Double acting telescopic leg**

Drill motor along with drill rod is mounted rigidly on to a double acting telescopic leg, which in turn, is fitted with foot/pedestal at its base. This foot/pedestal serves as a support for the entire unit during the operation.

**Control arm**

Control arm does the guiding mechanism for roof bolting operations. It is fitted with hydraulic control valves which control hydraulic drill motor telescopic leg.

**Other relevant details**

This machine can drill holes with diameter ranging between 28 to 45 mm and depth up to 1.5 m. Bolt rods are available in dia from 22 mm to 41 mm. The machine can give good results in rock formations with average compressive strength up to 150 MPa.

The machine, depending on the prevalent site conditions, can be used for dry/wet drilling with air/water flushing mechanism respectively. For wet drilling operations, water injections heads, with robust construction, along with matching adaptors are used.

The chief technical specs., of this type of machine, are furnished in Table 2.

**Wheel mounted, hydraulically powered machines**

Wheel mounted, hydraulically powered roof bolting machine is essentially a hydraulic rotary drilling machine mounted on self-propelled wheel base, which is driven by electrical motor. The main advantage of such machines is that as well as being stable on slopes, the four-wheel motor drive system enables it to tram up grades. This machine is also capable of dry as well as wet drilling operations. Bolting adaptor is fitted at the drill head. The machine is fully flame proof and requires the prior approval, for its electrical systems, from the appropriate mines safety authorities. A general arrangement of one such machine manufactured by Klockener Becorit Company (KBC), is illustrated in Fig. 3.

The main sub-systems, of this machine, are discussed below:

**Drill head**

The drill head comprises a roller vane/radial piston type hydraulic motor coupled to a gear box. Drilling speeds vary from 0 to 450 rpm.

| Table 2—Technical specifications of portable hydraulically powered bolting machine |
|-----------------------------|-----------------------|
| Weight                      | Nearly 50 kg          |
| Working fluid               | HFC or Hydraulic oil  |
| Operating pressure          | 200 bar               |
| Peak operating pressure     | 350 bar               |
| For short duration          |                       |
| Admissible back flow pressure| 10 bar                |
| Motor type                  | Hydraulic motor       |
| Motor capacity              | 16 kW                 |
| Rotation speed              | 100 to 600 rpm        |

![Fig. 3—Wheel mounted hydraulically powered roof bolting machine](image-url)
Tramming drive

Hydro-mechanical tramming drive consists of two hydraulic motors coupled to gear boxes on either sides of the machine (with the sprocket and chain drive mechanism) to drive the machine. The tramming speed varies from 0 to 40 m/min.

Prime mover

A single electrical motor, of substantial capacity (22 kW), drives a double vane pump which provides hydraulic power to the drive motor, drill head motor, tramming motor and hydraulic cylinders (for the temporary/optional roof support during bolting operations).

Other relevant details

As an optional safety feature for safe operation, under weak/friable roof condition, a roof support, which can be raised from the control area by raising the hydraulic cylinders, is provided.

All controls, including the controls for operation of optional supports are grouped together in the front portion of machine. The entire sequence of drilling/bolting operation can be conveniently done by one single person.

The chief technical specs., of this type of machine, are furnished in Table 3.

Crawler mounted, hydraulically powered machine

Crawler mounted roof bolting machine is an all hydraulic rotary drilling unit. This machine, unlike other machine, is equipped with two frames. One for drilling holes for roof bolt and other for setting of roof bolts in drilled holes. Both frames, however, follow the rotary drilling practice and are provided with individual hydraulic motors. The machine, which thus become heavy, has a weight of nearly 4000 kg. Manufacturers are examining the ways to improve the efficiency of the hydraulic drilling, as used in these machines, and also to reduce the hoisting requirements.

Following are the major sub-systems of this machine:

Drill head

The drill head is mounted on a frame which is supported at the front end of machine. To facilitate the operation of hydraulically powered, rotary drilling, the drill head is equipped with hydraulic motor. The frame, which is mounted on its support, is capable of traversing upon the support – 200 mm on either sides (LH or RH side).

Erection column

The erection column, having a hydraulic stroke of 1000 mm, assists in perfect anchoring of the machine between roof and floor.

Setting device

The installation of roof bolts, into already drilled holes, is done separately by means of a setting device. Setting operation is performed by rotary drilling method and, thus, setting device is equipped with a separate hydraulic motor. Both setting and drilling head are mounted on frame positioned at the front end of machine.

Hydraulic powerpack

Hydraulic power pack consisting of electrical motor, coupling, cooler with fan, pumps and hydraulic tank, is arranged in a suitably protected place upon the crawler platform. The use of piston pumps operating through unloading valves is not recommended due to overheating problems.

Under carriage

The crawler mounted under carriage act as support and carrier for roof bolting and setting drill erection columns/frames; hydraulic power pack with control unit and operator’s platform. It is driven by hydraulic motors. Two hydraulic brakes, coupled to travel motors, enable the machine to securely stand even on slopes.

Control and monitoring unit

Control of all hydraulic functions, viz, erection column fixing, roof bolting and setting etc., is done...
Table 4—Technical specifications of crawler mounted hydraulically powered bolting machine

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>Nearly 4000 kg</td>
</tr>
<tr>
<td>Overall length</td>
<td>3500 mm</td>
</tr>
<tr>
<td>Overall width</td>
<td>900 mm</td>
</tr>
<tr>
<td>Overall height</td>
<td>2000 mm</td>
</tr>
<tr>
<td>Operating pressure</td>
<td>200 bar</td>
</tr>
<tr>
<td>Operating fluid</td>
<td>HFC fluid</td>
</tr>
<tr>
<td>Electric motor power</td>
<td>37 kW</td>
</tr>
<tr>
<td>Rotation speed</td>
<td>0 to 800 rpm</td>
</tr>
<tr>
<td>Drill rod/bolt length</td>
<td>2200 mm</td>
</tr>
<tr>
<td>Hydraulic tank capacity</td>
<td>150 L</td>
</tr>
</tbody>
</table>

from a control unit positioned at the rear position of machine. This control unit is equipped with all controls and safety valves. Monitoring of working pressure levels, thrust, rpm and temperature is constantly done. Efforts are on to greatly simplify the various control and control mechanisms in these types of machines. This simplification is imperative in order to avoid the machine to be too complex to be practicable.

Other relevant details

The hydraulic drilling motor, for drilling operations, is fitted with water injection head for water flushing in case wet drilling is necessitated.

The bolting and setting machine are designed for a depth up to 2200 mm.

The chief technical specs. of one such machine, being manufactured by Schmidt Kranz and Company, is given in Table 4.

Conclusions

Currently, a wide variety of roof bolting machines are available in the global markets. However, selection of appropriate bolting machine is largely governed by seam/strata conditions, roadway dimensions and the existing mine facilities (as regard to compressed air and/or hydraulic power availability). Other pertinent factors, such as, flexibility and rapidity of operations, manoeuvrability of machine in most confined areas, noise/dust emission levels generated by the machine operation also play a significant role in deciding upon a particular type of machine.

Portable, pneumatically powered machines are cheap in initial cost as well as maintenance cost. These types of machines find an application in mines where compressed air, as an energy media, is readily available. However, noise/dust emission levels are generally high while using these type of machines.

Hydraulic roof bolters seem to be attractive machine with wide-ranging application possibilities, particularly, in view of immense future dependence of mining industry on hydraulic power as an efficient energy media in underground mines. The versatility of portable hydraulic roof bolters (being capable of drawing power from the hydraulic system of existing machines in underground) make them readily acceptable.

Self-propelled machines (wheeled/crawler), though expensive in initial investment, are capable of giving extremely good bolting speeds if utilized properly. Since they are equipped with their own hydraulic power pack hence the dependence on the external means of supply, for pneumatic/hydraulic power, is obviated. However, with hydraulic roof bolters it must be constantly borne in mind that hydraulic fluid based machines require greater maintenance cost and proper amount of care and attention.

References