ROOF BOLTING AUTOMATION AND INCREASED PRODUCTIVITY

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Safety and productivity have been tied together in the design and development of roof bolters since inception. Roof bolting first began to gain acceptance as a means of roof support around 1950. It was win-win-win technology, which spread rapidly. It lowered the cost of roof support by using four bolts instead of a cross bar timber or rail with timber legs, increased productivity by providing a room without timbers encroaching into the mobile equipment travel ways and increased safety since there were no timbers to handle, set, and reset. J. H. Fletcher & Co.'s new four head semiautomatic roof bolters have the same win-win-win values, but of course for different reasons. It is more productive installing roof bolts, provides for a well protected operator position and can reduce drill but and steel cost with closed loop computer control. The progression in design of past machines helps us to understand the many advantages of this new roof bolter.

The first mechanized bolters were auger drills mounted on existing equipment (we have some customers who still want us to do this). This greatly reduced labor and fatigue from using hand held drills. Next, a dust collection system was developed to improve the operator's environment. The additional dust collection system, the full time need for roof bolters, and the constraints presented by various types of underground mine environment soon led to a mobile machine specifically designed for roof bolting. J. H. Fletcher & Co. developed "through the drill steel" dust collection and even manufactured the hollow drill rods for a period of time since there was not a ready source for this product. This was a much more effective dust control system, which has not changed in principle to this day. Dry vacuum drilling provides for a better operator environment and, by not adding water may prevent the rapid deterioration of some types of roof and floor. Water mixed with drill cuttings also creates an abrasive slurry, which accelerates the wear of machine components.

By 1960 though, the drill rod dust collecting had been adopted by all manufacturers and the new focus was on rapid repositioning of the drill unit to reduce the non-drilling time spent in the place. Drills where the mast could slide from one bolt position to another, such as this model DB and drills with two sliding heads like the DDJ, which could bolt a complete row without repositioning the chasses, were developed. The dual drill concept became popular quickly in mines required to have two operators on a machine due to their labor contract. The Model DM and DDM machines took drill repositioning to the extreme. With up to nine feet of boom extend, the dual drill DDM could bolt a 20-foot cut from only two chassis positions. Even a four drill version of the laterally sliding "hydro-slide" machine and four drill units combining two drills on extending booms and two on lateral slides were produced by the mid 60's. The four-drill unit concept was not pursued at the time due to the exposed position of the drill operators between the machine and the face and the close proximity of operators to the powerful drilling mechanisms.

Injury from falling rock had been the leading cause of accidents in United States coal mines for decades and these injuries were particularly common to roof bolters due to the definition of their task. The late 60's and early 70's saw the development of integral roof support and overhead protection on roof bolters. Hydraulic cylinders, which went to the roof adjacent to the operator "safety post", were installed and plates "canopies" were added to help shield the operator from smaller pieces. Temporary roof support "TRS" systems were added to the machine inby the drills to prevent larger roof falls from initiating near or riding into the operator's area. In 1973, federal regulations required overhead canopy protection. This was phased in over several years from high to low mining heights. The safety advantages of canopies almost always outweigh any disadvantage the canopy may have. Today, Fletcher will not build or ship any standard roof bolters without this operator safeguard. Similarly, the remote controlled temporary roof support system mounted to the inby end of the drill and controlled from under permanently supported roof eliminates the roof bolter operator's need to work or travel inby supported roof. West Virginia first enacted remote controlled or "automated" TRS regulations followed by other states and federal requirements. The enhancements of TRS systems and canopies have been continuous since inception but these alone are not always enough.

Due to potential brow and rib falls, particularly in higher mines, efforts concentrated on positioning the operator to reduce exposure. The drill mechanism and boom can offer protection when the operator is positioned on opposite side of these components from the adjacent rib. Versions of almost every model dual boom bolters were developed with drilling controls between the booms. High seams present the problem of providing a means for the operator to safely drill and install roof support without standing on the floor. The model HDDR with its lifting man platform, inside controls, TRS and canopies helped to keep the operator in as safe a position as possible, by putting the man in a basket on the boom, these machines were as safe as remotely controlled drills, but with higher availability and more versatility. In 1983, a customer having severe rib roll problems requested J. H. Fletcher & Co. to develop a roof bolter which would provide passage from the rear (outby end) to the operator's station on the inside. The purpose was to avoid risk of traveling between the side of the machine and the rib. This "walk-thru" concept rapidly gained acceptance and has been designed into all higher seam dual boom machines, the most familiar being the Model HDDR. The latest version of this drill offers a wider walkway and rear ramp to facilitate loading materials, ergonomically designed operators platform, and safety devices like 2-hand fast feed and hydraulic disconnect control.

Machines with lifting platforms were also developed for high seam applications particularly in the salt and limestone industries but they too, like the early coal bolters, had to be repositioned for each bolt installation or pair of bolts for dual drill machines. Some non-coal mines with long distances between working faces wanted the productivity gains that a drill with a swinging and extending boom offers on a higher speed chassis. In these conditions, roof support material flexibility was not as necessary, so a remote controlled drill was the logical answer. However, this did require the development of a dependable resin inserter. The first ARRD was developed in 1988 to answer this need. A roof referenced drill system to maintain the resin and bolt systems in position relative to the drilled hole was developed. This stabilized the bolter's position relative to the drilled hole for resin and bolt insertion. With the success of the ARRD bolter, it was recognized that the dual boom HDDR could be fitted with remote control drills capable of installing resin bolts and one man could feasibility bolt a place faster than using a conventional HDDR without being in close proximity of the drill and bolt mechanism. A joint development contract to pursue this concept was undertaken between J. H. Fletcher & Co. and Marrowbone Development Co., then owned by Shell Corporation. Due to having one operator controlling more than one drill unit, PLC was employed to automate several of the functions. This machine was built and tested in 1989 but never made it to a production section before the contract ended. Several valuable lessons were learned from the ARRD and this drill regarding remote control automation.

We decided that there was tremendous potential for computer controlled drilling on the "Marrowbone" drill and we needed to do more development in this area. The auto bolter module was designed in 1992 to create a computer controlled drilling and bolting unit that could be fitted to different machine platforms depending on the mine type and conditions. The module was tested at A. T. Massey's Martin County Coal Mine in Kentucky and FMC's Trona Mine in Wyoming. Foreseeable uses included not only the HDDR platform like the Marrowbone drill for place changing, but also on miners, surge cars, continuous haulage, and on the diesel articulated chassis for non-coal applications. The auto bolter module demonstrated the feasibility of such a unit and provided exciting drill performance. The module would drill in fairly hard sandstone at rates as high as 17' per minute without breaking 7/8" diameter drill steels or burning up drill bits. In fact, drill bit life was improved over conventional operator controlled HDDR roof bolters. This brings us to our four head semiautomatic computer controlled bolter now undergoing testing underground.

The new machine's basic concept was first outlined in February 1997. It had to be safer and more productive than the current Model HDDR. No configuration of two drill units could provide the productivity required, therefore, it became necessary to figure out how to run four drills in parallel preferably with only one or two operators. We knew we could not use conventional drill systems with control position detents since these have proven to be so dangerous that all roof bolter manufacturer's voluntarily agreed to stop using detent controls in the late 1970's. All detent drilling controls were recalled in 1985. We turned to the automated unit as a way to drill the hole without the operator handling the drill rod. We positioned the controls to keep the operator close enough to the drills so as to give him good visibility to locate the drill units yet far enough away to be beyond incidental contact. With the automated drill system on board we next considered the question of installing the roof support hardware. The ARR-D had carousel and rack systems for carrying the hardware but these took more time to load than the bolter operators have available in highly productive mining systems. The automated drill provided time for the operator while it was drilling unattended. This time was sufficient for an operator to prepare bolts and resin for two holes or more depending upon drilling conditions. Therefore, the machine is designed to have a storage device for each drill, which will hold a drill rod, a resin cartridge, and a bolt. In operation the drill rod is handled totally by the machine and the operator loads a resin cartridge and bolt for each unit while they are drilling, optimizing the use of the operator's time and improving the productivity potential of the machine.

With increased safety and productivity without sacrificing availability as the four head project goals, we set off to develop reliable systems and hardware. The lessons learned from the ARRD, the Marrowbone project, as well as the remote drill module project, were applied to the newly designed four head bolter.

Recent innovations on production machines also greatly shaped the four head bolter. The machine uses a center walk way and a powered rear ramp. These features provide the same safety and convenience as found on a HDDR. The machine has bolt on crawler assemblies similar to those on production machines. The ATRS resembles the production "T" style ATRS. The hydraulic system uses variable volume piston pumps similar to those found on the Mobile Roof Supports.

The four had bolter uses modular construction allowing easier replacement of machine components. The drill rigs are constructed from sub-assemblies that bolt together. The roof reference drill mast has a machined pad that accepts the mount for a manipulator arm assembly and a material carousel. In the event that these assemblies are damaged, they can be replaced with available replacement assemblies. Individual parts in the assemblies can also be replaced on a part basis.

The machine uses the manipulator arm assembly to position and control the drill steel, the resin delivery system, and the bolt. The manipulator arm assembly is made up of an upper and lower centralizer. The upper centralizer acts as a guide while the lower centralizer acts as both a guide and clamp. The manipulator arms move the drill steel, resin delivery system and bolt from the material carousel. The manipulator arms also return the drill steel and resin delivery system to the material carousel. In this way, the drilling materials can be clamped to allow accurate positioning and then guided to provide improved control. This is accomplished with the operator never touching any drilling material while it is in the drill motor. The hardware used in these assemblies is proving to be reliable but will certainly continue to evolve.

The machine has a total of 180 HP. Two dual piston pumps provide the hydraulic power; each set driven with 75 HP. Horsepower consumption is a concern during only part of the bolting cycle and potentially during severe tramming situations. To eliminate these concerns, the pumps are also fitted with a load sense and horsepower limiting control. The four vacuum blowers are powered by two 15 HP electric motors. Each 3600 RPM dual shaft motor accepts two direct coupled blowers. The blower motors are individually controlled and only operate during drilling. The blower on demand reduces the operator's exposure to noise and lowers the overall machine horsepower draw.

To this point, the discussion has targeted physical hardware and touched on some of the operator's environment features. The next step is to consider the operation of the machine. The four drill rigs are run by two operators. Each operator has the responsibility of loading the material carousels on that side of the machine. Material loading takes place as the hole is being drilled. Since all four holes are being drilled at once and material handling is in process during drilling, it becomes obvious there is potential to reduce the time required to bolt a place.

Additionally, the resin delivery and bolt up cycles may be running concurrently further increasing productivity.

Bolting consistency is also addressed. The machine will repeat the same feed rate, spin or mix time, and hold or thrust time on each bolt in accordance with the resin manufacturers guidelines.

The machine is obviously not controlled by the traditional feed, rotation, and fast feed manual valves. The operator has a control station with toggle switches, rocker switches and selector switches. A given switch may initiate various solenoids in accordance to the program loaded into the PLC. Various sensors feed information back to the PLC, which controls the outputs to the solenoid valves. These are not detented controls but are controls sensitive to feed forces, feed rates, drill torque, drill RPM, drill position and vacuum conditions. Monitoring and reacting to various parameters, having two centralizers per drill motor, and using the material carousel as a physical barrier shielding the operator from the drill string allows the operators to turn attentions to material handling. The operator needs to initiate the three parts of the bolting cycle. A toggle switch with an enable switch is activated to initiate drilling, or resin insertion, or bolt insertion.

To date, some worthy benchmarks have been reached. The machine has drilled, and bolted holes in under two minute cycles. This includes a drill time of less than 30 seconds for a five-foot hole and a 15 second hold time for the resin. The machine does install each bolt the same providing improved consistency. The solenoid test function and on board diagnostics have proven themselves. The bit life looks good but shows more potential for improvement.

What's next? Each of these items, as well as the entire machine, will continue to evolve in accordance with the coal industry. The shape and structure of the machine will change in various ways to adapt it to varying mining conditions.