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Development and implementation of spin to stall resin at Anglo Americans Australian underground coal operations

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ABSTRACT

Longwall mining is by far the most common method of underground coal extraction in Australia. The industry trends and expectations are placing increasing emphasis on the reliability and productivity of these operations. The longwalls are becoming wider and longer while retreat rates are continuously increasing due to significant improvements achieved in longwall equipment reliability and automation. This increased longwall productivity is placing significant emphasis on the reliability of longwall panel development. Although there have been significant improvements in the reliability of continuous miners and hydraulic drill rigs, the traditional resin encapsulated bolt installation is still the principal method used in all major coal-producing countries around the world. Anglo American realised an opportunity existed to introduce an alternative roof bolt installation technique called "spin to stall" in Australia. Spin to stall was first introduced in Anglo American Coal in South Africa where it has been successfully used for over a decade, though implementation of South African spin to stall resin in Australia has proven to be near impossible due to a significant difference in geotechnical conditions, mining method, and, subsequently, roof bolting equipment. Therefore, a new spin to stall development project was initiated between Anglo American Coal and Jennmar Australia (SPIN2STALL®). This paper summarises the journey of this project, the results, and the successful implementation of spin to stall achieved at Grasstree Mine.

1. Introduction

The Anglo American Coal business unit operates Grasstree and Moranbah North underground longwall mines in the Bowen Basin of Central Queensland, with a third longwall mine, Grosvenor, currently being developed, and two more (Aquila and Moranbah South) in the project pipeline. The vision for Anglo American is to achieve "zero harm" through the effective management of safety at all operations, while for the coal business unit, at the same time to achieve industry-leading operational performance. Currently, both Grasstree and Moranbah North longwalls are operating at industry best practice rates. This is placing increased pressure on the development process to allow such high productivity levels to be sustainable.

In order for the development process to be more efficient, continuous miners must operate for longer and or cut at an increased rate. The rock bolting process is a key constraintto increasing development cutting rates, particularly at the beginning of a pillar cycle. It was recognised at Anglo American that extended hold times, while appearing insignificant individually, can result in considerable productivity delays when accumulated over a panel. In addition, conventional resin and rock bolting processes were recognised as being susceptible to human error during the installation process. Among other shortcomings, failure to adhere to correct Spin And Hold (SAH) times can potentially damage the resin bond and, hence, load transfer capacity of the system; this process is completely reliant on the operator. Hold times, to allow the resin to set, are also known to fluctuate seasonally with temperature. Therefore, in an attempt to decrease the bolting constraints in the development process and, at the same time increase bolt installation consistency, in late 2010, Anglo American approached Jennmar and J-Lok Australia with a view to develop a "Spin To Stall" (STS) resin bolting system suitable for Australian ground conditions, mining methods, and equipment.

2. Rock bolting

Over the past 40 years, rockbolting has progressed to become, without exception, the primary form of strata reinforcement in

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both Australian hard rock and soft rock underground mines [1]. The type of rockbolting system applied is relevant to the associated "scale of instability" as shown below: surface instability: 0–3 m long elements, roof bolts; near surface instability: 3–15 m long elements, cable bolts; and deep seated instability: 10–30 m long elements, ground anchors [2].

For surface stability in Australian underground coal mines, the "resin and roof bolt" system is the most common form of primary support, although, increasingly, this is being supplemented with cable bolts or other means of high-capacity support. The roof bolts are installed almost exclusively from a continuous miner with in-place bolting rigs.

With reference to the component of internal fixture, the reinforcement system has been catalogued into three fundamental types: Continuous Mechanically Coupled (CMC) systems, Continuous Frictionally Coupled (CFC) systems and Discreetly Mechanical or Frictionally Coupled (DMFC) system [2,3]. According to this classification system, cement and resin grouted bolts belong to the CMC system [3].

2.1. Conventional roof bolt installation

The use of capsules for resin anchoring roof bolts was first developed in France during the 1960s [4]. Initially, the resin was used to point anchor the bolt, with the nut tightened up and subsequent pre-tension applied. Over the past 20 years, installation has moved towards encapsulating the bolt as much as possible, utilising a dual speed (i.e. fast and slow), and single cartridge resin to apply pre-tension on roof bolts. Conventional installation is carried out using the "spin and hold" technique, where the fast setting part of the resin is located at the top of the hole and the slow setting part at the bottom in the hole, and bolt is spun through the resin capsule at maximum rotation speed using a constant feed rate until the bolt reaches the top of the hole. This process usually takes about 12 s with an additional 2–4 s spin at the top of the hole to ensure the top part of the resin capsule is effectively mixed. The spinning is then stopped, and the operator waits for the faster setting section of the resin capsule to cure before tightening the nut and placing the bolt in tension. This waiting time is referred to as the "hold time". Internal studies conducted over two years between Jennmar and Anglo American have found that with a recommended range of 10–60 s, actual hold times range between 5 and 45 s, with an average of approximately 18 s.

2.2. Spin to stall roof bolt installation

The spin to stallresin bolting system was first developed at Goedehoop Colliery in South Africa in the late 1990s and has been widely used for over a decade at Anglo American Coal operations. The STS system involves the same process of first installing a bolt by spinning it through the dual speed resin to the top of the hole; however, spinning then continues into the resin gel phase with no hold time (Fig. 1). Spinning into the gel phase increases the resistance acting on the bolt, resulting in breakout of the shear pin. The nut then runs up the thread and is tensioned against the plate until the rig stalls. To be successful, the setting process for STS resin has to occur in a much quicker overall time than for conventional spin and hold methods.

Spin and hold systems do not advocate spinning into the gel phase of the fast setting section of the capsule as the gelling resin bond could be permanently damaged. However, this effect is minimised in STS resin by using a rapid curing resin with careful selection of filler size grading, closely matched to a precisely engineered bolt breakout mechanism and drill rig operational parameters. Despite the widespread use of STS in South African collieries, it was not possible to simply have a direct transfer of the technology to Australia due to a significant difference in geotechnical conditions, mining method, and, subsequently, roof bolting equipment.

The main benefits of the STS system can be summarised as follows: elimination/reduction of hold time and, therefore, faster installation; increased installation consistency and minimisation of possible human error; the system is largely self-auditing (i.e., the installation quality can be visually assessed); and increased consistency of roof bolter operation and maintenance.

3. Resin development

In order to develop an STS resin suitable for Australian conditions, a Jennmar project team conducted a field trip in South Africa, incorporating underground visits. During these visits, it was noted that the STS system was a complex and demanding relationship between the correct resin properties (catalyst type, catalyst concentration, filler grade, and viscosity), bolt properties (profile, breakout nut) and drill rig properties (rotation, thrust, and torque). This work culminated in a suite of test STS resins being developed at the J-Lok laboratory in Sydney, with the first installation trial conducted at Grasstree mine in October 2011.

3.1. Initial trials

During the initial investigation, a number of resin and bolt combinations were experimented with including the following: oil-based vs. water-based catalyst, 50:50 vs. 60:40 fast/slow mixtures, resin speeds, and breakout pins. It was deemed preferable that an oil-based system could be developed because this was the industry standard resin. In addition, it was shown in laboratory tests that oil-based systems produced a higher strength and faster cure-time resin. Installation was performed on Quick Detachment System (QDS) hydraulic bolters, air over hydraulic "air-track" bolters, and continuous miners with in-place hydraulic bolting rigs. Drill rig parameters were not set to specific values. Torque was measured with both an inline torque meter from the chuck and a torque wrench on the nut of installed bolts. Rotation was measured with hand-held tachometers on a spindle installed in the chuck. Thrust was estimated using a load cell installed between a dowel and the roof. It should be noted that, during this phase, all installations were conducted as additional support in outbye areas of the mine.

3.2. Key findings

Installations using an "airtrack" bolting rig were unsuccessful due to lack of air pressure in that area of the mine. The QDS bolter was powerful enough to install the bolts, and testing progressed with this machine. Three separate types of resin speeds, Type A, Type B, and Type C, were trialled. Holes were drilled using 27 mm diameter modified spade tungsten carbide drill bits. Bolts utilised were 1800 mm long J-profile HSAC 840 "X-grade" steel with nominal diameter of 21.7 mm, "rib to rib" diameter of 23.5 mm, and nut breakout of 120–175 Nm. It was found that both Type A and Type B resins could not reach the back of the hole before breaking the nut out, leaving 300–500 mm long tails. Remaining testing was conducted using Type Cresin for oil-and water-based catalyst.

For the water-based resin, two of four installations successfully spun to stall, with the remainder not reaching the back of the hole. Four consecutive installations were successful using oil-based Type C resin; however, high levels of back pressure were noted during installation. Torque on the nut was measured at 200–350 Nm for these successful installations. Pull testing was then conducted on Type C resin.