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Application of Vibration in Longwall Top Coal Caving Method

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Abstract

Coal is an alternative replacement for oil that has an exhausted prospective to produce energy. The Most of coal seams were located in high depth below surface that leads to use underground mining methods. About half of all coal seams are thick seams that should be exploited by longwall top coal caving method. In order to have a good condition in this method, coal seam should have weak or near weak strength. On the other hand, this strength condition always is not available so that coal seam was break to large blocks and creates a stable arch. To exceed to this situation, a vibration system that located on the top of shield was invented. This system can produce a vibration with low frequency and high power that causes a reduction in cohesion and friction angle, and hence the stable arch was simply fall down. Coal recovery is increased and dilution is decreased. Some studies reported that coal recovery was increased about 5 percent after using vibration. In addition, this system can reduce risks of air blast and rock burst, significantly

Keywords: coal seams, longwall, top coal caving, vibration system, recovery

Introduction:

Energy resources play a significant role in national economy and GDP and can classify countries by that. According to population growth in the world and industrialization of the world, more and more energy resources are needed (Lotfi Azad et al., 2012). Based on growth of energy consumption in recent century, coal usage is significantly increased. Predictions show that in 2030, the annually production and consumption of coal will reach to 8.6 Mt that is twice of values in 2000 (Afzal et al., 2012).

Coal commonly is formed in layer formations. These layers are extended in surface and/or below surface and have different thicknesses less than one meter to greater than four meters. For these reasons, different methods are used for exploiting coal seams. Coal thickness is an important parameter in underground mining method selection. A coal seam with 4 m thickness as more common and current underground methods like longwall, room and pillar are appropriately used (Kumar et al., 2015).

About half of coal deposits are thick seams (greater than 6 m) that lead to use a combination of current underground mining methods (Yastili and Unver, 2005). There are three methods that suggested for high thickness seams including Single Pass Longwall (SPL), Multi-Slice Longwall (MSL) and Longwall Top Coal Caving (LTCC) (Hebblewhite and Cai, 2004, Ozfirat et al., 2005). SLP is used in coal seams with 4-5 m thickness. This method contains some limitations including equipment size, weight and stability, coal seam characteristics and face conditions. The MSL method was operated sequentially, in the top half of the seam and then immediately below in the bottom half by using artificial roof/floor between cuts (Hebblewhite and Cai, 2004).

Longwall Top Coal Caving Method:

LTCC is performed for thick coal seams that relatively a new method and is a combination of longwall and sublevel caving (SLC) methods. According to Fig.1, bottom part of seam exploited by longwall at first, then the top part of seam was failed under gravity forces and caved. After that, caved coals are recovered by an AFC in behind of shield (Basarir et al., 2015, Hebblewhite, 2005, Sismir and Ozfirat, 2008, Xie and Zhao, 2009a).

Thickness greater than 4.5 m, moderate strength coal and depth greater than 150 m below surface are ideal conditions for LTCC operation (Khanal et al., 2014). Note that, coal production in thick seams by LTCC is simpler rather than cutting methods and fewer developments are required (Yasitli and Unver 2005).

LTCC was firstly operated on 1940 in Russia and then was used in France, former Yugoslavia, Hungry, Romania, former Czechoslovakia and Turkey in order to exploit coal from thick seams. Also, LTCC was used in P.R.C and India after 1982 (Wang et al., 2015, Yasitli and Unver 2005). This method was extensively used in P.R.C for coal seams. After 1982, because of advantage of LTCC such as high production, low cost and high performance, comprehensive studies were done in this field (He and Wu, 2004, Hebblewhite, 2005, Xie and Zhao, 2004, 2009a, 2009b). Compared to conventional longwall mining method, LTCC has an additional rear conveyor belt attached behind the chock/support, on which

the caved coal from the top coal is drawn by a moveable flipper attached to the canopy at the rear of the support (Khanal et al., 2014).

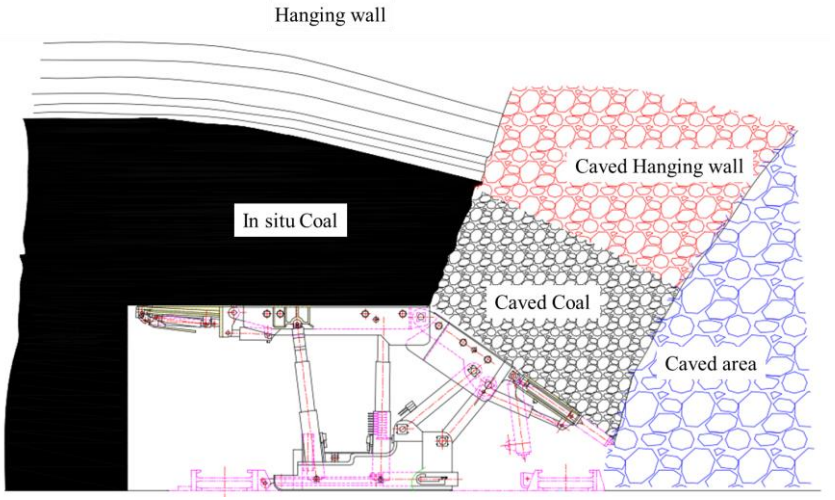


Figure 1: a perspective of LTCC method (Xie and Zhao, 2009a)

Although LTCC has several advantages like high production and low cost, there are some technical limitations such as coal seam strength, thickness and dip angle for LTCC applications. For instance, if coal seam has high strength, LTCC is not applicable and decrease the strength of seam by artificial methods is significantly important (Xie et al., 1999). In addition, LTCC can impose some important problems in coal flow, timing and rate of drawing, loss of coal in goaf and dilution (Yasitli and Unver, 2005).

LTCC Problems and difficulties

There are numerous intrinsic and non-intrinsic parameters which govern the feasibility of LTCC in any mine, which should be evaluated suitably. The intrinsic parameters are thickness of the coal seam, coal strength and deformation properties, inclination of the coal seam, roof sandstone strength and deformation properties and coal geology. The non-intrinsic parameters exist equipment support for the normal longwall extraction, life of the mine, financial health of the mine and a detailed geological study of the mine (Khanal et al., 2014). In addition to these parameters, coal seam cavability and fragmentation and horizontal stresses can have significant influences on LTCC safety and effective application (Hebblewhite and Cai, 2004).

High strength of coal seam is the major problem in LTCC applications. As noted, coal seam should have middle to weak strength and with increasing the coal seam strength. Coal cannot cave naturally and lead to dangerous conditions and rock burst and air blast or coal break in large blocks and formed stable arch.

To exceed current problems, three approaches including Pre-blasting, Hydraulic Fracturing and vibration were suggested. For example, in Omerler underground mine in Turkey, 1.5 m of coal was properly caved but after that, caving process face with problems. Based on numerical modeling by FLAC3D Itasca, a pre-blasting in 3.5 m of coal seam was suggested to obtain a suitable coal flow (Unver and Yasitli, 2006, Yasitli and Unver, 2005). In other studies, a pre-blasting was required, to improving and increasing of coal recovery in Xinzhouyao Coal Mine located in north China (Xie et al., 1999).

Hydraulic fracturing is another way to exceed the noted problems. Application and performance of this method was evaluated in Liuxiang coal mine. In this study, a linear multi-hole control of hydraulic fracturing with 20 MPa pressure was applied. By this method, a normal and safe production was prepared (Huang et al., 2015).

Vibration System

Although coal loss in LTCC is unavoidable, coal recovery is a noticeable issue in LTCC. Therefore, coal flow control and recovery improvement are key problems in this method. Unfortunately, there are some shortcomings that lead to recovery reduction and dilution increasing.

Using vibration technology in LTCC was recommended to solve some technical problems like large blocks locking (Xie et al., 2006). If caved coal with large blocks (particles about 30 percent of drowpoint) formed a stable arch, vibration is useful and can decrease arch stability and improve coal flow. For this aim, some tools are required to produce vibration. Fig. 2 presents a schematic diagram of these requirements.

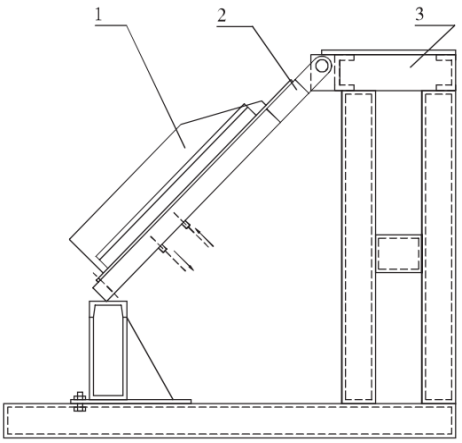


Figure 2: schematic diagram for the LTCC with vibration system: 1- vibration device, 2- yield beam, 3- support (Xie and Zhao, 2004, 2009a)

Vibration tools were installed on top of support system then can perform high magnitude and low frequency vibrations along yield beam. The vibration system commonly contains cylinder, shield beam, rocker and vibration plate which presented in Fig. 3 as followed.

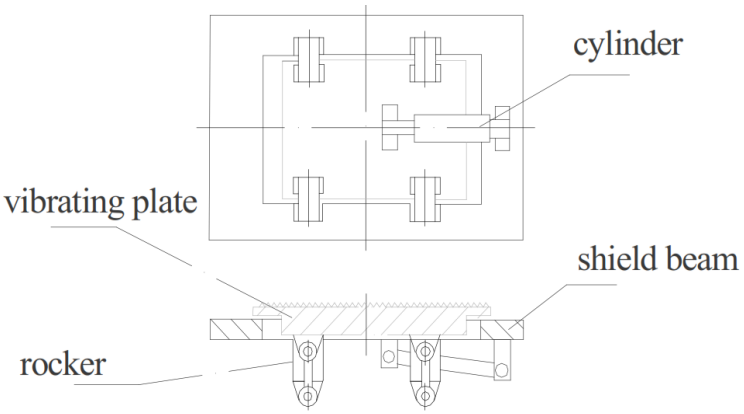


Figure 3: Vibration system components (Jian et al., 2012)

Vibration controller system was showed in Fig. 4. When controller system was starting, the required power provided by emulsion pump station for all vibration system, then generator produce pulse and accordingly, piston was moved up to down, repeatedly. Then, rocker mutually moved and finally, vibration plate was vibrated (Jian et al., 2012). A kind of installed vibration system installed on shield was showed in Fig. 5.

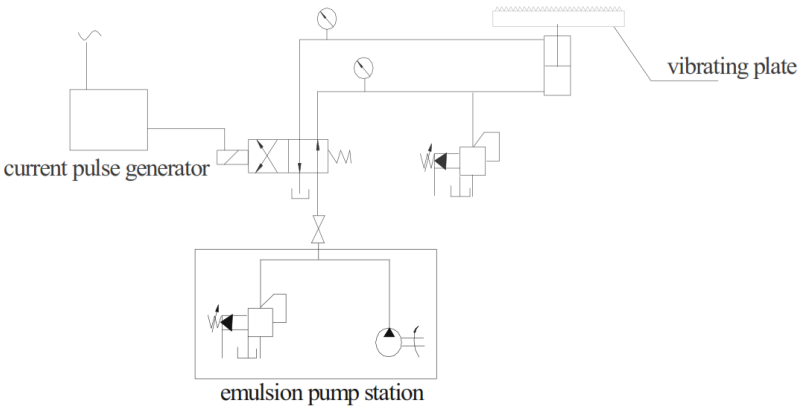


Figure 4: Fundamental of vibration system operation (Jian et al., 2012)



Figure 5: an example of installed vibration system on shield (Xie et al., 2006)

Vibration Theory

In order to investigate vibration waves and how influencing on LTCC, a study was done by using granular materials and effect of P, SH and SV waves are assessed (Jian et al., 2012). Results shows that P and SH waves are extended in elliptical shapes. Vibration waves have low effect on granular material flow if have low magnitude and frequency.

Anyway, by increasing wave's magnitude and frequency, some properties such as cohesion strength, internal friction angle and shear between granular are reduced. Also, weakness coefficient of granular is increased and material flow is improved. Therefore, a low frequency and high magnitude vibrator is useful to install on shield. These waves can decrease cohesion strength and internal friction angle coal and increase shear strength of top coal blocks and horizontal movement will be increased and vertical movement will be decreased (Jian et al., 2012). An optimum value of one hertz was obtained after a laboratory study about vibration frequency in China (Yangsheng et al., 2008).

Vibration system advantages

The operational and technical problems in LTCC were explored in this study. Interlocked and stable arch are the most important problems that ignored by vibration system. The studies show that core recovery improvement and dilution reduction are evented after vibration application. As coal loss is unavoidable in LTCC, controlling of coal loss and recovery play key roles in this method (Xie and Zhao, 2004). Coal recovery is dependent to top coal failure mechanism and size distribution (Khanal et al., 2014) and recovery can improve in low strength that is suitable condition and vice versa (Xie and Zhao, 2004).

The numerical simulation results illustrated that the top coal could be caved layer by layer, with the effect of vertical weighty and horizontal vibration forces working together. Consequently, the waste stone ratio in mined coal was decreased and the recovery ratio of top coal was increased (Yangsheng et al., 2008). Altogether, results of a comparison between LTCC with and without vibration explained that vibration can easily destroy stable arch and coal caving is a uniform process. For instance, in Wang Zhuang Mine, coal recovery was improved as 4.62 % by using vibration (Jian et al., 2012).

Conclusion:

LTCC is the most important reason in coal high productivity in recent years. LTCC is a suitable method in order to exploit high thick coal seams. Coal strength should be middle and low if a successful application of LTCC is needed but sometimes these conditions are unavailable. High strength of coal seams will be resulted in stability of coal seam or large blocks and form a stable arch. This arch can increase dangerous potential and decrease coal recovery. Application of vibration systems is a suitable way to exceed those problems and has a good potential for development. The systematic investigation of vibration systems presents that LTCC with vibration is an advantageous method in order to enhance coal recovery and reduce dilution, although it can reduce the rock burst and air blast potential.

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