International Journal of Rock Mechanics & Mining Sciences 70 (2014) 192–200

Contents lists available at ScienceDirect

International Journal of Rock Mechanics & Mining Sciences

journal homepage: www.elsevier.com/locate/ijrmms

Investigation and analysis of the rock burst mechanism induced within fault–pillars

Zhenlei Li [a,b], Linming Dou [a,b,*], Wu Cai [a,b], Guifeng Wang [a], Jiang He [b], Siyuan Gong [a], Yanlu Ding [a,b]

[a] State Key Laboratory of Coal Resources and Safe Mining, China University of Mining and Technology, Xuzhou 221116, China
[b] School of Mines, China University of Mining and Technology, Xuzhou 221116, China

ARTICLE INFO

Article history:
Received 6 July 2013
Received in revised form
1 February 2014
Accepted 17 March 2014
Available online 29 May 2014

Keywords:
Rock burst
Fault–pillar
Strata movement
Roof rotation
Pillar stress

ABSTRACT

An investigation is made of the characteristic strata movement and mechanism underlying fault–pillar induced rock bursts (FPIRBs) in order to mitigate rock burst damage in fault areas. A mechanical analysis of the fault–pillar model is established and roof rotation criteria is obtained. A formula is derived for the average static stress in the pillar through theoretical analysis, physical simulations, and engineering practice. The results show that when a coalface approaches a fault area, two or more roof strata simultaneously fracture in the fault area, leading to an increase in the dynamic and static stresses in the pillar. The most important factors affecting FPIRB are the static stress in the pillar and the dynamic stress induced by fault slides. The roof block rotates more easily when the pillar width is smaller, the roof thickness larger, and the roof subsidence smaller. The average static stress in the pillar increases with decreasing pillar width and/or increasing roof fracture length. The stress is greater if there is a voussoir beam structure, in which case the stress is directly proportional to the squared length of the fractured roof, and inversely proportional to the squared width of the pillar just before rotation occurs. After rotation, it is directly proportional to the roof fracture length and inversely proportional to the pillar width. Based on the FPIRB mechanism and analysis of the mechanical model, six methods of FPIRB prevention are proposed. Also, we find that FPIRB occurrence can be effectively reduced by the use of de-stress blasting and large diameter drilling.

1. Introduction

Rock bursts are currently one of the severest threats to safe coal mining, especially in China. Their results can be disastrous and can result in tremendous numbers of casualties and socioeconomic loss. For example, a rock burst in the Sunjiawan Coalmine in 2005 caused 214 deaths and left 30 people injured. Six years later, on 3 November 2011, a rock burst due to a fault in the Qianqiu Coalmine caused the death of 10 people and left 75 people trapped underground.

As mining depth is increasing year by year, rock bursts are happening more frequently [1,2]. When mining activities approach high stress zones (like faults, folds, and residual pillar areas, *etc.*), rock bursts or tremors with high energy are more likely to happen [1–7]. As a result, rock bursts around faults and pillar areas and their mechanisms have been studied and analyzed using various methods by scholars around the world [8–16]. However, no unanimous viewpoint has been reached on rock bursts because of their complicated formation mechanism. Furthermore, fault–pillars have rarely been taken into consideration when studying the fault activity mechanisms that induce rock bursts. Consequently, the importance of fault–pillars has been overlooked.

In this paper, the importance of fault–pillars is investigated with regard to rock bursts. A mechanical model of a fault–pillar is established and analyzed to reveal new insights into the in-depth mechanism underlying FPIRBs. Based on the elucidated mechanism and mechanical model analysis, corresponding burst prevention methods are proposed and their validity is confirmed using practical tests.

2. The FPIRB mechanism

2.1. Rock bursts induced by superposition of static and dynamic stresses

A rock burst may occur when the total stress (due to the superposition of the static stress in the coal and the dynamic stress induced by tremors) reaches a certain critical stress level [17]. The stress criterion for rock burst occurrence can be expressed in the form

$$\sigma_j + \sigma_d > [\sigma_b], \quad (1)$$

* Corresponding author at: State Key Laboratory of Coal Resources and Safe Mining, China University of Mining and Technology, Xuzhou, Jiangsu 221116, China. Tel.: +86 13952261972.
E-mail addresses: cumtzhenleili@163.com (Z. Li), lmdou@cumt.edu.cn (L. Dou).

http://dx.doi.org/10.1016/j.ijrmms.2014.03.014
1365-1609/

where σ_j is the static stress in the coal, σ_d is the dynamic stress induced by the tremor, and $[\sigma_b]$ is the critical stress required for rock burst formation. Eq. (1) indicates that the interaction of σ_j and σ_d can lead to a rock burst. Hence, it is possible to control rock bursts by reducing σ_j or σ_d.

2.2. Strata movement characteristics

Fracturing in the overlying strata is in terms of the "O–X" structure and coal mass is subject to abutment stress during coal extraction [18,19]. When the coalface approaches the fault area, the abutment stress increases gradually or suddenly and rock burst accidents can easily occur [4,10].

A physical simulation experiment was performed to compare normal mining and the situation in which the coalface approaches the fault area. The results, shown in Fig. 1, allow the differences in strata movement to be figured out and the reasons for rock bursts to be investigated. Under normal mining conditions, the roof strata fracture occurs one by one, not simultaneously, from bottom to top. Almost none of the fracture surfaces lie in the same straight line. In fact, nearly all the fracture surfaces lie behind the coalface, leaving roof strata hanging behind in the gob area. On the whole, the coal ahead of the coalface is affected by the lead abutment pressure. On the other hand, when the coalface approaches a fault area, two or more roof strata fracture simultaneously in the fault area, leading to a decrease in the stress in the fault area. As a result, the weight of the fractured roof layers is imposed on the fault–pillar. As the pillar sizes decrease, the stress within the pillars rises.

2.3. The rock burst mechanism

The physico-mechanical properties and stress distribution in the coal-rock mass are discontinuous in the fault area [7,10,14]. Thus, when mining activities approach the fault area, fault–pillars are formed [11]. In such cases, pillar failure or fault slides can induce rock bursts. This is the root cause of the FPIRB phenomenon. According to main factors involved, FPIRB can be divided into rock bursts that are fault slide induced, pillar failure induced, and those induced by the interaction between fault slides and pillar failure [corresponding to (a), (b), and (c) in Fig. 2, respectively]. These three cases are discussed separately, as follows:

2.3.1. Fault slide induced rock bursts

When mining activities are far away from the fault area, the influence of the fault on the stress distribution in the coal–rock mass is small. As a result, the stress in the coal–rock mass is the

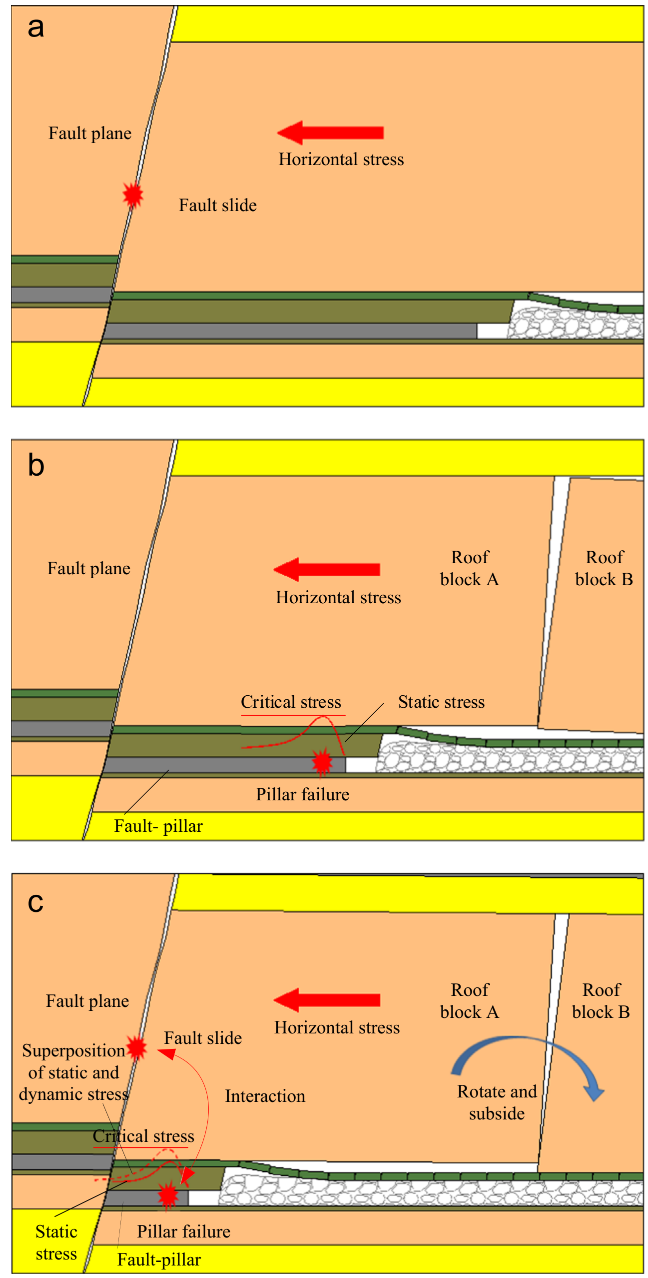

Fig. 2. Sketches showing the mechanism associated with FPIRB.

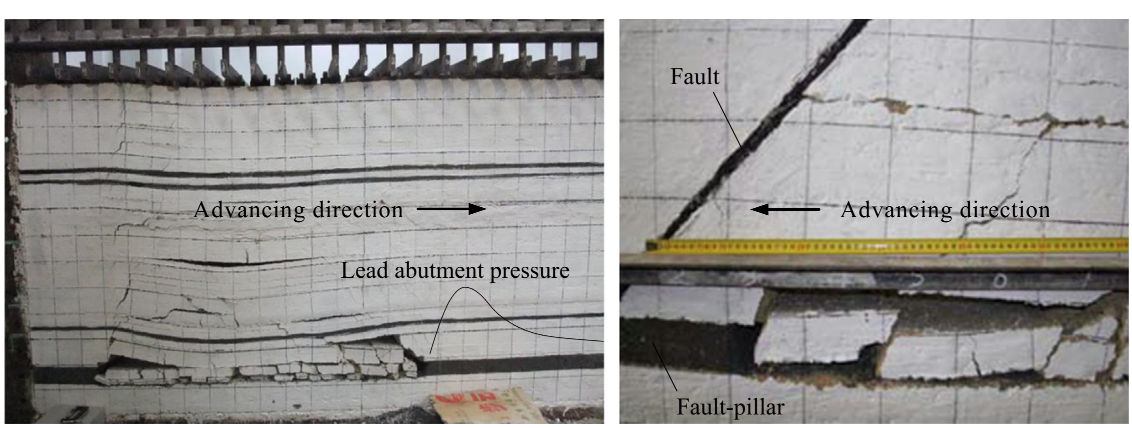

Fig. 1. Strata movement characteristics probed using physical simulation.