International Journal of Rock Mechanics and Mining Sciences 106 (2018) 342–349

Contents lists available at ScienceDirect

International Journal of Rock Mechanics and Mining Sciences

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

Mechanism and risk assessment of overall-instability-induced rockbursts in deep island longwall panels

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ARTICLE INFO

Keywords:
Rockburst
Overall instability
Island longwall panel
Risk assessment
Stress monitoring
Microseismic monitoring
Numerical modeling

ABSTRACT

An increasing number of mines in China are being subjected to overall-instability-induced (OII) rockbursts in extracting deep remnant island longwall panels, causing severe damage at far larger scale and intensity compared with common local rockbursts. Using the island longwall panel LW1305 at Zhaolou Coal Mine as a case example, this paper investigates the mechanism of the newly defined OII rockburst by means of stress and microseismic monitoring, and then proposes a straightforward risk assessment method for OII rockbursts based on the actual bearing index in an attempt to provide guidelines for making engineering judgement. The proposed risk assessment method was successfully applied to LW1305, and the assessment result is supported by the occurrence of an OII rockburst in LW1305, and further verified by numerical modeling and microseismic monitoring.

1. Introduction

With coal resources being continuously extracted for decades, a great number of coal mines in China have entered into deep mining, and as a result, rockbursts have become one of the most dangerous dynamic hazards.[1–6] To date, around 180 rockburst prone mines have been identified with over 50 of them currently mining at a critical depth of over 1000 m.[7,8] Even worse, these mines are being confronted with the challenge of extracting resources from deep remnant island longwall panels, which are subjected to highly concentrated stresses arising from adjacent goafs and large mining depth. Under such a condition, rockbursts can occur frequently and intensively during mining activities.

Currently, the majority of the documented rockburst events have occurred in a local area in gate roads within a limited range around the coal face, e.g., roof rockburst, floor rockburst, and sidewall (rib) rockburst.[9–11] These common local rockbursts, although posing a threat to mining safety, tend to be tractable based on extensive studies undertaken for decades.[9] However, in deep island coal panels, it is observed in recent years that regional rockbursts occurred simultaneously at the coal face and in both gate roads, with a significantly larger intensity and damage area compared to the local rockbursts, as illustrated in Fig. 1. Through extensive site investigations and case studies, we found that the regional rockburst is intuitively induced by the overall instability of the volume (coal and rock) within a certain range around the working face in deep island panels. To distinguish it from the common local rockbursts and to better study its mechanism, this new type of rockbursts is referred to as overall-instability-induced rockburst (OII rockburst) hereafter.

In recent years, a great number of OII rockbursts have occurred in China, causing severe casualties and tremendous economic losses.[8,9,12,13] For example, on May 9, 2015, a violent OII rockburst event occurred when setting up the working face in the island longwall panel 3112 (LW3112) at Chaoyang Coal Mine in Shandong Province. This rockburst injured 8 workers, and destroyed the whole 120 m wide working face and its adjacent gate roads with over 20 hydraulic supports and a coal shearer damaged. Site photographs of this event are shown in Fig. 2. This led to an immediate shut down of this coal panel for months and an overall economic loss of several millions of dollars. LW3112 has a depth and width of 860 m and 120 m, respectively, and the goafs on both sides of it have a width of around 270 m. This is a typical OII rockburst hazard in a deep island longwall panel.

A number of studies have been undertaken in an attempt to acquire insights into rockbursts occurring in island panels. Liu et al.[14] numerically investigated characteristics of the abutment pressure distribution in super-wide island longwall panels using FLAC^{3D}, and concluded that extending the width of island panels can effectively reduce its stress concentration resulting from stress transfer from adjacent

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https://doi.org/10.1016/j.ijrmms.2018.04.031
Received 30 August 2017; Received in revised form 29 January 2018; Accepted 10 April 2018

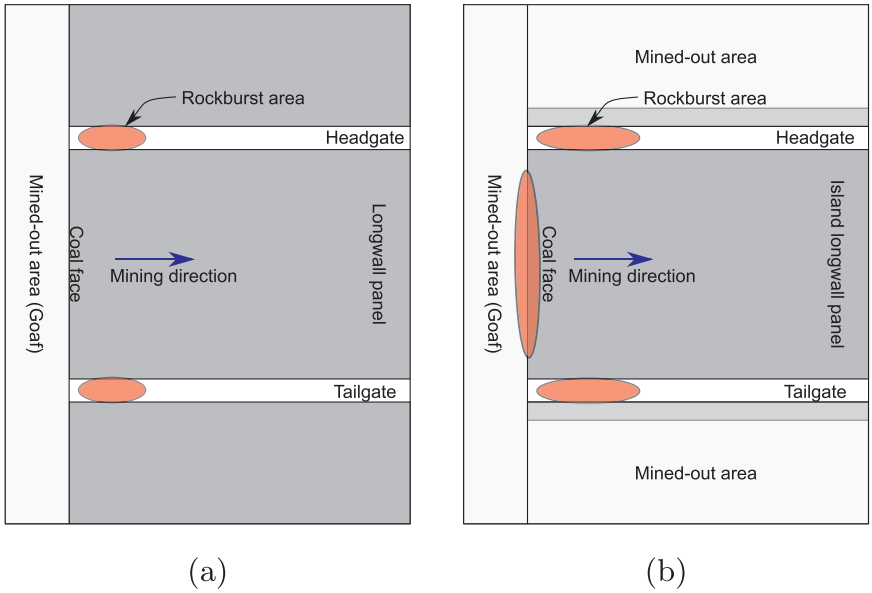

Fig. 1. Schematic of comparison between (a) local rockbursts and (b) OII rockbursts.

Fig. 2. Photographs of an OII rockburst in LW3112 at Chaoyang Coal Mine showing (a) collapsed supports and (b) blocked gate roads.

goafs. Wang et al.[15] employed microseismic and electromagnetic monitoring techniques to explore valid precursors for rockbursts in island panels, and further proposed a multi-parameter early warning method. Jiang et al.[16] and Wang et al.[17,18] simulated the stress distribution in a island longwall panel subjected to periodic weighting through FLAC^{3D}, and they believed that the location of the peak abutment stress shown in modeling results has a high rockburst risk and drilling a dense pattern long boreholes in island longwall panels along gate roads can effectively release abutment stress. Jiang et al.[19] stated that with the mined-out area (goaf) expanding, its overlying strata structure sequentially experiences fully-hanging, partially-hanging (or partially-broken) and fully-broken, and accordingly for an island panel with goafs on both sides, 9 combinations of overlying strata structures can be identified. Feng et al.[20] developed a preliminary theoretical model for estimating stress distribution in island panels for different combinations of overlying strata structures, e.g., an island panel with fully-hanging overlying strata over both sides, and with fully-hanging and fully-broken overlying strata on each side.

However, the above studies are primarily aimed at local rockbursts occurring in gate roads and few researchers have been aware of the necessity of specially investigating OII rockbursts, although in some cases OII rockbursts did occur. In addition, merely numerical investigation for island panels can neither reveal the mechanism of OII rockbursts nor explicitly assess OII rockburst risk. Therefore, a comprehensive study that can provide insights into OII rockbursts is urgently needed.

To this end, this paper first uses a deep island longwall panel LW1305 at Zhaolou Coal Mine as a case example and reveals the mechanism of OII rockbursts by means of stress and microseismic monitoring. Following this, a theoretical model is proposed to estimate stress distribution in island panels based on overlying strata structures. An OII rockburst risk assessment method is then established in an attempt to provide guidelines for making engineering judgement, e.g., whether to mine the island panel of interest or not. Lastly, a FLAC^{3D} simulation and microseismic monitoring are employed to verify the risk assessment result.

2. Case study of an OII rockburst in a deep island panel

2.1. Description of the OII rockburst event

On July 29, 2015, a notorious OII rockburst hazard occurred in the coal face and gate roads in the island longwall panel LW1305 at Zhaolou Coal Mine when the gate roads were just driven for several meters. According to the site investigation, 24 workers were severely injured; 32 hydraulic supports and the coal shearer and conveyor at the coal face were damaged; the whole support system in both gate roads practically collapsed; and some segments of the gate roads were nearly