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Spatial structure evolution of overlying strata and inducing mechanism of rockburst in coal mine

Lin-ming DOU[1], Xue-qiu HE[2], Hu HE[3], Jiang HE[1], Jun FAN[1]

1. State Key Laboratory of Coal Resources and Safe Mining, China University of Mining and Technology, Xuzhou 221116, China;
2. China Academy of Safety Science and Technology, Beijing 100012, China;
3. School of Resource and Earth Science, China University of Mining and Technology, Xuzhou 221116, China

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Abstract: Spatial structure of overlying strata existed and evolved dynamically with the exploitation scope (boundary conditions) changes in coal mines and to induce rockburst. Based on the “key strata” theory, the integrated spatial structure of overlying strata was put forward, which was composed of “O−X” structure in the plane section and “F” structure in the vertical section. The formation and ongoing instability of the “O−X” and “F” structures were called as dynamic evolution cycle of the overlying strata. Three basic categories of “O−X”, “F” and “T” structures were defined, and the strata behaviors of each spatial structure were analyzed. According to energy theory, mechanism of rockburst induced by spatial structure instability was discussed. The research expanded the scope of traditional ground pressure theory and provided a guide for the prevention of rockburst and mining tremors induced by structure instability of overlying strata.

Key words: spatial structure; overlying strata; rockburst; key strata

1 Introduction

With the increase of mining depth and intensity, dynamic disasters have become gradually serious, of which rockburst and mining-induced tremor are the main forms [1−4]. According to the energy theory, the occurrence of rockburst satisfies “superposition principle of static-dynamic loads” [5−7], namely, the dynamic disaster will happen when the superposition of static load in coal measure strata around mining space and the dynamic load generated by mining-induced seismicity exceed the minimum load. Especially, overlying strata damage and movement is one of the main reasons to generate dynamic load [8−10].

The overlying strata will fracture and move as the result of coal seam exploitation, and both static and dynamic load will be applied to the roadways and workfaces in this process, inducing roof and rockburst disasters [11]. Overlying strata movement is not only the result of a single workface, but also the interaction of more faces. Microseismic monitoring results show that the rockburst sources are mainly concentrated in the adjacent gobs especially when thick and hard key strata exist, which indicates that spatial structure of overlying strata exists in the coal mine and can evolve dynamically with the exploitation scope (boundary conditions) changes [12].

In the past, numerous researches have been carried out to investigate the instability of strata structure as well as coal or rock dynamic failure mechanism, and great achievements have been obtained [13−16]. The most important outcomes are the “Voussoir Beam” and “Key strata” theories of roof strata proposed by QIAN et al [17,18], which provide the theoretical basis for studying the formation and instability of overlying strata [17,18]. JIANG et al [19] proposed the concept of spatial structure of overlying strata, and made four categories

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Corresponding author: Hu HE; Tel: +86-13705206814; Fax: +86-516-83995904; E-mail: hehu_cumt@126.com
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(θ, O, S, and C types) based on the boundary conditions of the workface. The excellent jobs have important guiding significance for expanding the scope of traditional underground pressure. But it was found that most the previous studies were confined to limited zones not far from the coal seam, which in the vertical direction were not more than the main roof and in horizontal layer within the scope of abutment pressure. Nevertheless, dynamic disasters such as rock bursts and mining-induced tremors have involved range to the main key strata and were more than mining influencing zones. On the basis of analyzing mining tremors and rockbursts rules during the first "square" of one workface, second "square" of two workfaces and third "square" of three workfaces, the spatial structure evolution of overlying strata was studied based on the key strata theory in this work. The structure and fracture characteristics both on the horizontal and vertical layer of the overburden strata were discussed, as well as the effect to rockburst during the evolution of spatial structure. The research achievements would provide a guide to reveal the mechanism and prevention of rockburst induced by instability of overlying strata structure.

2 "Square effect" of overlaying strata and rockburst phenomenon

The movement height of roof strata in the goaf is controlled by its short side which is generally the workface width. The roof movement height and strength will reach the maximum when the mining distance rises to the workface width, and will not rise with the coal mining advance if the workface is not wide enough. The roof movement will develop to upper strata until the next workface is exploited since the gob width enlarges, the roof activities strengthen gradually and reach the maximum again when the mining distance equals to about the width of two gobs, therefore, roof movement will gradually strengthen with the increase of gob size before it develops to the surface. The phenomenon is called as "square effect" by rockburst experts.

The "square effect" exists in many collieries, for instance, a longwall workface located at 34 mining district, No.3 mining level of a coal mine in China, is 182 m in width and 690 m in length, so far 375 m has been extracted and 315 m is left with fully mechanized coal winning technology. The coal seam is 3.38 m in thickness on average with the dip angle of 28° to 31°. The immediate roof is gray siltstone with the thickness of 5.9 to 15.6 m, the main roof is gray gritstone, 44.9 to 69 m in thickness, and the floor is the off-white fine siltstone of 1.3 to 22 m in thickness. The pillar between the tailentry and the goaf is 2 to 8 m in width.

Two gobs adjacent to the tailentry side of the workface are shown in Fig. 1. A strong tremor with the energy of 1×10^6 J occurs when the workface advances to the first square area. And when the workface advances to the second square area, tremors with energy of 10^4 J and 10^5 J increase. At the third square, the seismicities are concentrated toward to the tailentry and those with energy of exceeding 10^4 J increase significantly, which indicates that the coal/rock failed is aggravated and the energy release is enhanced, followed by several tremors energy larger than 10^5 J. Finally, a strong rockburst disaster occurs. As shown in Fig. 1, high energy mining tremors happen densely at all the three square areas.

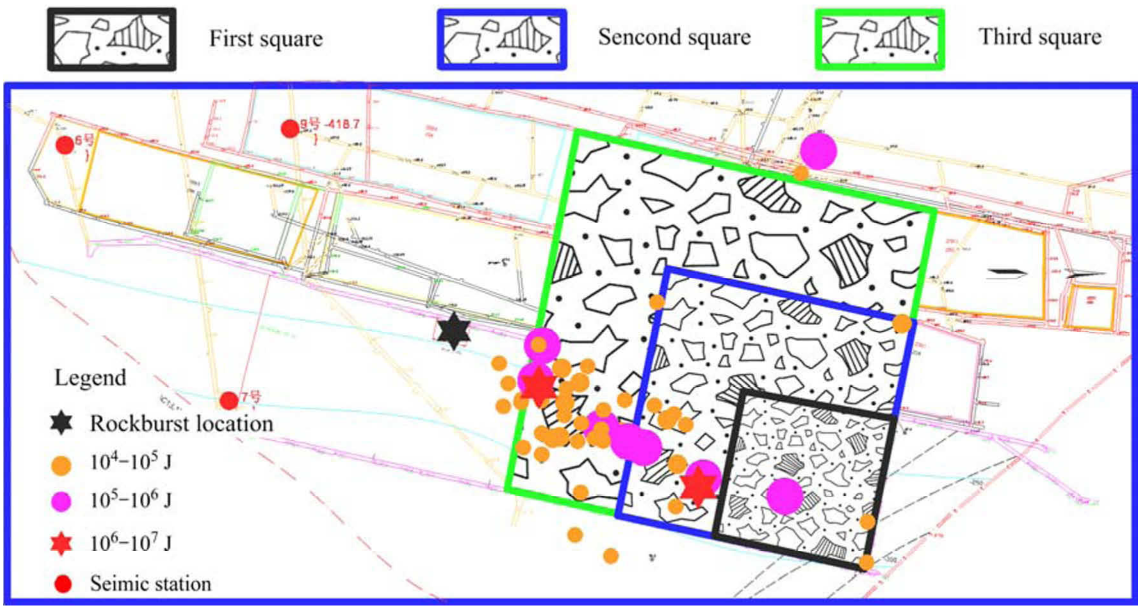

Fig. 1 Relationship between "square effect" of overlying strata and strong mining tremors