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* Influence of Hard Roof on Rock Burst

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Abstract: By theoretical analysis and actual measurement of field and phenomena analysis of rock burst, the author illustrates the directionless pressure, sudden movement and rupture of hard roof lead to the internal cracks of coal instable development, which easily results in rock burst happening.

Key words: rock burst; hard roof; crack; instable development
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1 Introduction

With mankind's constant demand for the mineral resources and the mining scale expanded constantly, The shallow and mined easily mineral resources are exhausting gradually, it is an inevitable trend for the underground mine to deeply exploit. With the increase of mining depth, the problems of mining engineering facing is more complex, and engineering accidents are more serious, rock burst is more so. Theory and practice indicate rock burst easily happens in hard roof, especially heavy layer sandstone roof. The rock burst not only brings about the accidents such as casualty, equipments destruction, roadway destruction and collapse, but also result in the other mining disasters such as gas explosion, the coal dust explosion[1], which threat seriously the normal production of mine and personnel's security. Therefore, effective exploration base theories and technique measurements of rock burst happening in condition of hard roof have important significance of increase economic benefit of mine, even national economic development.

2 Mechanism of Rock Burst Happening

After ground coal body is mined, the roof, the floor and the coal body between them form a high stress equilibrium system, from thermodynamics; the system is automatically in lower energy state for keeping balance. If outside energy goes into the system and breaks the intrinsic balance, the system automatically adjusts, according to the principle of least dissipation energy, the system automatically searches bottle neck and releases energy[2]. Obviously, the bottle neck

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of system is lower intensity coal, which is approved by the macroscopical representation of a mass of crashed coal invade into roadway in scene[3]. Therefore, although the influence factors of rock burst is much, it is induced by clamped coal losing stability and invading into excavated room in the final analysis, studies the mechanism of rock burst happening should be from breach and lost stability behavior of coal that is loaded by its roof and floor.

As is well known, coal is a medium material with various joints and cracks, which mean coal to exit natural vices which are named Griffith vice[4]. The vices decide the mechanism behaviors of coal to a great extent, and the breach of coal just starts with the development of cracks.

Mechanics analysis for single crack, introducing G C Sih model, the tensile stress in peak of crack is[5]

$$\sigma_t = \frac{(a+b)^2}{4ab} \cdot \frac{(\sigma_1-\sigma_3)^2}{\sigma_1+\sigma_3}, \tag{1}$$

where a and b is respectively the length and width of the crack; σ_1 and σ_3 respectively refer the maximal and minimal main stress.

If the tensile stress in the peak of crack is greater than tensile strength of coal-rock mass, the crack will develop, and whether the development of crack stable or not is judged from following formula[6]:

$$U = \frac{G\boldsymbol{n}^2\boldsymbol{b}^2}{4\pi(1-\upsilon)}\ln\frac{4R}{C} + 2\gamma C - \frac{\pi(1-\upsilon)\sigma^2C^2}{8G} - \frac{\sigma\boldsymbol{nb}C}{2},$$

where G is shear strength of coal mass; σ is the tensile stress in the peak of crack; R is the border where coal mass take place dislocation; ν is poisons ratio of coal mass; $\boldsymbol{nb}$ is Burgers vector; C is the length of crack; γ is volume weight of coal mass.

If the energy is balanceable, $\partial U/\partial C = 0$, thus

$$C^2 - (1 - 2\sqrt{\frac{r_1}{r_2}})r_2C + r_1r_2 = 0, \tag{2}$$

where $r_1 = \frac{G\boldsymbol{n}^2\boldsymbol{b}^2}{8\pi(1-\upsilon)\gamma}$, $r_2 = \frac{8G\gamma}{\pi(1-\upsilon)\sigma^2}$.

No solver of equation (2) means that influent energy of outside isn't wholly consumed when crack develops, and stores in loaded coal mass with elastic energy, which result the crack instable development. Obviously, the condition of no solver of equation (2) is

$$\frac{r_1}{r_2} = \frac{\frac{G\boldsymbol{n}^2\boldsymbol{b}^2}{8\pi(1-\upsilon)\gamma}}{\frac{8G\gamma}{\pi(1-\upsilon)\sigma^2}} = \frac{\boldsymbol{n}^2\boldsymbol{b}^2\sigma^2}{64\gamma^2} > \frac{1}{4}.$$

Instable development of crack is the necessary condition of storable energy in coal mass breaks through the restriction of coal-rock system and is released in a short time, at this time, if the storable energy reaches a certain value, such as 1.25×10^5 J[1], rock burst will happen.

3 Characteristic of Mining Pressure in Hard Heavy Layer Roof

As is well known, with face advancing, the exposed area of main roof of gob area is gradually increaseing, when the area reaches to some extent, the main roof will rupture, and thus first weighting and periodical pressure of face occur. According to the theory of beam, the first breaking and periodic breaking distance of main roof is respectively[7]:

$$L_0 = \sqrt{\frac{2h^2R_T}{q}},\ L_p = \sqrt{\frac{2h^2R_T}{3q}}, \tag{3}$$

where q is unit load of the key stratum and its covering rock stratums, N/m^2; E is the elastic modulus of the key stratum, MPa; J is inertia moment of the key stratum, and $J = h^3/12$; R_T is tensile strength of the key stratum, MPa; h is the thickness of the key stratum, m.

From equation (3), the first breaking and periodic breaking distance of main roof is direct proportion with its ten-

sile strength and thickness, therefore, mining will result in large area exposed roof in hard and heavy layer roof, premising that the suspending distance of main roof is a, the abutment pressure of limited balance area in front of coal wall without support is[8]

$$\sigma_y = \gamma H \sqrt{\pi(a/2 + x)} + \sqrt{2/\pi}\int_0^x \frac{f_0(x)}{\sqrt{x_1 - x}}\mathrm{d}x, \tag{4}$$

$$f_0(x) = \sigma_0 - \frac{2R_C}{M}x.$$

According to strength theory of Mohr, the horizontal stress of limited balance area is

$$\sigma_x = \frac{1 - \sin\varphi}{1 + \sin\varphi}(\sigma_y - R_C),$$

where x is coordinate from brim of coal seams, and x is not more than x_1, the width of limited balance area; σ_0 is the stress at the brim of coal seam; R_C and φ is respectively uniaxial compressive strength and internal friction angle of coal mass.

Therefore, for hard and heavy layer roof, with uniaxial compressive strength of roof enhancing, thickness of roof increase, both the first breaking and periodic breaking distance will increase, and the vertical stress and horizontal stress of coal mass in front of face, and mining pressure becomes violence.

4 Analysis of Hard Heavy Layer Roof Influence Rock Burst Happening

4.1 Directionless Pressure of Hard Roof Impress Coal Mass

From above analysis, coal mass in front of face is in high stress state in condition of hard roof, importing equation (5) into equation (1), and ignoring constant term (constant term has little effect on partial differential of σ_1 and σ_1), premising $\sigma_x = \frac{1 - \sin\varphi}{1 + \sin\varphi}\sigma_x = \xi\sigma_y$, thus

$$\sigma_1 = = \frac{(a + b)^2}{4ab} \cdot \frac{(\sigma_1 - \sigma_3)^2}{\sigma_1 + \sigma_3} = \frac{(a + b)^2}{4ab} \cdot \frac{(1 - \xi)^2}{\xi + 1}\sigma_1. \tag{5}$$

The elastic energy storied in unite coal mass (density of strain energy) is

$$U_e = [\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - 2\upsilon(\sigma_1\sigma_2 + \sigma_1\sigma_3 + \sigma_2\sigma_3)]/(2E).$$

According to above analysis, in the condition of hard roof, tensile stress in peak of crack of clamped coal mass increases, and the danger of instable development of crack and momentary release energy of coal mass also increases, in addition, elastic energy storied in coal mass increases, which all result in the rock burst happening easily in clamped coal mass.

4.2 Abrupt Sinkage of Hard Roof

Exposure and sinkage of hard heavy layers roof firstly show slow pressure or compression of coal seam (directionless pressure), after a period of time the roof will abruptly sink in one day or several days, and the load bore by roof and coal seams raise big value in a short time[8], and the increment of abutment pressure in coal seams is[1]

$$\Delta P_2 = f'(u_2, t)\Delta u_2,$$

where u_2 is vertical displacement of coal seams; $f(u_2, t)$ is abutment pressure of coal mass in clamped area, and it is a function of time and displacement; M_1 is quality of coal mass in clamped area; u_1 is displacement of roof.

Abrupt sinkage of roof resulting system formed by roof, floor and coal seams release energy is $\frac{1}{2}M_1\left(\frac{\mathrm{d}^2u_1}{\mathrm{d}t^2}\right)^2$ more than that of slow sinkage of roof.

From above analysis, abrupt sinkage of roof results in the abutment pressure of clamped coal mass increase, thus the tensile stress in peak of crack of coal mass also increase, which result the balance system losing stability and instantly releasing energy. Comparing with slow sinkage of roof, the energy is very great, therefore, rock burst easily hap

pens, observation in scene proves the opinion, as is shown in fig. 1[3]. From fig. 1, rock burst always happens when roof rapidly sink.

4.3 Rupture of Hard Roof

Roof will rupture if its exposed area reaches to some extent, the roof will rupture, which is the reason of first weighting and periodical pressure of roof, and the roof accumulates plentiful elastic energy before it ruptures, and the energy will mostly release when roof ruptures. Accumulated elastic energy of roof during first weighting and periodical pressure is respectively:

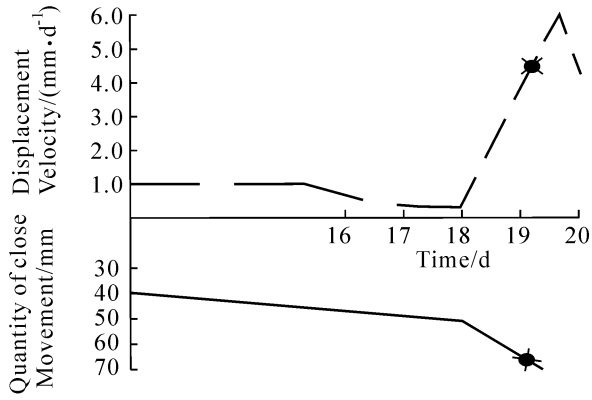

Fig. 1 Dynamic Curve of Roof Before Rock Burst Happening

$$U_{w0} = \frac{Q^2 L_0^5}{578EJ},\ U_{up} = \frac{Q^2 L_p^5}{8EJ}.$$

Introduce equations (3) and (4) into above two formulas:

$$U_{w0} = \frac{h^2}{12E}\sqrt{\frac{2h^2 R_T}{q}},\ U_{wp} = \frac{h^2}{6E}\sqrt{\frac{2h^2 R_T}{3q}}.$$

Released energy radiate outward in vibration when roof ruptures (stress wave), which results in energy storied in unit coal mass to increase, and tensile stress in peak of crack of coal mass to increase too, and horizontal restriction decrease[9]. Therefore, in condition of hare roof, because of augment of storied energy of coal mass in clamped area and increase of tensile stress in peak of crack, rock burst easily happens.

In addition, hard roof touching discard brings sharp vibration again, which increases more elastic energy storied coal mass and induce crack instable development, leading to rock burst happening.

Furthermore, when roof ruptures, the horizontal component of the roof inflicting coal seams almost disappear, and the abrupt decrease of support pressure of coal seams makes coal mass elastic rebound, but because of the compress of above rock strata and below rock strata, coal seam is quickly in higher stress state, thus horizontal stress remarkably reduces, while vertical stress only little decreases, according to equation (1), tensile stress in peak of crack of coal mass in clamped area increase, which lead to rock burst easily happening.

5 Instance Analysis

5.1 Rock Burst in Shanhejian Mine

Rock burst happened 21 from 1991 to 2000 in Shanhejian mine. Analyzing the reasons of rock burst happening, concentrated high stress of coal mass in front of face is the main reason. From fig. 2, hard roof of 9104 face made a quick move which finally resulted in rock burst happening, from fig. 3, when 7204 face advanced 120 m, the rock burst happened, the reason is that above hard roof didn't form stable structure after rupture.

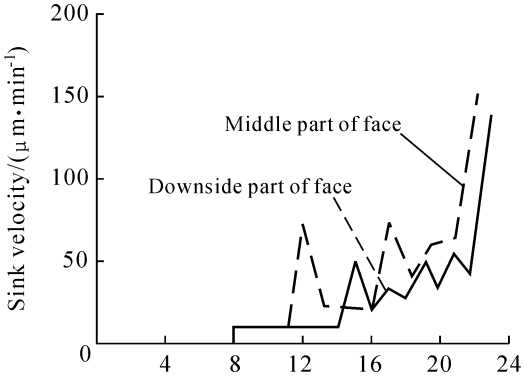

Fig. 2 Sinking Velocity of Roof in 9104 Face

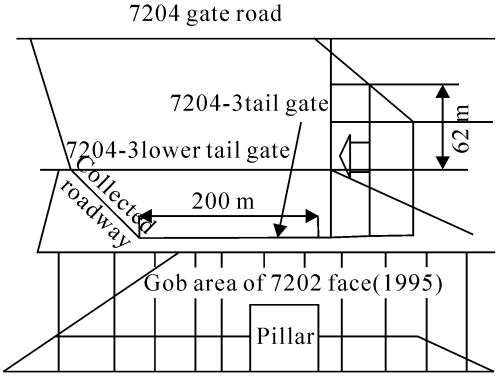

Fig. 3 Rock Burst Happening on December 6, 1998

5.2 Rock Burst in Huafeng Mine

Huafeng mine is typically deep mine where rock burst often happened in china. Because of the thin quaternary Period surface layer (0~ 4 m) and whole 550 m Paleocene conglomerate stratum, the subsiding law of surface reflects the movement law above covering conglomerate stratum. In order to observe the relations between the movements of the main key stratum, mining distance and rock burst, Huafeng mine set 23 observation stations and got the relation picture(as is shown in fig. 4).

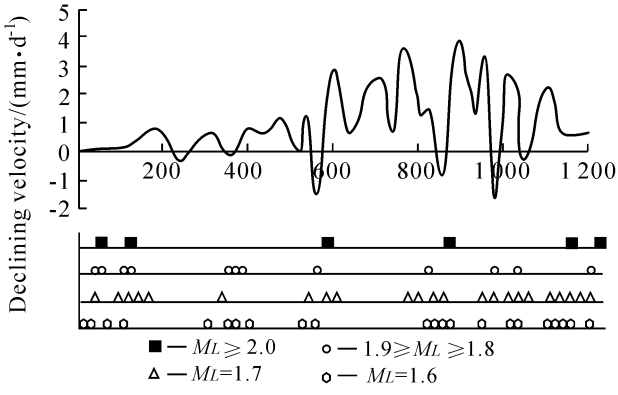

Fig. 4 Relationship Between Area of Extraction Speed of Surface Subsidence and Rock Burst

From the above picture, the place of the conglomerate stratum violent movement where rock burst happens with high frequency and big magnitude, therefore, sharply sinkage and rupture of hugely thick conglomerate stratum is the main reason of rock burst happening.

6 Conclusions

(1) There exit Griffith vice in coal mass, and breach of loaded coal mass starts from crack development, and whether the development is stable or not lies on outside unloaded system, if tensile stress in peak of crack is too high, the crack will unstably develop and instantly release energy, at this time if storied energy in unit coal mass reaches a certain value, rock burst will happen.

(2) Therefore, in condition of hard and heavy layer roof, both the first breaking and periodic breaking distance will increase, and the vertical stress and horizontal stress of coal mass in front of face will also increase, which result in both tensile stress in peak of crack and storied energy in unit coal mass increase.

(3) Abrupt sinkage of hard roof lead to system releasing $\frac{1}{2}M_1(\frac{d^2u_1}{dt^2})^2$ energy more than that of slow sinkage of roof.

(4) Rupture of hard roof instantly releases plentiful energy, and the energy go into coal mass in seismic wave, furthermore, hard roof circumvolving and sinking and touching discard induce vibration, in addition, the rupture of hard roof cause horizontal stress of coal mass in front of face decrease, which all induce rock burst to happen.

(5) Monitoring of rock burst in scene indicated that the movement and rupture of hard roof had great effect on rock burst happening.

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坚硬顶板对冲击矿压发生的影响

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摘 要: 通过理论分析、现场实测和冲击矿压现象分析, 说明了顶板坚硬岩层产生的静压和突然运动、破断均可使煤体内部裂纹不稳定扩展而容易发生冲击矿压.

关键词: 冲击矿压; 坚硬顶板; 裂纹; 失稳扩展
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An Reaserch of Methods of Frequency Measure in Automatic Synchronism Equipment Based on AVR Single-Chip Processor

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Abstract: Frequency measure is very important in the design of automatic synchronism equipment. The reason lies in the fact that it exerts a direct influence on the acccuracy of the voltage difference , phase difference and the quality of cutting-in operations. Taking the ATMEGA128 single-chip processor for example, accroding to author's experience, two methods of measure are proposed in this article, which would be significant for engineering applications.

Key words: input capture; overflow; interrupt

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