ENERGY DISTURBANCE OF ROCK WALL AND ENERGY DENSITY CRITERION OF ESTIMATING ROCK BURST UNDER THE STRESS WAVE

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ABSTRACT

The energy accumulation and its position are two main factors to be used to judge the rock burst occurring. Software ANSYS/LS-DYNA is applied to simulate the process of the energy accumulation and the effect of the depth of roadway to the energy accumulation, the character of the energy accumulation and its position is gained. The research results shows the stress wave is an important factor to accumulate the energy in surrounding rock and induce the rockburst; And the depth of roadway H decides value of the maximal energy density $(U_d)_{max}$ and the distance between its position and the surrounding roadway. The study results has an important significance to open out the mechanism of inducing rockburst and to forecast the rockburst.

Key words: stress wave, surrounding rock of roadway, depth of roadway, rockburst, numerical simulation.

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INTRODUCTION

With the mining deeping, the rock burst frequency and its intensity increase continually, such the mechanism of control the rock burst becomes one of the important problems in mining. The scholars of internal and overseas pay attention to the problem widely, and a series of theoretics are put forward one after the other based on the systemic study on the generant mechanism and practice in prevention and cure. Classical theoretics[2-5] such as: intensity theory, energy theory, impact tendency theory ,three guide line theory and so on. In nature rockburst is a dynamical phenomena that part rockbody destroying quickly and releasing a great deal of transformative energy momently. Whther the rockburst occurs lies on the accumulative energy of the wall rock and the position of the energy accumulation. the higher and the more of the energy accumulate, the nearer the position to the boundary of the roadway, it is easy to occur voilent rockburst. Most rockburst induced by the stress wave, but presently the dynamic study of the rockburst is few. Aiming at characteristic of roadway of mining the energy ditribution characteristic is analysed and energy density criterion is put forward based on the ditribution characteristic.

ENERGY DISTRIBUTION CHARACTERISTIC UNDER THE STRESS WAVE

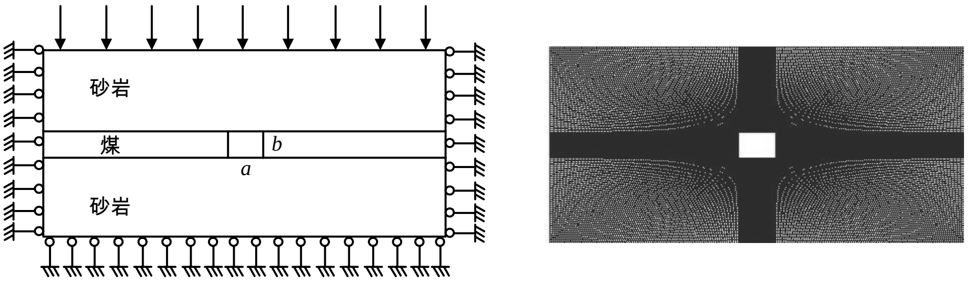
Numerical simulation model

The rockburst occurs nearly correlative to the depth of the roadway. So the influence of the upper terrane must be taken into account. In the paper the implicit function of LS-DYNA is applied to analyse the action of the upper terrane on the roadway structure before analysing the action of the stress wave. Then the result is added on the structure as a initial stress, the last the explicit function of the LS-DYNA software is applied to analyse the action of the stress wave on the structure. Accronding to the request of the implicit analysis, the numerical calculation model of statics analysis is shown as Figure 1(a). horizontal chain poles restriction are set on the both sides of the model to simulate the boundless boundaries; the constrained boundary is set on the bottom of the model; and the top of the model is added the even distributing load q to simulate the upper terrane’s action, and the value of the q is decided by the formula below.

$$q = \gamma H$$

Where; γ is the average density of the upper terrane’s rock mass (set $\gamma = 2 \times 10^4\ \mathrm{N/m^3}$); H is the depth of roadway.

When analysing the stress and energy accumulation of the roadway wallrock, due to the request of the explicit analysis, the non-reflect bounadries are set on the both sides of the model to eliminate the effect of the boundary on the stress wave spread ; the constrained boundary is set on the bottom of the model; and the freedom boundary is set on the top of the model; Then a disturbed stress wave $p(t)$ is added on certain scope of the middle part of the left side of the model. The disturbed stress wave $p(t)$ is shown as Figure 2. to simulate the disturbed load aroused by the driving exploder of theroadway nearby or the ground pressure of coal face of stope. Finite element gridding of roadway’s surrounding rock is shown as Figure 1(b).



(a) (b)

Figure 1.: Numerical calculation model of roadway’s surrounding rock and its finite element gridding.

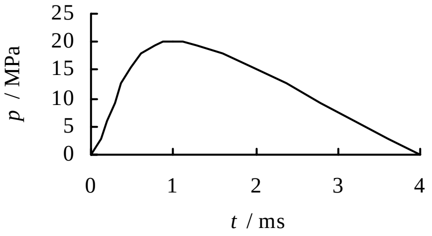


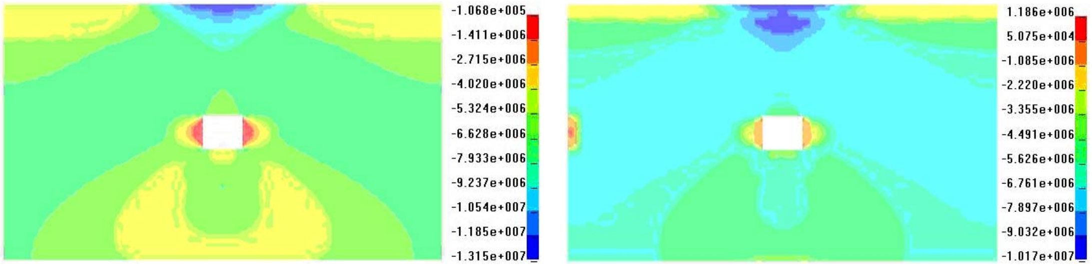
Figure 2.: Curve of disturbing stress wave vs. time.

Energy distribution characteristic of roadway wall rock

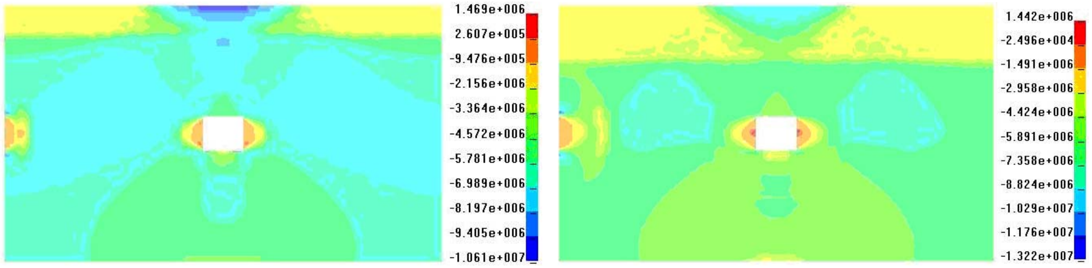
On account of the statics analysis is the foundation of the dynamic analysis, the numerical system considers the initial stress-strain state as zero strain energy, so the value of the numeric is the strain energy increment. The mechanical parameters of the roadway’s roof, floor and the coal seam are listed in Table 1. When *H*=600m, $p_{\max}$ =10 MPa, time t is 0. 0, 0.4ms, 0.8ms, 0.12ms, 0.16ms, 2.0ms respectively, the roadway wall rock energy denisity distribution plot is shown as figure 3. and the corresponding $(U_d)_{\max}$ and the distance *d* between its position and the surrounding roadway are listed in Table 2.

Table 1.: Mechanical parameters of roadway’s surrounding rock

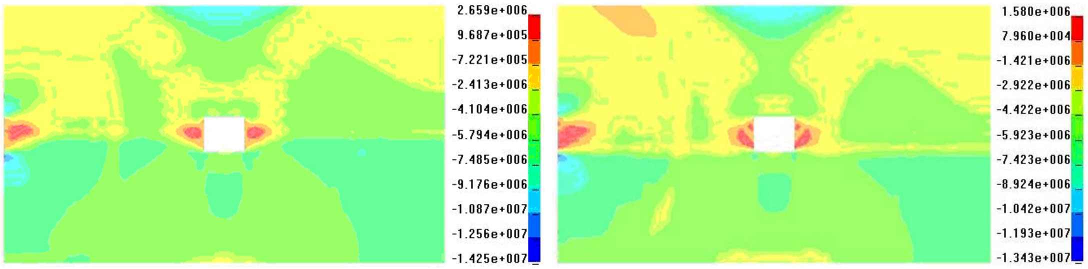
lithology	thickness *h*/m	Elastic modulus *E*/GPa	Poisson’s rati μ	Compressive strength σ_c /MPa	Bon strength *c* / MPa	Internal frictional angle φ /°
sandstone	11	15	0.30	20	2.5	41
coal	3	5	0.35	5	1.5	30
sandstone	11	15	0.30	20	2.5	41



t = 0 ms t = 0.4 ms



t = 0.8 ms t = 1.2 ms



t = 1.6 ms *t* = 2.0 ms

Figure 3.: Different time roadway energy density distribution plot.

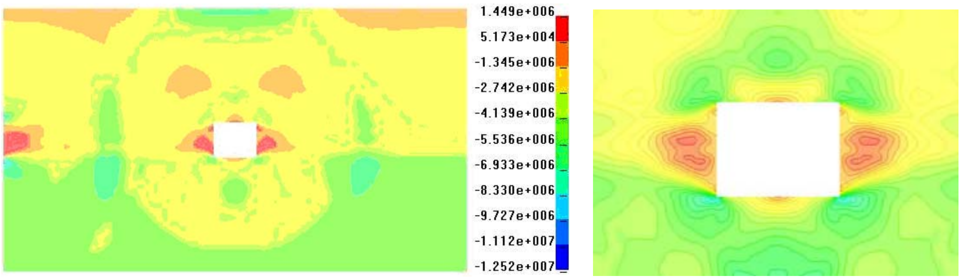
Table 2.: $(U_d)_{max}$, *d* Vs time t

t / ms	0	0.4	0.8	1.2	1.6	2.0
(Ud)max / J m-3	0	1.186×106	1.469×106	1.553×106	1.406×106	1.496×106
d / m	0	0.11	0.12	0.40	0.31	0.10

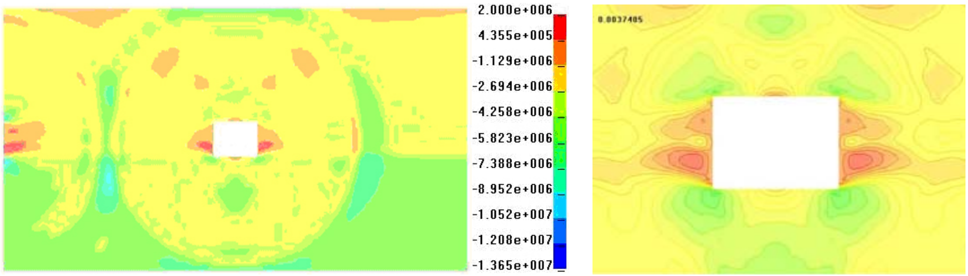
From Figure 3. and Table 2., it can be seen that: (1) With the stress wave spreading, the value of the maxium energy density and its position is changing , that illuminates the energy density of wall rock is distributed over again for the action of the sress wave, some area energy accumulated and some area reduced; (2) The position of the maxium energy density $(U_d)_{max}$, firstly lies on the top of the roadway side, and the value is little; with the stress wave spreding the position of the $(U_d)_{max}$ moves to the below and inside of the roadway side, and the value of the $(U_d)_{max}$ is increasing.

Energy density U_d vs *H*

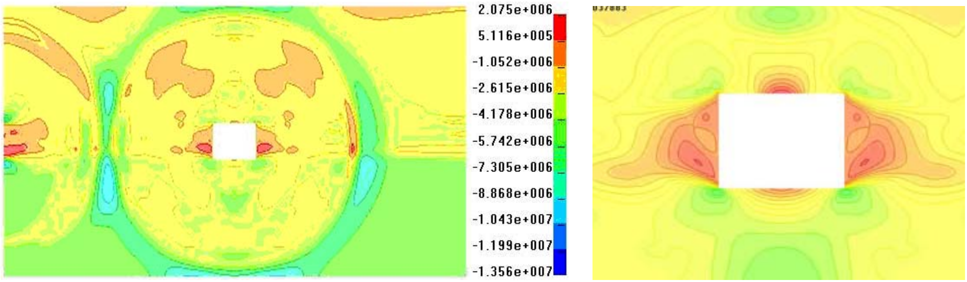
Set $t = 2.5$ ms $p_{max} = 10$ Mpa, when analysing the effect of the depth of roadway ***H*** on the enegy accumulation of the wall rock. From simulation the roadway wall rock energy denisity distribution plots of different *H* are shown as fig.4, the right is blown-up plot of the local of the roadway wall rock. The $(U_d)_{max}$ and the distance *d* between its position and the surrounding roadway vs *H* are listed in Table 3. The rule of the maxium energy density $(U_d)_{max}$ vs depth of roadway *H* is shown as figure 5. The rule of the distance *d* vs depth of roadway *H* is shown as figure 6.



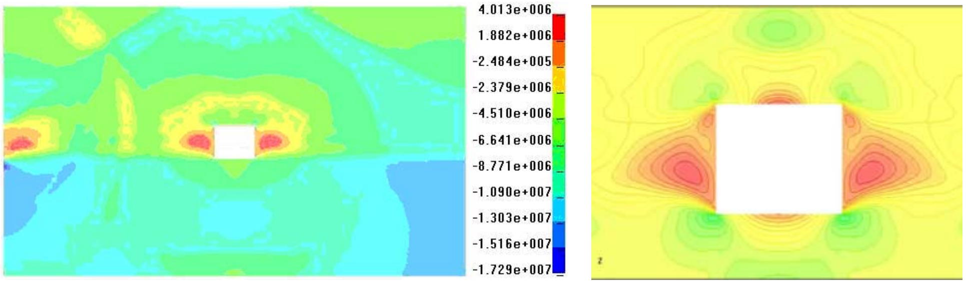
H = 500 m



H = 600 m



H = 700 m



H = 800 m

Figure 4.: Different depth roadway energy density distribution plot.

Table 3.: $(U_{\mathrm{d}})_{\mathrm{max}}$, d vs H

H / m	500	600	700	800
$(U_{\mathrm{d}})_{\mathrm{max}}$ / J.m^{-3}	4.013×10^6	4.307×10^6	5.077×10^6	5.430×10^6
d / m	1.49	1.25	0.83	0.55

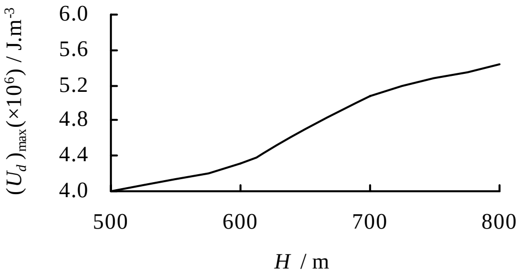


Figure 5.: $(U_{\mathrm{d}})_{\mathrm{max}}$ vs $\boldsymbol{H}$

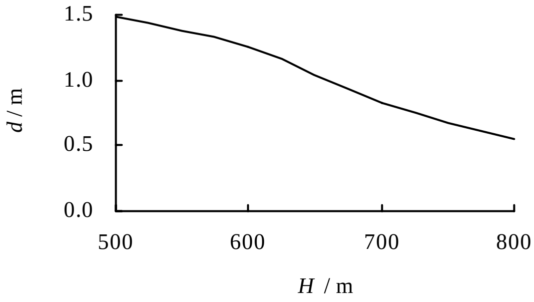


Figure 6.: d ***vs*** H

From the figure 4., figure 5., figure 6. and table 3. it can be seen that (1) the maxium energy density increases with the increasing of roadway depth in mines. When *H* increasing from 500m to 800m, the incremental value of the maxium enegy maxium is 1.417×10^{6}/ J.m^{-3}, incremental rate is 35.3%. It shows the degree of the energy concentration is higer and higer with the increasing of roadway depth in mines; (2) With the increasing of roadway depth in mines, the position of the maxium energy density moves to the middle or below of the side of the roadway. So the the rock burst is easy to happen near the two bottom corner of the roadway.

ENERGY DENSITY CRITERION OF ROCK BURST

In nature rockburst is a dynamical phenomena that part rockbody destroying quickly and releasing a great deal of transformative energy momently. The intensity of therock burst lies on the dispersion between the accumulation energy and the energy comsumed by the wall rock ruptured. The higher and the more of the energy accumulated, it is easy to happen violent rock burst. And the less the energy comsumed, it is easy to happen violent rock burst.

The rock burst is nearly correlative with local energy accumulation of rock mass, whether the accumulative energy leases lies on two factors: one is the degree of the local energy accumulation, it can be token by energy density U_d; the other is the position of the energy accumulation, it can be token by the vertical distance between the position of the maxium energy density $(U_d)_{\max}$ and the boandary of the roadway side. Obviously, the bigger the value of $(U_d)_{\max}$ is, the higer the degree of the energy accumulation is, if the position is near the boundary of the roadway side and the stress of wall rock is close to the strength of the rock mass, the rock burst is easy to occur. Similarly the nearerthe distance between the position of the maxium energy density $(U_d)_{\max}$ and the boandary of the roadway side, the less energy comsumed, so rock burst is easy to occur. Thus a combined quantity of maxium energy density $(U_d)_{\max}$ and the distance *d* between the position of the maxium energy density $(U_d)_{\max}$ and the boandary of the roadway side is applied to weigh the fatalness of rock burst in roadway wall rock. Obviously, it is reasonable and feasible. Let

$$k = \frac{(U_d)_{\max}}{d} \qquad (1)$$

From the formula (1), it can be seen that when the value of $(U_d)_{\max}$ is big and the diastance *d* is small, the value of *k* is bigger ,the fatalness of rock burst is bigger; contrarily, when the value of $(U_d)_{\max}$ is small and the diastance *d* is big, the value of *k* is smaller ,the fatalness of rock burst is smaller. Obviously , the value of *k* reflects the degree of energy acculation and its position, we name *k* as energy density gen. When the value of *k* exceeds a criterion, rock burst occurs. The criterion is token k^*, k^* is named critical energy density gen. So the condition whether rock burst occurs can be shown :

$$k \geq k^* \qquad (2)$$

critical energy density gen k^* is only relational with the rock features and structure of wall rock , so its value must be acquired by experiment, practical measure and mass rock burst data and so on. And energy density gen of wall rock can be obtained by numerical simulation.

CONCLUSIONS

In the paper LS-DYNA software is applied to simulate the process of the energy accumulation and the character of the energy accumulation is studied. Time and the depth of the roadway’s effect on the energy accumulation are discussed. .It has an important significance of researching the mechanism of inducing rockburs.

The research results shows that the maxium energy density increases and the distance decreases with the increasing of roadway depth in mines. The study results has an important significance to open out the mechanism of inducing rockburst and to forecast the rockburst. A criterion of estimating rock burst is put forward based on the analysis of the character of the energy accumulation. For the value of the maxiumal energy density $(U_\mathrm{d})_\mathrm{max}$ and the distance d can be obtained by numerical solution, the criterion is operational, so a new way to forecast rockburst is provided.

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