Numerical simulation of phenomenon on zonal disintegration in deep underground mining in case of unsupported roadway

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Abstract.. Zonal disintegration phenomenon was found in deep mining roadway surrounding rock. It seriously affects the safety of mining and underground engineering and it may lead to the occurrence of natural disasters. in deep mining roadway surrounding rock, tectonic stress in deep mining roadway rock mass, horizontal stress is much greater than the vertical stress, When the direction of maximum principal stress is parallel to the axis of the roadway in deep mining, this is the main reasons for Zonal disintegration phenomenon. Using ABAQUS software to numerical simulation of the three-dimensional model of roadway rupture formation process systematically, and the study shows that when The Direction of maximum main stress in deep underground mining is along the roadway axial direction, Zonal disintegration phenomenon in deep underground mining is successfully reproduced by our numerical simulation..numerical simulation shows that using ABAQUA simulation can reproduce Zonal disintegration phenomenon and the formation process of damage of surrounding rock can be reproduced. which have important engineering practical significance.

1. Introduction

With the continuous development of economic construction, the demand for energy and resources has been increasing. Shallow resources gradually reduce, The depth of the underground mining is more and more deep. As the underground mining depth increase, deep rock mass engineering in excavation roadway and mining, Surrounding rock deformation and failure result in a series of new scientific phenomenon. Zonal Disintegration phenomena in deep Surrounding rock has been increasing attention[1].Zonal Disintegration phenomena in deep Surrounding rock first has been founded in South Africa Witwatersrand gold Mine by G.D.Adams and A.J.Jage[2], in last century 80' ,E.I. Shemyakin et al have made further research[2-6]， As is shown in Fig 1-Fig 3. Many researchers have done further research on this scientific phenomenon[7-10].In this paper, based on numerical simulation, using the large-scale finite element analysis system-ABAQUS, the extended process from initiation to formation of zonal disintegration is studied by numerical Simulation, when The Direction of Tectonic Stress or The maximum main stress in Deep Underground Mining is along the roadway axial direction, reproduction of zonal fracturing phenomenon in deep underground mining is successfully reproduced by our numerical simulation.

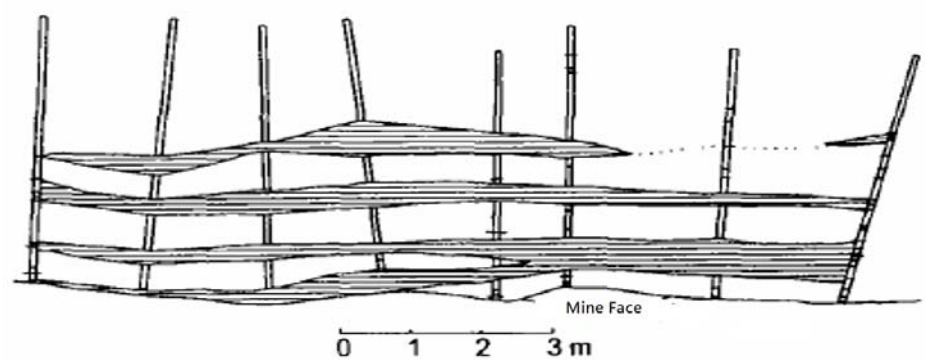


Fig.1. Zonal Disintegration phenomena of South Africa Witwatersrand gold mine

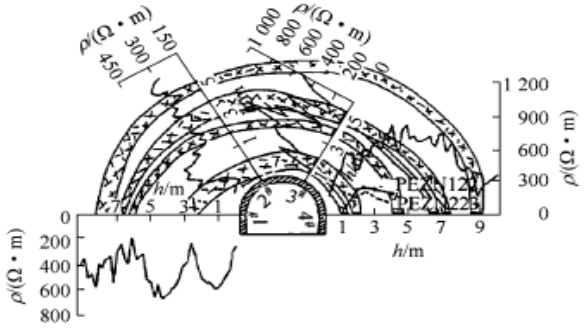


Fig.2 Zonal disintegration of Taimyrskii Mine in Russia

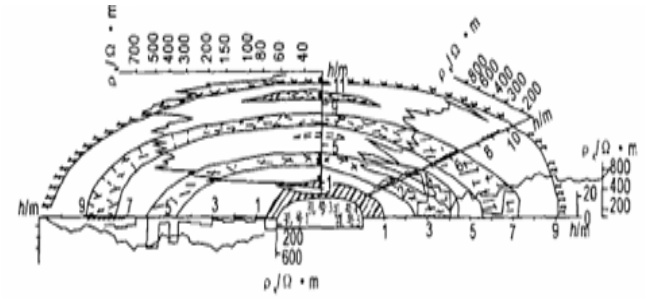


Fig.3 Zonal disintegration of deep roadway in Russia Oktyarbskii mine (-957m)

2. Numerical model

In our numerical model calculation, we use the linear elastic criterion and Mohr-Coulomb criterion.

$$\sigma = q - \frac{3p\sin\varphi + 3c\cos\varphi}{\sqrt{3}\cos\theta - \sin\theta\sin\varphi} \quad (1)$$

Where p is mean stress; q is generalized deviation stress; θ is Lode angle of stress, c is cohesion; φ is internal frictional angle. The numerical ABAQUS model in our numerical simulation is shown in Fig.4,and ABAQUS boundary of x-y direction and load of z-direction in our numerical simulation is shown in Fig.5.

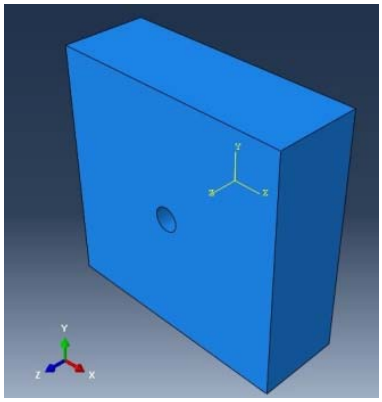


Fig.4 ABAQUS model

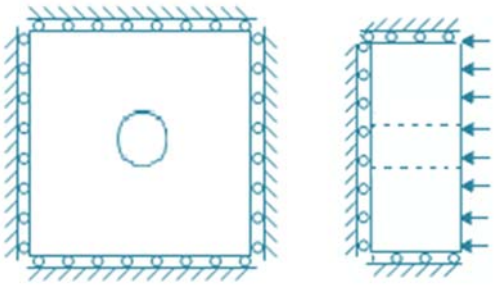


Fig.5 boundary condition of x-y direction and z-direction

Numerical model size is 200 mm × 200 mm × 70 mm, and the radius of roadway in deep surrounding rock is 10 mm. Rock parameters of Surrounding rock used for numerical simulation are shown in Table 1

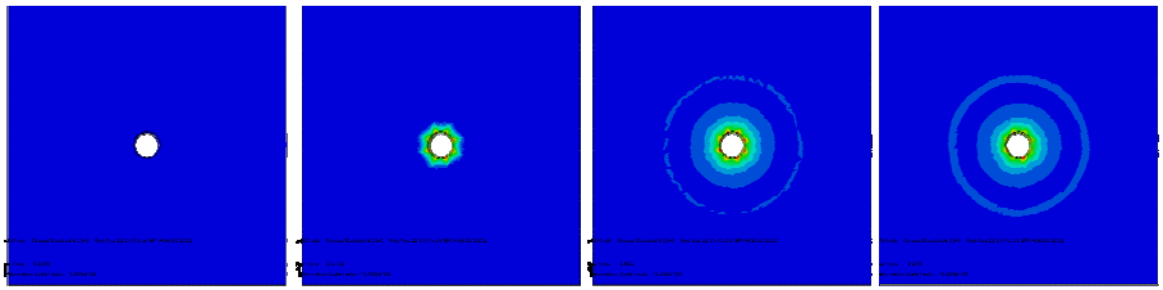
Table 1 Rock parameters of surrounding rock used for numerical simulation

Modulus of elasticity / Mpa	Poisson' Ratio	Density / Kg/m^3	Friction angle / °	Dilatancy angle / °	Cohesion / Mpa
26000	0.167	2400	38^0	10^0	1

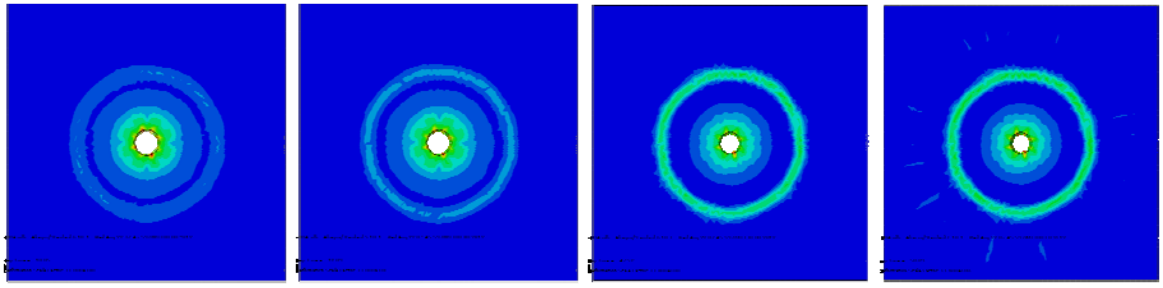
In our ABAQUS model, boundary conditions are set as the displacement constraint, around the X, Y direction constraints (X = Y = 0), Z direction freedom; All the constraints on the Z = 0, three direction (x = y = Z = 0), on the Z = 70 mm, the displacement loading is loaded, (" - "negative direction along the Z axis), namely the axial direction of roadway, as shown in figure 5, Rock mass model choose nonlinear three-dimensional entity 68 node coordinate unit , In ABAQUS simulation analysis, when the equivalent plastic strain PEEQ values is greater than zero, that show that material yield, rock element is about to burst.The simulation test is the fracture of rock under Static load analysis, so the analysis type choose Static solution (Static).Set the total load step length of 60 time, that can be generalized as displacement load per unit time is 6 mm / 60 = 0.1 mm. Open the large deformation options, use the unsymmetrical solver to solve

3. Numerical simulation of Zonal disintegration in deep roadway surrounding rock in case of unsupported

The Numerical simulation results of Zonal disintegration in deep roadway surrounding rock without supporting are shown in Fig.6. Figure 6 is the key point in the process of analysis and calculation of the equivalent plastic strain nephogram PEEQ



（a） 0.35 time point （b） 0.575 time point （c） 1.925 time point （d） 3.24 time point



（e） 10.06 time point （f） 12.83 time point （g） 47.52 time point （h） 60.0 time point

Fig 6 The nephogram PEEQ of equivalent plastic Strain for numerical simulation of Zonal disintegration in deep roadway surrounding rock in case of unsupported

From figure 6 (a), (b) shows that in the condition of no supporting axial loading, The stress concentration first is produced around the tunnel walls bulge, Opening the first fracture instability of surrounding rock. By figure 6 (c), with the applied load, the stress to the surrounding rock mass diffusion, to a certain extent after the collapse of surrounding rock around the hole, in a certain distance from the destruction of center micro crack. By figure 6 (d), further gradually formed from the wall of roadway in deep rock mass in the process of the extension, the concentrated stress appears big and small appear alternately, to produce the fracture zone and the fracture zone partition rupture phenomena appear alternately. As shown in figure 5.3 (e) (f), through the comparison analysis of equivalent plastic strain nephogram PEEQ can be seen that the basic partition burst has been formed and well versed in, along with the load increase, rupture zone face increasing, namely the rupture section surface is relatively narrow, the surrounding rock, a large area of micro cracks under the partition is broken, that is not obvious.By figure6 (g) - (h) analysis, along with the further load, the original fracture zone depth of damage, rather than the fracture zone relative force is small, and the bursts relative to differentiate clearly, form the final partition break down phenomenon. As shown in figure 6 (h), as load increasing, stress and fracture degree increase, but the partition area the bursting of the rupture phenomena and the fracture width of the relative position and size and other basic no longer change. Figure 7 is size effect analysis diagram for Zonal disintegration in deep roadway surrounding rock without supporting, this figure is according to the overall size and mesh size contrast measurement model, in roadway for reference to the relative size of diameter d, that is helpful to research and analysis.

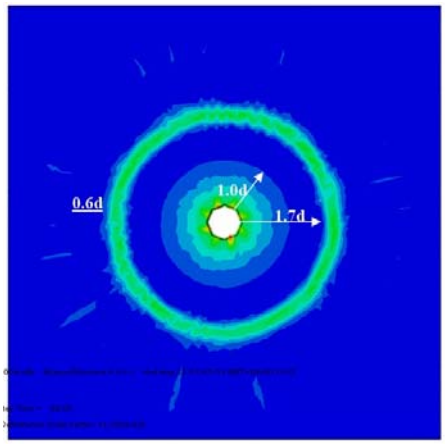


Fig.7 Size effect analysis diagram for Zonal disintegration in deep roadway surrounding rock without supporting

As you can see from the size analysis diagram, close to circle around the roadway surrounding rock burst thickness of about 1.0 d roadway diameter (d), from the broken circle 0.7 d, surrounding roadway expedite rupture zone, namely from the roadway wall about 1.7 d, the rupture zone width is

about 0.6 d. Because no supporting of roadway and appropriate load strength, surface damage of surrounding rock around tunnel walls area and the zoning of rock bursts zone width is bigger.

4. Conclusion

To sum up, in the axis direction compression is the partition of surrounding rock of roadway, on the basis of this view, the main reasons for using ABAQUA simulation can reproduce partition burst phenomenon, without supporting of roadway surrounding rock under the partition first of roadway surrounding rock bursts, to the failure to achieve a certain degree again after generating an rupture zone and fracture zone partition alternately the phenomenon.

Deep tectonic stress in rock mass, usually after reaching a certain depth, horizontal stress is much greater than the vertical stress, this is the main reason for the Zonal disintegration in deep roadway surrounding rock..

With finite element software ABAQUS, three-dimensional model of deep roadway surrounding rock rupture formation process and support for the numerical simulation of the system, and the study shows that through the axial compressive stress, Along the cavity axis compressive stress is larger, which is the fundamental cause for Zonal disintegration in deep roadway surrounding rock. using ABAQUS software, numerical simulation of the three-dimensional model of roadway can be reproduced phenomenon Zonal disintegration in deep roadway surrounding rock.

Acknowledgements

This research is supported by “The Natural Science Foundation Project of Liaoning Province of China (201602038, 2015020222)” and “The general Project of scientific research of Education office of Liaoning Province of China (L2012436) ”

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