IOP Conf. Series: Earth and Environmental Science **170** (2018) 022063 doi:10.1088/1755-1315/170/2/022063

Dynamic Response Characteristics on Both Sides of the Filling Body in Difficult Mining Stope by Using Deep Hole Blasting

Chengyu Xie[1], Nan Jia[2,*], Dongping Shi[1], Xinfeng Wang[1], Xiaoqiang Zhang[1], Liwen He[1]

[1]School of Environment and Resources, Xiang tan University, Xiang tan, China
[2]Institute of public safety, Tsinghua University, Beijing, China

*Corresponding author e-mail: 575580701@qq.com

Abstract. It was complicated and difficult for blasting vibration controlling when applying deep hole blasting in the ore body filled with filling method, especially when the two sides of the filling body was unstable. Take one lead-zinc mine engineering practice as case, the dynamic response dynamic response simulation numerical model of deep whole blasting was constructed by nonlinear dynamic software LS-DYNA, and five feasible side whole charge structures were proposed in order to analyse laws of explosive stress wave transmissed in filling body. The result shows that: "scaling" phenomenon did not occur in two sides of stope when tensile stress is less of dynamic tensile strength; blasting stress distribution tends to be more uniform when the air separation factor is 0.528; the speed and stress of blasting vibration reach the maximum value from pack center of the projection position of the filling body when blasting vibration velocity and stress are superimposed; the optimal blasting effect was getting when air interval as 1 meter. Field experiments show that, the effect of blasting vibration on the two-sides of fillings can be controlled by optimized edge-loading structure.

1. Introduction

Some difficult mining could form with the mining progress. After mining when it mined with filling method, due to various reasons caused by poor filling quality, column, the blasting vibration will obviously affect the stability of the two fillers, so the requirements for blasting vibration control will be improved [1].

A lead-zinc mine was blasted with large diameter deep hole blasting, single blasting dose was large and had a large effect on the stability of the two-packs, even a large-scale stop collapse [2]. At present, the research on the dynamic response characteristics of rock mass under blasting load has made some progress. For example: literature [3] studied the dynamic response and vibration reduction measures of open blasting vibration to adjacent buildings. Literature [4] studied the blasting vibration test and response law of slope by ANSYS time history analysis. Literature [5] analyzed impact of blasting excavation on the stability of high cutting slope is carried out. In literature [6], the blasting failure of concrete is predicted and verified by safe PPV. However, there are still few studies on the vibration velocity distribution and stress characteristics of the two-hole filling of the deep whole blasting.

IOP Conf. Series: Earth and Environmental Science **170** (2018) 022063 doi:10.1088/1755-1315/170/2/022063

Based on the actual engineering of lead-zinc mine project and a stope as the research object, the numerical simulation analysis of the blasting process is carried out. Combining the safety threshold of blasting and the mechanism of blasting rock breaking, the velocity and stress field of different charges was analyzed, thus predicting the blasting effect of the stope, preferably the side-hole charge structure and applied to the field practice.

2. Project Overview

The lead-zinc mine uses a backward deep-hole blasting lateral collapse of the mining process (shown in Figure 1). The upper chamber and the bottom chamber are first excavated, and then the upper chamber is drilled in the vertical crest through the entire ore body, and the new free surface and the compensation space are formed at the end of the stope in the form of cutting and blasting. After breaking the top, then 2 to 4 times collapsed the sides, the use of the remote control scraper at the bottom of the mining chamber out of the mine.

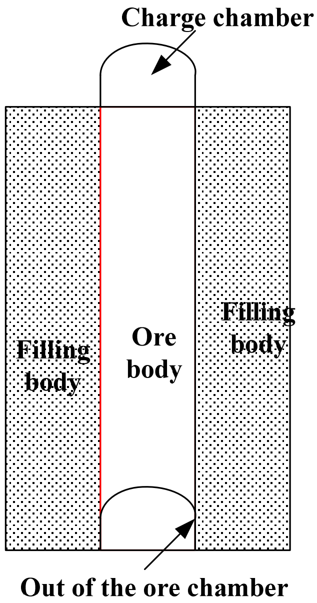


Figure 1. Layout of stope

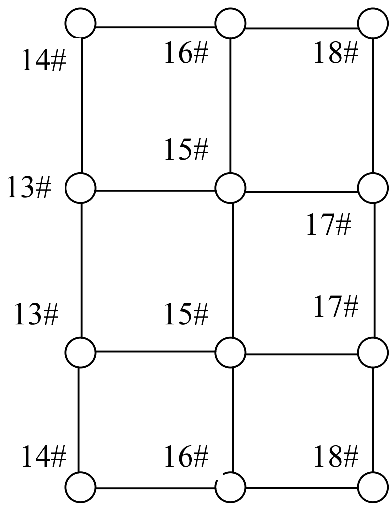


Figure 2. Sketch of blasting sequence

Using the "V" type detonation method (shown in Figure 2), the middle hole of each column detonated first, side row of holes suspended from the detonation, ahead of the latter column of the middle hole, the adjacent hole burst interval 25 ~ 100ms. Side of the hole diameter of 110mm, hole parameters for the row distance × hole spacing = 2.0 m × 1.8m, side row of holes and the distance between the filling body is 1m.

3. Numerical simulation model

3.1. Charge structure

The uncoupled charge structure and air layer are placed in the middle of the charge, so the blasting energy can be efficiently transferred to the rock[7~8]. Therefore, using the uncoupled charge structure combined with the actual situation of the mine, the axial air-drug charge structure using five kinds of design, the air separation coefficient were: 0.402,0.427,0.47,0.528,0.57. The charge is the same, the length of each explosive is 0.67m, diameter is 90mm.

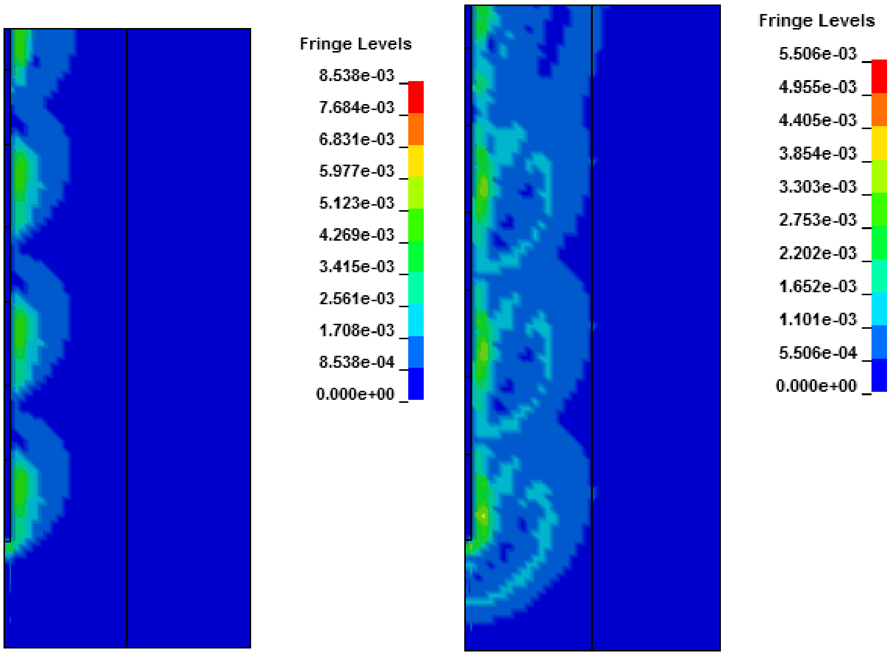
3.2. Numerical simulation analysis model construction

Under the condition of five kinds of charge structure, the effect of deep whole blasting on the stability of filling body was studied and the optimal charge structure was determined. By arranging a series of points at the interface between the rock mass and the filling body of the model, the blasting vibration velocity and stress curve corresponding to the extraction point are analyzed, and the peak value of each curve is analyzed and the optimal charge structure is obtained. LS-DYNA can solve the large deformation dynamic response such as explosion [9], respectively, the design of the five kinds of charge structure for blasting simulation, edge to the filling distance of 1m, the minimum resistance line to take 1.5m, the width of the filling Take the length is 1m, take the length of the model is 20m, the height is 10m, stop width is 7.4m, in addition to free surface, the other boundaries are set without reflection boundary conditions. The main parameters of ore and fill body are shown in Table 1.

Table 1. Main parameters of mine rock and filling body

Rock types	Ore body	Filling body
Density /(g·cm-3)	3.4	2.25
Elastic Modulus /GPa	32.5	0.78
Poisson's ratio/v	0.25	0.28
Yield Strength /MPa	70	18
Tangent modulus /GPa	7.61	0.22
Static tensile strength /MPa	6.16	0.5

IOP Conf. Series: Earth and Environmental Science **170** (2018) 022063 doi:10.1088/1755-1315/170/2/022063



(a)t=180us (b)t=339.72us

Figure 3. Contours of effective stress of blasting process plan 2

4. Numerical results analysis

4.1. Effective stress field analysis

Figure 3 shows the effective stress cloud at the different time of blasting process in scheme 4 (the stress field of the other schemes not listed one by one because of the limited space).

From Figure 3, it can be concluded that the stress wave propagates at the same time, and when t=179.92us, the effective stress wave begins to superposition. When t = 339.772us, the effective stress wave reaches the ore body filling the interface of the body and began to produce a reflection phenomenon.

4.2. Influence of blasting speed on filling body stability

Use peak velocity PPV to the propagation characteristics of the explosive stress wave at the interface between the ore body and the filling body [9-10]. A series of Gaussian velocity curves were selected and the results were saved as.csv file. The Origin software was used to obtain a series of Gaussian point blasting velocity extremes (Figure 4) and the Gaussian point blasting velocity extremes (Figure 5).

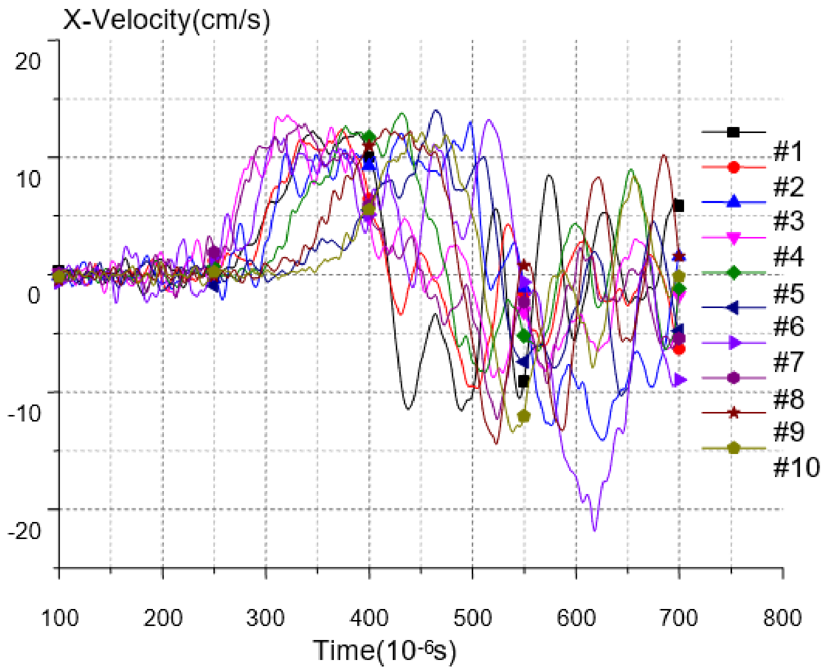


Figure 4 Change curve of blasting velocity with time

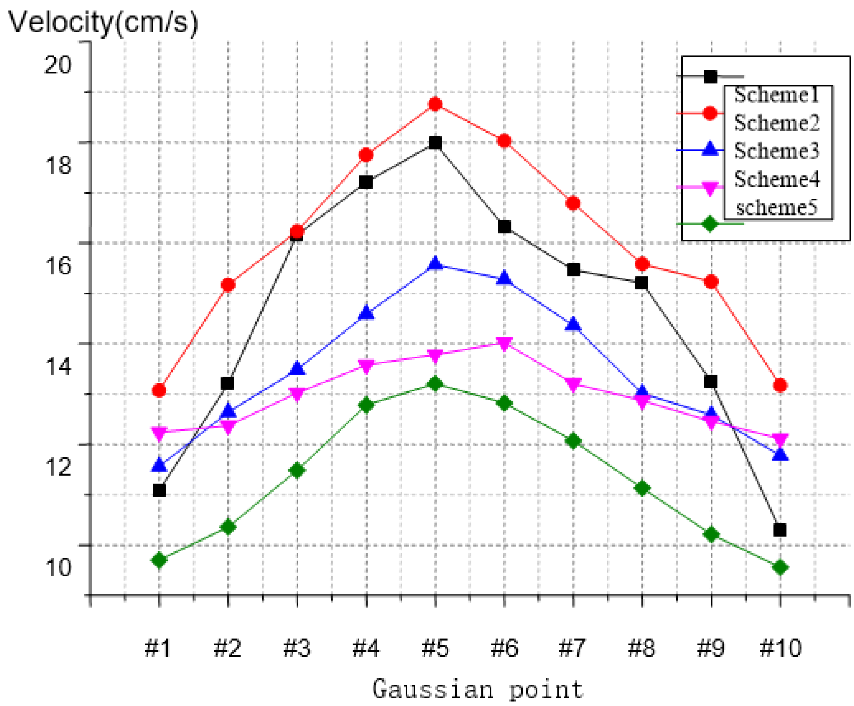


Figure 5 Blasting velocity peak of each project

From Figure 4 (because of the limited space, only list the speed-time curve of scenario 4), we can conclude that: 1) The overall trend of blasting vibration velocity is increased to the maximum then to decrease and increase to another peak, and vibrated at 0 o'clock; 2) P wave velocity is bigger than the S wave velocity, P wave rate first reaches the Gaussian point and reaches the maximum value, S wave velocity is another peak point.

Figure 5 shows that: 1) The peak blasting vibration velocity of 5 blasting programs are 17.98cm/s, 18.76cm/s, 15.57cm/s, 14.02cm/s and 13.21cm/s respectively, that means the size of air interval has a certain impact on the blasting vibration peak value. the greater of air interval, the smaller of the peak vibration blasting velocity; 2) 5 kinds of blasting vibration velocity peak size difference is not large and concentrated on the Gaussian point # 5 and # 6. And the blasting vibration velocity is superimposed to increase the speed of the center of the package to the projected position of the filling body. 3)The variance of the peak velocity of the blasting vibration velocity of five schemes are 5.94, 3.35, 1.79, 0.41, 1.64 respectively. Description of the program 4 charge structure blasting velocity distribution is more uniform, more conducive to the protection of the filling body, so the program 4 charge structure is more reasonable.

4.3. Effect of stress on the stability of filling body

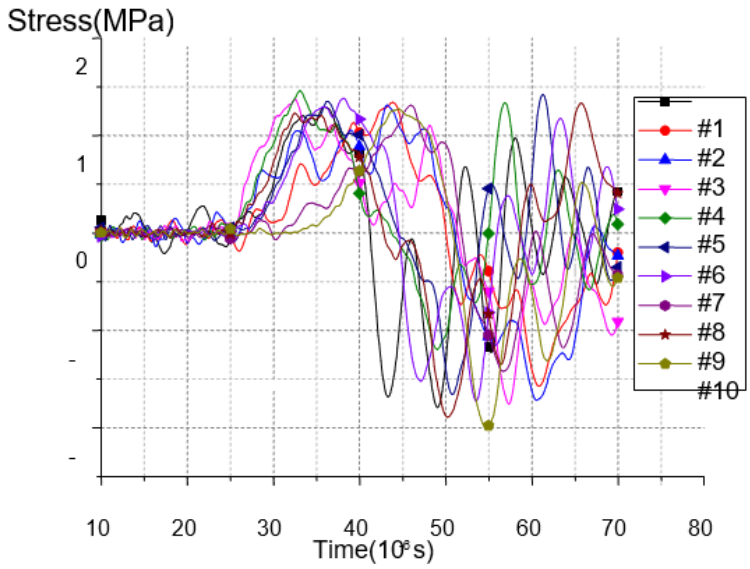


Figure 6 Change curve of stress with time

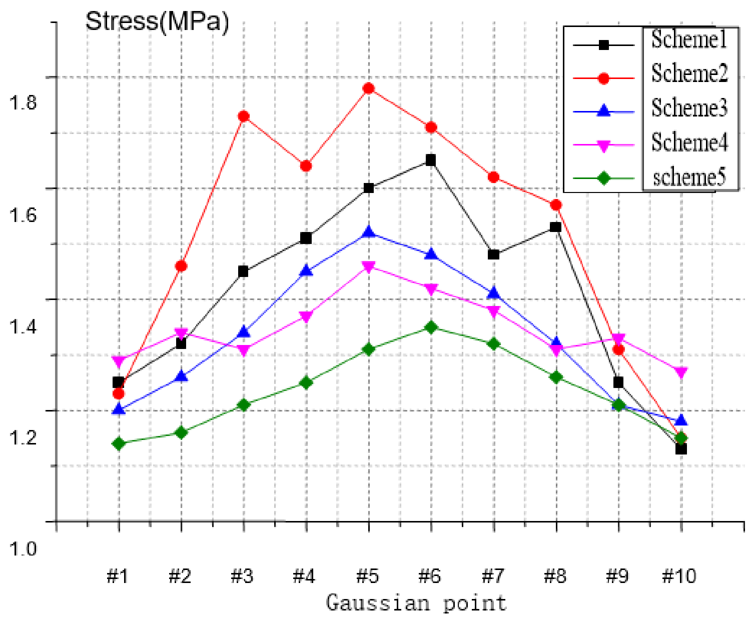


Figure 7 Blasting stress peak of each project

The dynamic stress analysis software LS-DYNA cannot get the tensile stress of the filling body. Therefore, take the maximum principal stress as the maximum tensile stress (the maximum principal stress curve is the tensile stress curve). If the peak stress of the Gaussian point is lower the dynamic tensile strength of the filling body, then the place did not yield, "film" phenomenon did not occur. According to Figure 6, the maximum tensile stress of the filling body is 1.65Mpa, 1.78Mpa, 1.52Mpa, 1.46Mpa and 1.35Mpa respectively, which is smaller than the dynamic tensile strength of the filling body, and will not cause the failure or failure of the filling body.

Analysis of Figure 7 shows that: 1) the middle of the value of the Gaussian point stress is generally greater than the two sides, this is because the explosive stress intensity decreases with the target point to the explosive center of the distance decreases, deep hole drug center point to the filling position of the blasting which the stress is constrained; 2) The variance of the peak value of the Gaussian point blasting stress is calculated as: 0.026,0.044,0.013,0.003 and 0.005 respectively, which shows that the stress peak curve of scheme 1 and scheme 2 is large, program 5 stress peak curve fluctuation is relatively gentle, which program 4 stress peak curve of the best degree of ups and downs, indicating that the device 4 charge structure can make full use of explosive energy and to make the explosive energy distribution more uniform; 3) 5 curves in general according to the program 5, the order of scheme 4, scheme 3, scheme 1 and scheme 2 is gradually increased, but the peak difference is not large, because the five regimens are the same but the air interval is different. Schemes 3 and scheme 4 are closer to the curve, indicating that the size of the air gap will affect the blasting dynamic response, reasonable air spacing can improve the blasting effect. The air separation factor of calculation scheme 4 is 0.52, which indicates that the air separation coefficient is 0.52 when the whole charge is designed. Based on the above analysis, it can be confirmed that scheme 4 is the best blasting charge design.

5. Conclusions

(1) According to the basic situation of the mine, the LS-DYNA numerical model can reasonably simulate the dynamic response of the deep hole blasting to the filling body. The maximum peak point of the velocity time curve is the P wave velocity, and the other peak point immediately follows the S wave velocity. The larger the air interval, the smaller the peak blasting vibration velocity.

(2) Deep whole blasting under the condition of hidden resources to fully consider the stability of the filling body during the mining process. The tensile stress of the filling body is less than its dynamic tensile strength, and the filling body does not occur. The air separation factor of 0.52 under the condition of the uncoupled charge structure can make the distribution of blasting stress more uniform. The blasting vibration velocity and the stress superposition make the speed and stress of the center of the package to the projected position of the filling body reach the maximum value. The optimal charge structure is scheme 4.

(3) The optimal solution is applied to the actual project, and the better blasting effect is obtained. Based on the comprehensive analysis of the amplitude and stress intensity of the vibrating velocity of the filling body, the stability of the deep whole blasting can be well solved.

Acknowledgements

This work was financially supported by the Hunan Province Science Foundation for Youth Scholars of China fund (2018JJ3510).

References

[1] Duan B, Xia H, Yang X. Impacts of bench blasting vibration on the stability of the surrounding rock masses of roadways[J]. Tunnelling & Underground Space Technology, 2018, 71:605-622.

[2] XIE Cheng-yu, LUO Zhou-quan, JIA Nan, et al. Dynamic effects of open blasting vibration on adjacent buildings and measures for vibration reduction[J]. Journal of Vibration and Shock, 2013, 32(13):187-193.

[3] Jiang N, Zhou C, Lu S, et al. Propagation and prediction of blasting vibration on slope in an

IOP Conf. Series: Earth and Environmental Science **170** (2018) 022063 doi:10.1088/1755-1315/170/2/022063

open pit during underground mining[J]. Tunnelling & Underground Space Technology, 2017, 70:409-421.

[4] Li P, Lu W B, Wu X X, et al. Spectral prediction and control of blast vibrations during the excavation of high dam abutment slopes with millisecond-delay blasting[J]. Soil Dynamics & Earthquake Engineering, 2017, 94:116-124.

[5] Tripathy G R, Shirke R R, M.D. Kudale. Safety of engineered structures against blast vibrations: A case study[J]. Journal of Rock Mechanics and Geotechnical Engineering, 2016, 8(2):248-255.

[6] GU Wen-bin, WANG Zhen-xiong, CHEN Jiang-hai, et al. Influence of charge structure on the energy transfer of blasting vibration and explosive effect[J]. Journal of Vibration and Shock, 2016, 35(2):207-211.

[7] Singh P K, Roy M P, Paswan R K, et al. Blast vibration effects in an underground mine caused by open-pit mining[J]. International Journal of Rock Mechanics & Mining Sciences, 2015, 80:79-88.

[8] Qiu X, Shi X, Gou Y, et al. Short-delay blasting with single free surface: Results of experimental tests[J]. Tunnelling & Underground Space Technology, 2018, 74:119-130.

[9] LIANG Shu-feng, WANG Yu-tao, LIU Dian-shu,et al. Determination of safety coefficient for predicting blasting vibration velocity[J] Explosion and ShockWaves,2015, 35(5):741-746.

[10] Segarra P, Sanchidrián J A, Castedo R, et al. Performance of some coupling methods for blast vibration monitoring[J]. Journal of Applied Geophysics, 2015, 112(112):129-135.