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The Application of Shaped Charge Blasting Technology in Open-pit Mine

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ABSTRACT

Open-pit mine bench blast meet a problem of chunks in Xinjinag Province, using PVC pipe to make a simple shaped for chunk broken, not only to improve the crushing efficiency, economic cost considerations are also more reasonable. The bursting of the open-pit mine will inevitably encounter boulders, secondary crushing principal means of mechanical blasting method, most of mine to DTH blasting crushing method based. The open-pit bench blast for chunk problems In the City of Hami. Using PVC pipe and tin made simple shaped kits broken chunk, not only to improve crushing efficiency, economic are more reasonable. Using ANSYS/ LS-DYNA element shaped concavity blasting of numerical simulation, and the result are analyzed. Proved in field experiments and application of the method used is more feasible method to greatly improve the large secondary crushing efficiency.

Keywords: Shaped charge, Broken, Large chunk, Numerical simulation.

1. INTRODUCTION

The mine opencast coal mine of Xinjiang by mining deep concavity bench blasting method, Early mining of upper coal seam need blasting broken rock cover is mainly silty mudstone, granulite, limestone, protodyakonov coefficient in between 4 to 8. Design of bench height of 12 m, because the rock bedding is disadvantageous for blasting, the banked-up ledge is hard and complete.

According to the requirements of the owner lump size shall not exceed 80 cm *80 cm x 80 cm, in the initial blast, after after blasting site statistics, most of them are long, wide and high, and one of them is not qualified, the main unqualified in size between 90 - 150 cm. Initial construction used Komatsu pc260 efflux hammer and traditional hammer hand drill blasting with broken pieces, high cost and production efficiency is relatively low. Therefore, the bare shaped charges of breaking lump ore experiment is particularly important, site using shaped charges to fragment lump ore. The boulder yield has been significantly improved. Due to the mine opencast coal mine location and lack of material and cold climate of higher price factors, using the numerical simulation method of self-made with cavity shaped charge package broken chunk is used to simulate the process of, with cavity shaped charge from the energy distribution and effusive development process is conducive to boulder fragmentation through verification of the shaped charge is a suitable method for breaking lump ore.

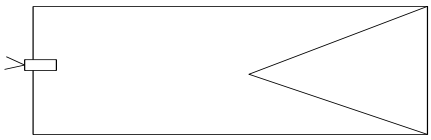
2. EXPERIMENTAL DESIGN

2.1 Cumulative effect

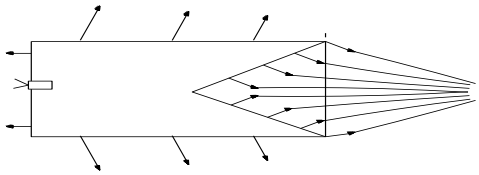
Shaped charge blasting is the movement of explosive product direction and loaded surface approximate vertical rules, made of special shape of the charging construction, can make explosion products together, increase the density of energy flow, and enhance the explosion effect. Shaped charge end is provided with a concavity, when the explosion when the taper part of explosive products for flying, first along the cone surface normal concentrated in one direction, formed a stream of high speed, high pressure efflux flow, area of effect for tapered concavity surface area, the cumulative flow on the rock area is far greater than the ordinary charge at the end of the area, so can form a larger depth. This is because the concavity increase in the cumulative damage.

In order to improve cumulative effect, it should try to avoid high pressure caused by expansion of energy scattered and not conducive to energy concentration factor, when the loaded drug cone groove surface lining on a drug shaped cover charge detonation, taper groove near the explosive energy will transfer to drug shaped cover, the drug shaped cover with great speed to the axis of motion, at the same time, the medicine type cover in under the effect of high temperature and high pressure of the detonation products, the formation of metal efflux, can be seen as a high energy density of the efflux. The detonation wave energy, potential accounted for 3/4, the kinetic accounted for 1/4. And cumulative process, kinetic energy is able to focus, potential energy is not concentrated, and dispersion, so shaped airflow

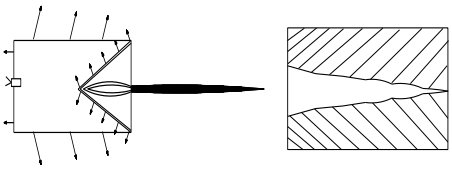
energy concentration degree is not very high. And cumulative process, kinetic energy is able to focus, potential energy is not concentrated, but dispersion, so shaped airflow energy concentration degree is not very high. If you do manage to put energy as possible to convert kinetic energy in the form of, can greatly improve the energy concentration [1-7].



(a) Plug with concavity



(b) The role of cumulative effect diffusion direction



(c) Cumulative effect on rock action principle

Figure 1. Shaped blasting action principle

2.2 Experimental program

Liner cover material and angle characteristics for penetration effect has very important significance, liner cover is pressed to form continuous without fracture of the efflux is longer, the greater density, penetrating deeper. Therefore, the requirement of the medicine liner is that the material is of high density, good plasticity, and cannot be formed in the process of forming the gas.

Shaped material selection according to the different shaped in the shape of a shaped charge liner in different engineering applications, combined with the cost, achieve performance and cost balance.

The use of two kinds of charging methods, the first method is to use 400 mm PVC long plastic tube symmetric cutting in half, the two halves of the same size of the half pipe is tightly pressed together, as shaped charge shell, scene selection more approximate 1000 mm * 1000 mm * 1000 mm large volume block representative as broken objects. A PVC double tube buckle in the central part of the lump ore, curved pipe upward, installed in the pipe internal explosive pressing pressure, through practical woven bag into the sand, the both ends of the pipe and the upper block is dense, both ends of the pipe must be blocked to prevent the explosion of energy dense, from both ends of the explosive energy leakage, efflux to rock direction greatly to reduce the use of charge charge. When do growth strip folded and iron in the same shape with a square wood, when charge sticks in the position below the concavity shaped cover play a supporting role, the purpose is to make the charge Can be as coupling, charge will stick out. Two schemes of pipe volume slightly larger than the volume of explosive, charge to ensure the explosive completely inside the pipe.

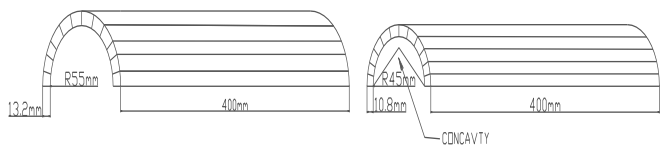
After many trials, for selected one meter square chunk use 500 g - 600 g commodity emulsion explosive can the depth of about 1 m chunk. In the field of many tests and after blasting rock central that explosive explosion site of action can be obvious broken traces similar irregular circular, rocks which were to the ends of the extension of crack dehiscence, reached the expected effect of large broken.

Experimental scheme of two kinds of blasting, rock size with 1000 mm * 1000 mm * 1000 mm, the first scheme shaped tube shaped concavity, use commodity emulsion explosive loading 500 g, shaped tube use PVC pipe for water supply, material is polyvinyl chloride, tube length 400 mm, tube diameter 110 mm, the tube radius 55 mm, tube wall thickness 6.6 mm. half pipe cross-sectional area 4749.25 mm^2, volume 1899700 mm^3, shaped tube wall thickness for double 13.2 mm, 500 g explosive volume 1607680 mm^3; binding energy tube volume is slightly larger than the volume of explosive, in the construction can be approximately regarded as coupling charging.

The second scheme in the tube shaped using white tin made into a simple triangle cone shaped concavity. Use of goods of emulsion explosive loading 300 g, pipe diameter of 90 mm, radius of 45 mm, thickness of the tube wall is 5.4 mm, shaped tube wall is a double-layer pipe wall thickness 10.8 mm, 300 g emulsion explosive volume 9646087 mm^3; semi pipe cross-sectional area of cross-section of 3179.25 volume 1271700 mm^3.

Shaped charge liner material using a 0.4 mm thickness of galvanized iron, the length of 400 mm wide 64 mm, by 64 mm length broadside midline fold formed triangle vertebral, 100 ^{o} energy cavity cone angle, lower volume 405000 mm^3 shaped cover, in part of the medicine is seen as the coupling charging. Field use tin broadside slightly longer than 64 mm, will be longer than the 64 mm to folded tightly wrapped PVC pipe edge, quite similar shaped cover and PVC pipe is closed the.

According to the efflux and with the cone angle of small changes in the characteristics [9-11], the cone angle at 80 ^{o} - 120 ^{o} known as cone angle shaped charge efflux, the main form of conventional rod like efflux. efflux is slender and the high speed, penetration concavity diameter is small, deep, large cone angle of efflux, velocity gradient, large diameter, large penetration recorder diameter, due to the large chunks of rock brittle materials such as crushed, both to ensure penetration depth, but also have some cracks extended range, according to the choice of materials, dimensions, determined at 100 ^{o} cone angle as energy cavity cone angle.



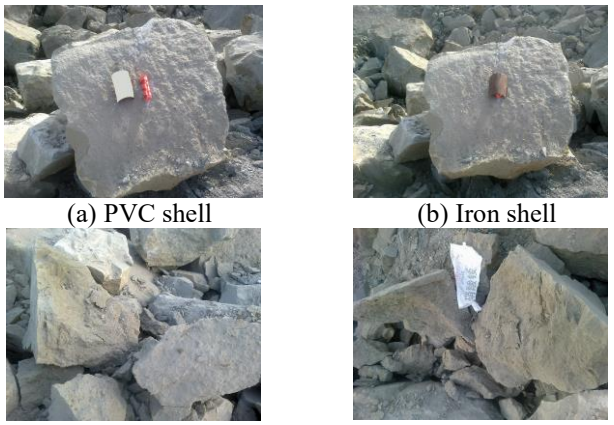
(a)Plan 1 (b) Plan 2

Figure 2. Schematic to two shaped tube

2.3 Test results

Two schemes due to charge different quality, can make the bulk from the central crack, see below. The effect of second kinds of charge scheme, compared to the first only in the pipe with internal self-shaped concavity, similar to the formation of groove shaped blasting effect, the tin made opening angle

for the folded shape 100°, explosive installed in the intermediate pipe and galvanized iron, for the bulk of the same size, about 300 g of emulsion explosives can make the rock crack, the first method is better than the crushing effect, through observation, relative to the first scheme adds a simple shaped concavity blasting of rock crushing after the shape of the fracture area is similar to the shape of long, trough traces due to roll length limit, broken only slightly longer than the length of tens of centimeters, shaped tube length.



(a) PVC shell (b) Iron shell

(c) Effect without concavity (d) Effect with concavity

Figure 3. Broken chunks of the effect of using two programs

3. NUMERICAL SIMULATION

3.1 Crushing process

Shaped charge efflux fragmentation rock cutting process is divided into three stages: slotted stage, quasi steady phase, the termination stage. Efflux in the length direction exist velocity gradient, fast head, tail speed slow, therefore cannot be applied directly to the Bernoulli equation, but a small effluent can think speed is kept constant, can therefore be applied to the Bernoulli equation, which is the so-called quasi steady conditions.

Slotted stage is the beginning stage of rock crushing, efflux head still hit the rocks, generating millions of atmospheric pressure. From the collision point to the rock and the efflux were introduced into shock wave, rock free interface in strong shock wave under the action of rock crack, and efflux residue splash, efflux set up high pressure in the rock, high temperature, and high strain zone. The quasi steady stage, efflux touch the rock after high state rock slot efflux, due to consume most of the explosion ability, so the ability of subsequent less pressure blasting. Subsequent collision energy distribution changes at this stage the efflux is slow, little change in the parameters, the radial variation slot is basically has nothing to do with the time slot, so called the quasi steady stage end stage, in this stage the situation is very complicated, the efflux velocity is quite low, the rock strength effect more and more obvious, cannot be ignored Slightly; secondly, due to the efflux velocity reduce, not only charge blasting of rock failure rate decreases and of rock damage ability also fell, following efflux push not to open the front has been released energy efflux residue, subsequent efflux effect on residue, so as to reduce the damage of surrounding rock, in fact between the rock and water efflux cutting, there is always a efflux residue accumulation layer, in the quasi steady stage accumulation layer is very thin, at the termination stage is getting more and more thick, the rock cutting process is completed. Efflux in the later have a neck shrinkage and fracture. In order to compute, using drugs to liner and the charge axis intersection coordinate origin o to shaped charge liner bus for the abscissa X of the Cartesian coordinate system. Charge, detonation product of the contact of the shaped charge cover to generate contact explosion, according to the instantaneous hypothesis, detonation product only in the perpendicular to the loading direction on flying in the shaped charge cover and explosives contact surface pressure are equal to the instantaneous explosive detonation pressure, but different role stress is different, the pressure time is equal to scattering at the time, that is, from the nearest free surface to reach the point of distance and scattering displacement speed ratio.

Large regarded as relatively complete overall in shaped charge cover office take infinitesimal body a (as shown in the figure), the coordinates (x, y).$Int = 0$ (explosive detonation instant) sudden increase in pressure and action time: stop suddenly. Therefore, role in the element of impulse can be calculated as

$$I(x) = \bar{p}_H \tau \mathrm{d}s \quad (1)$$

In Eq (1): $\bar{p}_H$ ---instantaneous blast pressure, Pa

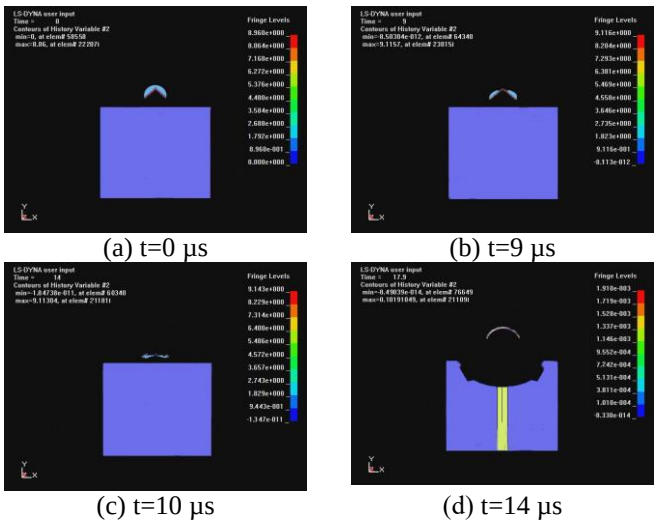
ds ---Infinitesimal body are, τ

τ ---When the instantaneous detonation pressur, s

3.2 Icavity effect breakup model

According to the theory of efflux mechanics [14-18], in the detonation process, the outer part of the metal liner will form a “triangle cone”, and the inside part of the formation of “efflux”. We use the medicine cover wall thickness is 0.4 mm, about 1 % of the diameter of the mouth inside, the liner material for tin, detonation wave arrive at the liner the initial pressure of hundreds of thousands of atmospheres, far greater than the liner metal material strength, and cover in the process of movement, plastic deformation work into heat, so that the cover temperature strength decreased, and the distortion is very strong in a very short period of time. The physical process so, the use of materials using Johnson-Cook material model and Mie-Gruneisen state equation to describe the dynamic response process. The numerical model of the explosive, liner, air and rock is composed of 4 parts, including explosives, liner and air used Euler mesh modeling unit using multi material ALE algorithm, the target Lagrange mesh modeling, target and air, the liner material by a coupling method for mesh ANSYS. using ALE algorithm, so the division for each model are used to map grid, body mapped mesh, the body must satisfy certain special conditions such as regular shape, the number of units are defined and opposite side the edge must be equal, and the explosive liner, the air domain shape is irregular, if divided into mapping grid is difficult, the segmentation approach here, the body is divided into several block volume shape rules, The use of grid stretching, rotation, sweeping and other commands, then the merged entity, explosives, drug shaped cover, air Part 3 corresponds to the surface should have a consistent form of grid, between such different part to ensure common node, in favor of explosion parameters transfer. Rock using square form, explosive type cover thickness is 0.4 mm, the shaped charge cover cone angle of 100 °. The target

cube, target size is 1000 mm * 1000 mm * 1000 mm, 4 cm and X in the blasting height, axis symmetry constraints applied perpendicular to the Z axis of symmetry on the surface, the other surface is a free edge interface. Outer boundary surface air is applied for non-reflecting boundary conditions, air dielectric material simulation of infinite domain. The model needs to consider them in high temperature, high pressure, and flow and failure behavior under high strain rate. The 100 º efflux cone angle is simulated and calculated. The parameters of efflux liner with symmetrical features, so it can be simplified as a two-dimensional axisymmetric problem, the calculation model of the use of 162 solid elements in the division. The definition of unit type, select the Axisymmetric and Area weighted options, use unit algorithm 14 because of metal cover of large deformation, the efflux formation process in the explosion under large strain, using the Lagrange algorithm will cause Dan Yuanyan heavy distortion, therefore To use the adaptive grid. But before Dyna treatment, the definition of adaptive grid is only applicable to the solid 163 unit, so add in K file editing control adaptive mesh of the solid 162 unit, so you can avoid the calculation due to mesh distortion in between explosive and metal cover contact using the CONTACI-2D-AUTOMATIC-SURFACE-To-SURFACE contact algorithm. The liner itself with CONTACT-2D-AUTOMATIC-SINGLE-SURFACE contact algorithm, using cm-g-s modeling. The computation time is 17 us, the use of small restart analysis process, 1 US basic explosive detonation is completed, the efflux formation is very small, and it will remove the explosive part and contact. Choose a suitable time step setting calculation in explosive and avoid the mesh distortion calculation caused by the suspension of explosives from the top center point initiation. The material model and the State Party shaped charge liner process, numerical model by explosives, air, target board is composed of four parts. The air an Eulerian mesh modeling, unit using single point integral multi material ALE algorithm, the rock medium using a Lagrangian mesh modeling, the constant stress solid element, mesh mapping by using the finite element model and unit length is 1 cm, so as to increase the accuracy, save computing time. The air, rock treatment for common node, to facilitate the energy of the explosive can be transmitted through the air to the rock. The air outside interface design for transmission to simulate the effect of infinite domain by flow solid coupling theory.



(a) t=0 μs (b) t=9 μs

(c) t=10 μs (d) t=14 μs

Figure 4. Simulation of shaped blasting a broken chunk

3.3 Results analysis

(1) From the rock breaking effect it can be seen that large pieces of rock are broken more evenly, and there is no obvious crushing area in the charge, which provides the conditions for the subsequent use of the rock, but also easy to transport.

(2) According to the simulation results, the blasting energy energy cavity is more concentrated, but also save the explosives, depth of crushing energy efflux enough. In the initial stage of the explosion and conventional charge blasting, there is no significant difference between t=4 cumulative point energy increased significantly, t=9 energy cavity was crushed, the efflux will be formed when the efflux formation can be t=10; see clearly the focus of efflux formation, the explosion in the split here gap, so that the subsequent function of explosion gas provides a guiding role, t=14 efflux has ended, and the explosion energy trace on the rock to rock fissures in the further development of the upper part of cover and trace the subsequent energy in the drug t=17. From the above analysis we can see that the efflux can make energy efflux into focus, therefore should choose a good fried high in engineering operation. The drug shaped vertical distance to cover cone bottom rock is called fry High [14].

(3) Efflux head and tail velocity difference, efflux movement in the process of elongation, and the efflux is longer, the more favorable for penetration, which requires a certain high. In fact there are high fried fried dual role, on the one hand with the increase of the height of the burst of efflux stretch, can improve the penetration depth; on the other hand, with the increase of height of burst, efflux radial dispersion and swing, extending to a certain extent after the fracture phenomenon, and the penetration depth decreases. And the maximum penetration depth corresponding to the height of burst, called height of burst, height of burst actually is a favorable high range, usually choose good height of burst and high liner materials, cone angle, explosive performance and so on. With the increase of height of burst favorable cover cone angle increases, the ductility of the material better liner, efflux formation is long, the favorable burst height is larger. In addition, the high explosive shell can increase and the type of Medicine Cover the impact pressure increases, the favorable burst height also increased. The commonly used drug shaped cover, the bottom of the cover is favorable blasting height diameter of 1 - 3 times [9] for cone angle of 100 º degrees of the drug shaped cover, cover height equal to width is the best fried parameter. For efflux penetration into rock, we choose choose the medicine cover bottom diameter of 1 times and 2 times the height of burst. The explosive in the air, damage to the target and the distance from the center of the explosion. The distance away from the explosion center distance, the air shock wave in explosion products from the target only by the shock wave. The target near the explosion the center, despite the shock wave front pressure is very high, destructive stronger, but because of the role of the smaller, with only partial destruction. The target is far away from the center of the explosion, although the shock wave front pressure decay, but because the target affected area expands, positive pressure time growth, often Cause large area overall damage.

4. CONCLUSION

Shaped charge shape has a lot of, a horn shaped, cone shape, round shape, the former two kinds of shaped charge efflux effect better, cone shape of the liquid efflux although not the best, but considering the large breaking does not need to strong efflux can make the broken stones does not appear to be crushed and shaped materials also facilitate processing. Moreover, is in the shape of tapered columns similar to a trough type, but also help to bulk fracture development, avoid fracture is too concentrated, cleft cannot well down the development. The construction method can be no drilling can achieve good crushing effect, so to control the engineering cost, and improving the progress of the project has a good promotion value.

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NOMENCLATURE

$\overline{p}_H$	Pa	Instantaneous blast pressure
s	m^2	Infinitesimal body are
τ	s	When the instantaneous detonation pressure