Tunnelling and Underground Space Technology 49 (2015) 249–252

Contents lists available at ScienceDirect

Tunnelling and Underground Space Technology

journal homepage: www.elsevier.com/locate/tust

Experiment research on the rock blasting effect with radial jet cracker

Wei Chen, Honghao Ma *, Zhaowu Shen, Debao Wang

Department of Modern Mechanics, University of Science and Technology of China, Hefei 230026, China

ARTICLE INFO

Article history:
Received 29 November 2014
Received in revised form 6 May 2015
Accepted 8 May 2015

Keywords:
Cut blasting
Crack
Shaped ring
Explosion
Shaped charge jet

ABSTRACT

Due to the low efficiency problem of cut blasting in rock drivage, a new type of jet cracker is invented. There are three development stages of this new type of radial jet cracker, and each stage has its corresponding experiment, and optimal design will be carried out based on the problems of the previous stage, but experimental principles of these radial jet crackers are still the same. The main structure of the radial jet cracker is circular tube, and there are several shaped rings designed on it, which not only can reduce charge quantity but also raise the utilization ratio of explosive energy. Experimental results show that, with this cracker, the utilization ratio of blasting hole is 98%, and the blasting efficiency and the length of cyclical footage had been improved.

1. Introduction

Drilling and blasting is the most important method of rock excavation and rock breaking in mining and tunnelling especially in hard rock conditions despite the rapid developments in the application of mechanical excavators (Jimeno et al., 1995; Langefors and Kihlström, 1978; Ramezanzadeh and Hood, 2010). Much safer and faster rock excavation technologies are possible with the recent developments in explosives, initiating and drilling systems, such as, emulsion, Nonel and electronic detonator and automation. However, conventional blasting often exists overbreak, underbreak, boulder yield problems, which are caused by unreasonable blast design or complicated geological environment. Those phenomenon may also give rise to additional mucking time, need extra drilling and are costly (Dey and Murthy, 2012).

Drill and blast technique has a disadvantage that sometimes it produces cracks in uncontrolled manner and also produces micro cracks in the block as well as in remaining rock, if not carefully carried out. Therefore, attempts have been made to develop controlled growth of crack in the desired direction (Fourney, 1995; Lu et al., 2012; Singh et al., 2014). Fourney (Fourney et al., 1978) used a blasting method which utilizes a ligamented split-tube charge holder in smooth blasting, through controlling the crack propagation direction of rocks, the forming quality of perimeter holes are improved and their maintenance costs are also reduced. Bjarnholt et al. (1983) put forward linear shaped charge used in contour blasting, achieving the aim of directional controlled blasting (Innaurato et al., 1998).

In rock blasting, most of the explosive energy consumption in smash district. Unspecified fractures are produced under the action of the stress wave from the explosion, which results in uneven rock fragmentation (Melnikov et al., 1978; Strelec et al., 2011). In traditional cut blasting, for the sake of eliminating the clamping effect of rocks at the bottom of blasting hole and reduce the resistance of bottom burden with the increase of mining depth, it is common to overcome the problem by increasing the subdrilling to lower the center position of the charge (Jimeno et al., 1995), which is largely enhanced the cost.

This paper describes a radial jet cracker which is designed to solve the uneven rock fragmentation problem and subdrilling phenomena in cut blasting. Experiments are conducted to demonstrate the ability of penetration in steel, and the efficiency of cut blasting and utilization ratio of borehole are studied by simulation cut blasting experiment in laboratory scale.

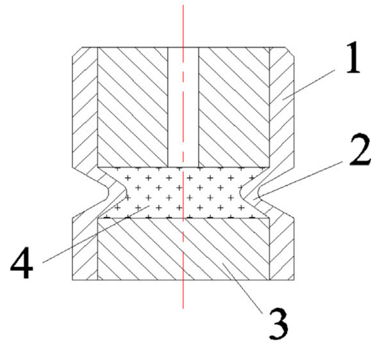
2. Basic design and principle of the radial jet cracker

As shown in Fig. 1, radial jet cracker makes the best use of its cartridge case to be shaped charge structure, and the cartridge case is a circular shell tube with a V-groove ring outside. The V-groove ring serves as shaped cover to accumulate energy, so it is called "shaped ring", and the shape of the vertical-section is wedge or semicircle.

The V-groove ring of shell tube inside are full of explosives, while the rest of shell tube are filled with charge divider device. The charge divider device is made of nylon rod or other materials

* Corresponding author. Tel.: +86 013637098366.
E-mail address: hhma@ustc.edu.cn (H. Ma).

http://dx.doi.org/10.1016/j.tust.2015.05.008
0886-7798/



1. shell; 2. shaped ring; 3. charge divider device; 4. main charge

Fig. 1. Structure diagram of the radial jet cracker.

with a hole in the center to pass through the detonating cord or detonator, and a radial shaped charge jet will be formed during the detonation process to penetrate the surrounding rock medium, and these cracked rocks will be threw out by delay blasting technology. By this method explosives are saved a lot and detonation energy can be reasonably distributed, meanwhile the blasting effect is improved and the cost of blasting is reduced.

3. Penetration experiment of a single radial jet cracker

In order to verify the penetration ability of a single radial jet cracker, we conducted a steel plate penetration experiment.

3.1. Material and design

In this experiment, cylindrical copper pipe is used as cartridge case, the length and external diameter of the pipe are 40 mm and 30 mm especially, and the thickness of the shell is 2 mm. Outside of the shell, there is a V-groove ring of 5 mm depth and 60 cone angle, see Fig. 2 (a). The awaiting penetration target is steel plate (type of Q235) with the size of 90 mm × 90 mm × 30 mm, and there is a central hole with the diameter of 42 mm in it. After putting the radial jet cracker in the central hole of the steel plate, the corresponding blasting height is 6 mm, see Fig. 2(b).

The formula of the explosives used in the experiments is RDX and TNT with mass ratio of 70:30, the density and mass of mixed explosives are 1.7 g/cm^3 and 8 g especially. The explosive is charged in the central of the radial jet cracker by casting method and plugged by nylon rods, and will be detonated by a detonator.

3.2. Experimental results and discussion

The steel plate is penetrated by the radial shaped charge jet after explosion, and in order to observe the penetration effect inside of steel target clearly, the steel target is split into two parts. Fig. 3 shows that the average penetration depth is 5 mm (the largest value is about 7 mm), which are created due to the radial shaped charge effect of one V-groove ring of radial jet cracker. Rocks belong to brittle materials, and their strength is far lower than steel. Therefore, through the experimental results, we can foresight that the radial jet cracker will have a much better cracking effect if applied in the rock blasting.

4. Cut blasting simulation experiment of a multiple-radial jet cracker

4.1. Introduction of the multiple-radial jet cracker

In the actual blasting engineering, the depths of some blast holes are very deep, only one single radial jet cracker may not meet the requirements for cut blasting. Therefore, we design a multiple-radial jet cracker to solve this problem. The radial jet cracker is the same as that used in the Section 3 except its length is 350 mm and the number of V-groove rings outside is 13, as show in Fig. 4(a). Its basic design and principle are still the same as the single radial jet cracker. The penetration ability caused by radial jet cracker has been validated in the section 3, but it is still not clear whether the structure is able to improve the blasting efficiency. To confirm the blasting effect of radial jet cracker, a cut blasting experiment of concrete is conducted in laboratory scale, and Fig. 4(b) shows the design of the experiment.

4.2. Preparation and experimental method

The concrete in the experiment is constrained by seamless steel tube, which not only can keep the concrete sample with high strength but also reduce the edge effect of concrete sample under laboratory conditions (Yong et al., 2006), see Fig. 4(b). The length and outer diameter of seamless steel tube are especially 500 mm and 310 mm, and the wall thickness of the seamless steel tube is 9 mm. In the center and peripheral of the concrete, precast seven holes are made by PVC tube of 25 mm diameter and 500 mm length. The formula of the concrete is the mixture of ordinary silicate cement, sand and water with mass ratio of 1:2:0.4 and the density of the concrete material is 2.13 g/cm^3. The common mechanical and physical parameters of the sample are shown in Table 1.

The purpose of cut blasting is to form cavity in the excavation face, which can increase free face for the blasting of following auxiliary blastholes. In this experiment, the auxiliary blastholes are designed as free face for the central borehole, which can provide free space for the borehole blasting, and cut blasting of rocks can be simulated by this experiment in laboratory scale. As shown in Fig. 4(b), the multiple-radial jet cracker is put into the central borehole of concrete, and auxiliary blastholes are charged with

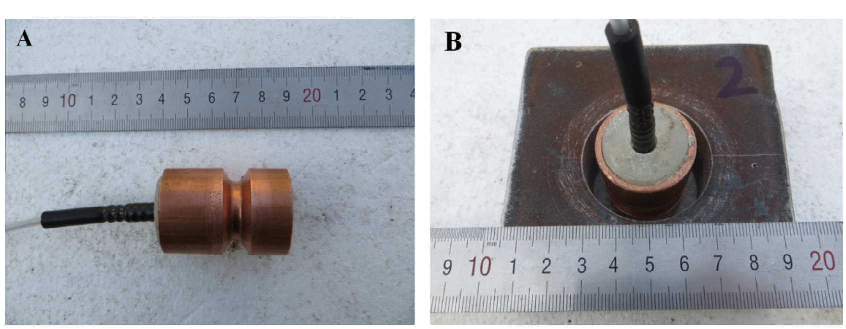


Fig. 2. Experimental materials and device.