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Cognition, Application and Discussion on Shaped Charge Hydraulic Smooth Blasting Technology

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ABSTRACT

In the past, the main method of tunnel excavation in China was drilling and blasting, but the biggest shortcoming of the traditional drilling and blasting method is that it is easy to cause serious overexcavation and underexcavation. At the same time, the operation cycle time of this method is long, which leads to a serious waste of resources. Not only that, a large number of toxic gases and dust produced after blasting also do harm to the health of construction workers. So this is an urgent need for a new construction technology to solve this worldwide problem. In this situation, the leading experts in the field of tunnel, "The survey and design master of China" Shi Yuxin, Liu Pei, and well-known expert in explosion field, yan-sheng ding, professor Chen Chengguang and Gu Yicheng, the experts group, cooperate with The Fifth Branch of China Railway 18th Bureau in northwest project management department, developed a new technology. This technology has passed the appraisal of scientific and technological achievements organized by Tianjin Science and Technology Commission, which is shaped hydraulic smooth blasting technology. The comprehensive evaluation of the technology is "international leading" level.

This paper is mainly aimed at the drawbacks of drilling and blasting construction, combined with the author's cognition and discussion on the introduction of the new technology of cumulative hydraulic blasting and the practical application effect in the tunnel excavation process of the fourth company of China Railway 14th Bureau Group in the second division of the 9th bid section of Zhangjihuai Railway in Huainan Province.

1. Introduction

Traditional smooth blasting requires "small spacing, large inner ring; The bottom of the hole is neat, and the external plug is controlled. Low detonation velocity, uncoupling; Thin wire, heavy blockage; Simultaneous initiation, less disturbance; Fine, smooth blasting well". According to incomplete statistics, the traditional method of drilling and blasting for tunnel excavation caused serious overexcavation, which resulted in serious waste (slag earthwork increased, increased the single cycle construction time, at the same time the initial shotcrete and lining concrete square also doubled), greatly aggravating the construction cost. The hole spacing of traditional blasting operations is generally controlled around 40-50 cm, but the shaped hydraulic smooth blasting technology can increase the hole spacing to 100 cm, which saves a lot of time and labor. The shaped charge hydraulic smooth

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blasting not only shortens the working procedure cycle, but also greatly solves the problem of tunnel excavation, which is difficult to be overcut and undercut. At the same time, the drilling operation is carried out by adopting the drilling trolley newly developed in recent years, which is not only efficient and fast, but also greatly reduces the construction cost. In addition, the water bag added in the blasting hole will produce water mist when blasting. The effective combination of water mist and dust will greatly reduce the effect of dust, reduce the harm of dust on the respiratory system of tunnel workers, and ensure the health of tunnel workers [1].

2. Definition and Principle of Shaped Hydraulic Smooth Blasting

When the traditional drilling and blasting method is used in construction, due to the non-directional blasting force during explosive blasting, the newly excavated face and blasting surface are uneven, especially the convexity of the vault can even reach more than one meter. If there are faults and interlayers in the rock, then this value is immeasurable. The people who have the tunnel excavation blasting construction experience know that the traditional smooth blasting during the construction of the explosive, will spread the rock stress wave generated when the radial stress and tangential stress, is arguably the burst pressure in all directions, the light shot hole adjacent each other "empty holes", so in the light shot hole on both sides of the attachment to produce stress concentration high tensile stress exceeds the rock tensile strength, so the formation of the initial crack in the hole between the rock mass is much more than the other direction, in addition, due to the explosive generated by the effects of the static high pressure gas expansion prompted the initial crack extension to expand further [2]. This is the key point why the tunnel face and the vault will be a large area of uneven and overexcavation. "Accumulated energy" in shaped charge hydraulic blasting is to gather the blasting energy as much as possible to produce a directional energy release. In addition to the stress wave action mentioned above, the high temperature and high pressure jet generated by the shaped charge tank and the "water wedge" effect produced by the water bag in the blast hole under the explosion action promote the extension and expansion of the initial crack in the rock. Due to the compound filling of water bag and mud, the expanded gas generated by explosive explosion is effectively controlled in the gun hole of shaped charge hydraulic photoblast. The static effect of the expanded gas is much stronger than that of the conventional smooth blasting without filling, which is more conducive to the extension and expansion of the formed cracks. Due to the high temperature and high pressure jet of the shaped tube, the function of "water wedge" and the enhancement of the static effect of the expanding gas, the smooth blasting technology of shaped charge water pressure has solved the shortage of the conventional smooth blasting, improved the flatness of the smooth blasting surface greatly and greatly improved the situation of overexcavation and underexcavation. In addition, the tunnel will produce serious dust after blasting excavation, which requires a large fan to support the air belt for dust removal. Under normal circumstances, a blasting operation takes about 0.5-1 hours for dust removal, and the incidence of lung disease among workers engaged in tunnel excavation is many times higher than that of ordinary people. But because the water bag is placed in the holes of water pressure blasting, the water mist produced in the blasting process can reduce the dust, this can improved the working environment, and protect the workers' health, and it can also avoid the dust spread into the atmosphere, also can also save a sum of spending on power resources, reduce the production cost [3].

3. Charge Technology of Shaped Energy Tube Device

3.1 Parameters and Principle of Shaped Energy Tube

The shaped energy tube is made of a kind of special plastic pipe with anti-static flame retardant. The shape of is shaped energy tube is special-shaped double groove, and the length of the pipe is 2, 2.5 and 3 m. The length of the shaped energy pipe on the construction site can be processed according to the depth of the hole. It is composed of two identical half-wall tubes with a wall thickness of 2 mm. There is a recessed groove in the middle of the half-wall tube, which is called "the shaped energy groove". The section size of the energy shaping tube: the top angle of the energy shaping groove is 70°, the distance of the top of the energy shaping groove is 17.27 mm, the width of the half wall tube is 24.18 mm, and the width of the energy shaping tube made of the two half wall tubes is 28.35 mm.The direction of energy accumulation can be adjusted by 8° ~ 10° to adjust the alignment of the energy accumulation groove with the excavation profile.The explosive in the shaped tube device is traditional rock emulsion explosive. The section formed by the dimensions inside the shaped tube is the section of the explosive. Its working principle is that after the charge explodes, the explosion energy near the shaped charge hole will converge towards the axis of the hole, forming a gas jet with high density,

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high speed and high pressure. In other words, when the charge pack has a shaped charge hole, it can locally gather in the direction of the shaped charge hole and generate supernormal blasting energy. Therefore, the gas jet with high density, high speed and high pressure formed by shaped charge blasting can improve the explosive power [4].

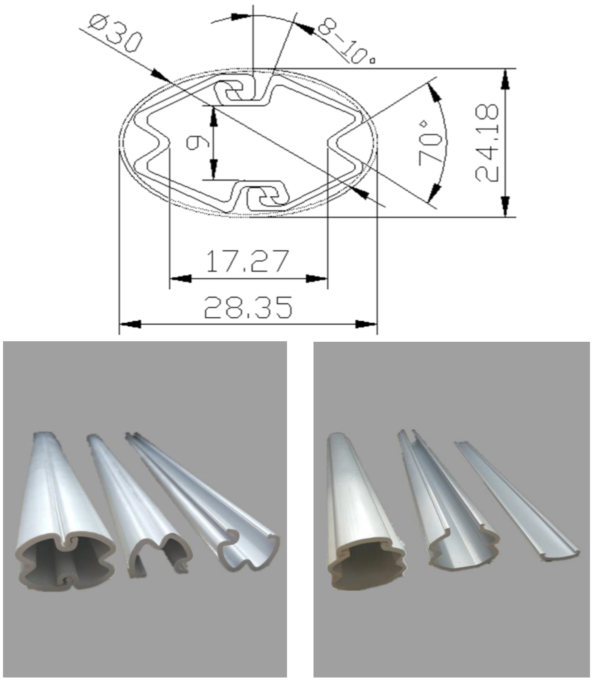

Figure 1. Energy collecting tube

3.2 Assembly Method of Shaped Energy Tube Device

Detonation line and detonator in shaped tube device are common detonating equipment in construction site, and the detonator is the same as the conventional smooth blasting detonator. Injection of half wall tube requires injection gun and air compressor and other equipment [5]. The length of injection gun is 45 cm and the weight is 0.8 kg. Small air compressor power 800 W, weight 23 kg (for reference only, equipment model should be ordered according to the actual need to confirm).

The first step: cut one end of the cartridge and the packing skin along the longitudinal side of the cartridge, then merge the two cartridges along the longitudinal cut surface and put them into the cartridge barrel, and finally tighten the rotating cover;

The second step: pressurize the injector gun with a pressure of 1 ~ 2 atmospheres.

The third step: the hand holds the injection gun along the half-wall tube from head to tail in a uniform speed, the explosive from the muzzle continues to flow into the half-wall tube.The density of line charge is generally 0.35 ~ 0.4 kg/m for hard rock, 0.3 ~ 0.35 kg/m for medium hard rock, and 0.2 ~ 0.3 kg/m for soft rock.Before the two half-wall tubes of explosives are connected, a blasting wire is placed in one of the half-wall tubes, and then assembled together;

Step 4: In order to achieve the ideal blasting effect, make the shaped tube not fit to the hole wall after it is placed in the gun hole, and ensure that the shaped groove in the shaped tube device is aligned with the tunnel contour to prevent rotation, both ends of the shaped tube device should be covered with foam cotton rings and fixed with rubber tape, so that the shaped tube can be completely assembled.

In particular, for the sake of safety, it is better not to install the detonator in the assembling room of the shaped tube device, and then install it when it is transported to the face of the palm.The whole charge injection process is simple and quick, and the number of shaped tube devices needed for one circular light blasting perforation can be assembled in about an hour [7].

3.3 Technical Points of Shaped Hydraulic Smooth Blasting

3.3.1 Determination of peripheral hole parameters

The hole layout of shaped charge hydraulic smooth blasting is exactly the same as that of common smooth blasting, and the drilling tools and techniques are unchanged [6]. The difference lies in the spacing of the surrounding holes. The spacing of the surrounding holes in the conventional smooth blasting is 40-50 cm, while the spacing of the surrounding holes in the shaped water pressure smooth blasting is 80-100 cm. The spacing of the arching line and surrounding rock joints can be appropriately reduced according to the field conditions. Due to the different properties of surrounding rock strata in Zhangjihuai railway construction site where the author is located, the spacing of the surrounding holes controlled by the step method is about 60-90 cm when the step method is used, and the ideal effect is achieved.

3.3.2 Loading operation steps

Before charging, the residue in the hole of the gun must be cleaned up to prevent the loading of the shaped energy tube, and the processed shaped energy tube should be transported to the construction face for loading.

Step 1: fill the bottom of the hole with a water bag. The water bag must be placed at the bottom of the hole without any gap.

Step 2: load the shaped tube device. The length of the shaped tube can be made according to the depth of the hole, usually 2.5m, which is 70% of the depth of the hole.

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The shaped tube device must be next to the water bag at the bottom of the hole, and the shaped groove should be consistent with the contour surface, that is, parallel to the tangent direction of the excavation line.

Step 3: Fill two water bags and pound them properly with wooden guns.

The fourth step: the gun mud processed by the gun mud machine is backfilled and stuffed until the gun hole mouth, and the gun mud is tamped with the gun stick to be solid and plays the role of filling.

After all the holes are loaded, they are connected and detonated like a regular smooth blast.

4. Time Consuming and Analysis of Each Process of Shaped Charge Blasting

According to the shaped hydraulic smooth blasting technology in actual construction application, according to different geological conditions, mechanical equipment, such as climate condition, adopt the realistic record method, the drill hole charge, slag zone, measuring unreeling, bolting and shotcrete time consumption and to keep a record amount of sprayed concrete and the initial design and the actual consumption of sprayed concrete were analyzed, according to the result of field records were analyzed, and a single loop operation time with an average of 17.15 hours, significantly less than the conventional blasting used in 19.2 hours.

The average working time of each process is as follows:

Table 1. average working time of each process

Process	Time(hour)	
	Conventional blasting	Accumulated hydraulic smooth blasting
Drilling and blasting	3	2.5
Eeslag	3.5	3.2
Eliminate danger	0.5	0.3
Measurement	1	1
Floor stand	3.0	2.5
Advance anchor bolt	3	3
Sprayed concrete	5	4.5
Total	19.2	17.15

5. Analysis of Technical and Economic Effect

Table 2. Comparison table of explosive and detonator dosage

Number	Project		Normal blasting amount	Shaped charge blasting amount	Savings	Savings per extension meter	Money saving per extension meter
1	Lujiazhuang tunnel exit	Explosive	194	162	-32	-12.8	-131.712
2		Detonator	165	134	-31	-12.4	-78.12
3		Detonating cord	0	54	54	21.6	61.34
4	Yanshan tunnel exit	Explosive	197	163	-34	-13.6	-139.94
5		Detonator	172	128	-44	-17.6	-110.88
6		Detonating cord	0	54	54	21.6	61.34

Table 3. Comparison table of the amount of tunnel slag and jet concrete

Number	Project		Normal blasting amount	Shaped charge blasting amount	Savings	Savings per extension meter	Money saving per extension meter
1	Lujiazhuang tunnel exit	Quantity of slag	375m³	328m³	-47m³	-15.6m³	-421
2		Jet concete	49m³	36m³	-13m³	-4.3m³	-2322
3	Yanshan tunnel exit	Quantity of slag	380m³	321m³	-59m³	-19.6m³	-529.2
4		Jet concete	51m³	37m³	-14m³	-4.7m³	-2538

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Table 4. Statistics of overcut and undercut sections of conventional blasting tunnels

Number	Tunnel section	Starting and ending mileage section	Average Overcut (cm)	Reserved settlement (cm)	Excessive cutting volume of this section (m³)	Average Excessive Excavation Per Duct (m³)
1		DK204+124-121	47	10	25.566	8.522
2	Lujiazhuang tunnel exit	DK204+121-118	44	10	24.528	8.176
3		DK204+118-115	50	10	27.183	9.061
4		DK206+191-188	43	10	23.874	7.958
5	Yanshan tunnel exit	DK206+188-185	46	10	25.134	8.378
6		DK206+185-182	51	10	27.906	9.302

Table 5. Overcut and undercut section statistics of shaped charge hydraulic smooth blasting tunnel

Number	Tunnel section	Starting and ending mileage section	Average Overcut (cm)	Reserved settlement (cm)	Excessive cutting volume of this section (m³)	Average Excessive Excavation Per Duct (m³)	
1		DK204+115-112	23.4	10	12.766	4.255	6.15
2	Lujiazhuang tunnel exit	DK204+112-109	22.2	10	12.341	4.113	6.16
3		DK204+109-106	25.1	10	13.153	4.384	6.17
4		DK206+182-179	22.1	10	12.324	4.108	6.15
5	Yanshan tunnel exit	DK206+179-176	21.3	10	12.288	4.096	6.16
6		DK206+176-173	20.6	10	12.213	4.071	6.17

Table 6. Comparison of the amount of tunnel resilient: Statistics on resilient of conventional blasting tunnel

Number	Tunnel section	Starting and ending mileage section	Average Overcut (cm)	Designed quantity (m³)	Excessive cutting volume of this section (m³)	Outgoing quantity of mixing station (m³)	Resilient rate amount (m³)	Resilient rate
1		DK204+124-121	47	18	25.566	50	6.434	35.7%
2	Lujiazhuang tunnel exit	DK204+121-118	44	18	24.528	49	6.472	35.9%
3		DK204+118-115	50	18	27.183	52	6.817	37.8%
4		DK206+191-188	43	18	23.874	48	6.126	34.0%
5	Yanshan tunnel exit	DK206+188-185	46	18	25.134	50	6.866	38.1%
6		DK206+185-182	51	18	27.906	52	6.094	33.8%

Table 7. Statistics on resilient of shaped water pressure smooth blasting tunnel

Number	Tunnel section	Starting and ending mileage section	Average Overcut (cm)	Designed quantity (m^3)	Excessive cutting volume of this section (m^3)	Outgoing quantity of mixing station (m^3)	Resilient rate amount (m^3)	Resilient rate
1	Lujiazhuang tunnel exit	DK204+115-112	23.4	18	12.76	34	3.24	18%
2		DK204+112-109	22.2	18	12.34	33	2.66	14.7%
3		DK204+109-106	25.1	18	13.15	35	3.85	21.3%
4	Yanshan tunnel exit	DK206+182-179	22.1	18	12.32	33	2.68	14.8%
5		DK206+179-176	21.3	18	12.28	33	2.72	15.1%
7		DK206+176-173	20.6	18	12.21	33	2.79	15.5%

Figure 2. Renderings of Yanshan tunnel exit after blasting

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6. Summing up of the Process of Shaped Charge Hydraulic Smooth Blasting

The new technology of shaped charge hydraulic smooth blasting was officially implemented and applied in 2016 [8]. Up to now, the usage of shaped charge tube has been greatly increased. The engineering projects using this technology have reached more than one hundred, and a large number of projects are focused on the roof cutting and mining of coal mines with shaped charge blasting in the tunnel of iron work foundation, as well as a large number of cooperative projects of defense system. Relevant personage points out, in the industry in energy saving, transformation and application, should think of conservation of energy and matter, big blasting has its strengths, but uneven, broken blocks of the secondary crushing will inevitably affect the improvement of mechanical efficiency, and general hand drill hole blasting method, low labor productivity, far cannot satisfy the digging of mechanical operation and production needs [9]. The blasting shaped charge tube is a breakthrough in the technical scope of smooth blasting. Under the environment of advocating energy conservation, emission reduction and effective application of energy in China, it will have an important impact on the current shaped charge tube industry, and is conducive to promoting the customization and promotion of the technical standards and specifications of the new generation of smooth blasting shaped charge tube [10].

The application of the hydrostatic smooth blasting technology in the construction site of Zhangjihuai Railway Nine Standard Two Branch has been strongly recommended and supported by the leaders of the group company [11], and the field trial has also proved that this technology is better than the conventional smooth blasting in terms of construction period, material consumption or environmental protection. Hunan Zhangjihuai high-speed railway project in addition to China Railway 14th Bureau other construction units have also introduced the new blasting technology, have received a good effect. It not only reduces the construction cost and saves the expenditure, but also plays a significant role in the field of environmental protection and teaching [12].

The author thinks that the shortcoming of the tube is that it can not be applied to different rock strata with different properties and joint direction, which requires further innovation in technology.However, with the rapid innovation and development of science and technology, it is believed that there will be more new technologies, new processes, new equipment to serve our engineering industry, and then to improve the quality of life of all mankind better!

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