Rock breaking methods to replace blasting

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Abstract. The method of breaking rock by blasting has a high efficiency and the cost is relatively low, but the associated vibration, flyrock, production of toxic gases since the 1970’s, the Western developed countries began to study the safety of breaking rock. This paper introduces different methods and their progress to safely break rock. Ideally, safe rock breaking would have little vibration, no fly stone, and no toxic gases, which can be widely used in municipal engineering, road excavation, high-risk mining, quarrying and complex environment.

1. Introduction

In modern construction, blasting is the predominant method used to break rock [1]. The rock breaking efficiency is high, the cost is relatively low, but its resulting vibration, possible flyrock, and toxic gas production makes it a dangerous method from a safety standpoint. Since the 1970’s, Western developed countries began to study alternative methods to break rock. During the 1980’s, China also started this re-search, although much progress has been made, due to its late start, the overall technology is relatively be-hind [2]. By using non-explosive means to break rock, there are several advantages such as little vibration, no fly stone, no toxic gas, and a high degree of safety [3]. These methods are widely used in municipal engineering, road excavation, high-risk mining, mountain quarrying, and complex environmental rock breaking projects [4]. Some of these methods include mechanical forces, physical chemistry, and electrical stimulus to break the stone.

2. Mechanical methods

2.1. Hydraulic Splitting

Hydraulic splitting machine in the country widely used in stone mining, which has a simple operation, high security, environmental protection and economic advantages. The hydraulic splitting machine consists of two parts: the splitter and the power station. The power station includes the pumping station, the hydraulic cylinder, the hydraulic pipe and the control element. The splitter is a wedge assembly with mechanical magnification to produce the pump station Longitudinal thrust into transverse thrust, broken rock.

Hydraulic splitting machine rock breaking process: According to the rock hardness, free surface, rock breaking degree and the requirements of the direction of rock breaking and other conditions, drilling with a drilling machine; wedge pressure into the rock, pressurized broken rock. The hydraulic splitting machine is mainly designed and manufactured using the principle that the tensile strength of the rock is much smaller than the compressive strength.
Splitting machines are more used in quarries in the United States, and their technology is developing more. Although China started late, after decades of development, China in the splitting machine manufacturing level has reached the international leading level. Splitting machine used in some precious stone, rare ore mining and a few other projects have a good economic benefits.

2.2. Hydraulic breaker
Hydraulic breaker is mainly used in the second rock broken, municipal engineering transformation, housing demolition, ice, mountains and other projects. Especially in the municipal engineering, the hydraulic breaker hammer noise is small, high security and flexibility is a better way to break the rock.

The power source of the hydraulic breaker can be an excavator, loader or pump station, which is mainly used to drive the hammer with a power source to reciprocate the broken rock. In the past, the hammer is a piston-type repeated blow, and now the use of hydraulic pressure can drive eccentric gear rotation centrifugal force, and then drive the broken hammer movement, broken rock, the impact frequency can reach 1600 ~ 2100 times / min, this high frequency Hydraulic hammer is more efficient, energy saving, it appears on the hydraulic hammer is an effective complement, can be more detailed broken construction.

At present, the hydraulic hammer has been applied in China for several decades, through practice and research of its production process, product quality has been a greater development, but in equipment research and development, product manufacturing and international advanced level or there is a certain gap.

2.3. Boring Machine
Boring machine is a kind of machinery and equipment which is mainly used for tunnel excavation and coal mining. The noise is small, the dust is less safe and efficient. In China, the market prospect of tunnelling is very good, especially in recent years, traffic road construction, water conservancy project construction and so on the boring machine demand is very large, and our country has become the world's largest road header manufacturing and application market.

The boring machine is a complex mechanical structure, including the walking mechanism, working mechanism, shipping organization, and reprinting mechanism. The walking mechanism is used to move forward, the working bits of the drill bit are constantly cutting the rock, and then the other structures will carry the rock away. The efficiency of the tunnelling and the nature of the rock and the self-stabilization of the working face has a great relationship, and the relative loss is more serious, for large-scale road boring machine only state-level key projects will be used. Although its high cost, complex structure, but its unique advantages in coal mining, tunnelling or in the use of a high value.

Abroad in the boring machine manufacturing in a high level of development, although the domestic manufacturing level can basically meet the domestic demand, but there is a certain gap, especially for high-quality large-scale road boring machine China still need to import. How to constantly improve, continuous innovation for the domestic boring machine manufacturing is an important issue.

3. Physical Chemistry Cutting

3.1. Static Expansion
Static expansion agent is mainly used for mining rock, concrete reinforced concrete rupture. This method is no fly stone, no vibration, no noise, no dust and toxic gases, and simple operation, to carry transport safety. But it is affected by climate, rock breaking efficiency is low.

Static expansion agent is generally used as a main component of lime, the use of hydration reaction to release heat, the product is calcium hydroxide, the volume of expansion, relying on the hole to produce expansion pressure to break the rock or concrete. According to experiments show that the expansion of the pressure generated in the 30 ~ 40Mpa, for the general soft rock and concrete rupture required 10 ~ 20Mpa fully meet the requirements.
Static expansion agent is a non-explosive pollution-free broken agent, is a physical process, does not belong to the flammable and explosive dangerous goods, the safety is relatively high. However, due to the low breaking effect of the expansion agent, cracking time is longer (usually more than 10 hours), low efficiency, so the scope of application is limited.

3.2. Carbon dioxide cracker
Carbon dioxide cracker is a low temperature blasting equipment, in the blasting process without fire, safety is relatively high, can be widely used in coal mining, quarry and other projects. It is mainly the use of liquid carbon dioxide heat and gasification when the volume of rapid expansion of high pressure, so that coal, rock or concrete rupture.

According to the experiment, the carbon dioxide cracker in the use of volume expansion can become the original volume of 600 times the diffusion radius of up to 10m or more. In coal mines, because carbon dioxide has the effect of suppressing blasting and flame retardation and at low temperature conditions, no gas explosion is caused. Ordinary rock fractures, resulting in small vibration, no throwing, energy control, high security. After blasting, in addition to heaters, gaskets, fixed shear slices, other components can be reused, which greatly saves the cost.

The United States in 1938 began to study high-pressure gas blasting device, and now this technology has reached a very mature level abroad, involving mining, concrete, steel, cement and other industries. China's current production of carbon dioxide cracker manufacturers have a lot, the overall technology is relatively mature, but there are still some problems.

First, the carbon dioxide cracker is simple to operate, furthermore there are still hidden dangers, lack of professional personnel operation; then, for different nature of the rock, blasting requirements do not have a unified standardized construction guidelines; industry technical specifications, industry standards are not unified, to be further standardized; For a large range of rock breaking lack of theoretical support and practice.

3.3. Metal Burners
Metal burners generally use metal oxides (such as manganese dioxide, copper oxide, ferric oxide, etc.) or strong oxidants (such as potassium chlorate, potassium perchlorate, etc.) and metal reducing agents (such as aluminum powder, magnesium powder, etc.) in accordance with a certain percentage with the combination.

Metal burner blasting method is mainly the use of the reactants in the rapid deflagration conditions, the release of a lot of heat to diffuse out, all used to heat the surrounding gas medium and reaction products, and then the formation of high temperature and high pressure, so as to achieve the purpose of breaking the rock.

From the reaction rate, the reaction rate is lower than the explosive, and almost no gas. Therefore, do not produce a strong shock wave, no throwing, and relative.

In the choice of hole depth, hole spacing, hole spacing to take full account of the blasting rock tensile strength, compressive strength, whether there are cracks, joints, shape size and other factors, but also consider cutting the rock, or Rock broken. Under normal circumstances, do not consider other factors, cutting the rock than the amount of broken rock pharmaceutical dosage much smaller. Generally recommended hole spacing selection of 200 mm ~ 500 mm, row spacing selection for the 300mm ~ 500mm, hole depth selection of 600 mm ~ 1 000 mm, the above is only recommended parameters, according to the length of the blasting rock, thickness, strength and other specific requirements Appropriate changes.

When the hole depth, hole spacing, hole spacing to determine circumstances, but also need to determine the single hole charge. The single hole charge is not only closely related to the parameters of the hole net-work, but also by the broken rock shape, strength and to the use of explosives higher
safety. But often with lively metal is more prone to danger, and the cost is high, so this method is only applicable to the precious stone mining

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4. Electrical Equipment
Plasma blasting is a method of using electric energy to excite the electrolyte solution into a plasma, so that the material is oscillating vigorously to produce high temperature and high pressure, forming ion cluster movement, and rapidly forming shock wave, and then the rock is broken. This method has the advantages of no toxic gases, no dust, no throwing, low noise and high safety.

Isocratic blasting operation is simple, the specific operation is to have the electrode with the electrolyte solution into the hole, connected to the circuit, the supply of electricity, the rapid expansion of electrolyte dissolved rock broken. Plasma blasting need to solve the key technology of power supply, special switch, electrode three parts. Power supply generally use high-performance capacitors, requiring storage power, the release of electricity fast; special switch to be able to work in the case of high voltage and high current, working voltage at least more than kilovolts, requiring power release rate greater than 200MV / ms. Because only in the case of high voltage and high current, the electrolyte solution can become a plasma; electrodes generally use composite materials, ordinary materials easy to damage, the rate of release of electricity may not be enough.

Canada Nolanda Minerals Company for the first time proposed plasma blasting, and carried out the relevant rock breaking test. In 1997, some domestic scholars have carried out the relevant experimental study, which uses the NaCl solution, the voltage value of up to 10KV, the test results prove the feasibility of this method. But after years of development, the domestic has not successfully developed a mature product. In 2000, South Korea successfully developed a complete set of equipment and applied for the relevant patents. Plasma blasting has a good application prospects, but there are still enough equipment to simplify, a burst of limited, power supply cumbersome and other issues, which is not widely used in the country the main reason. However, with the development of electronic circuits and the development of related supercapacitor, this method may become the mainstream of non-blasting rock breaking.

The thermophilic soil is a kind of auxiliary cutting rock method. For rock with large hardness, it may not be ideal to explode with explosives, and it is more difficult to break the rock with other non-explosive blasting. Therefore, the development of a foreign thermal splitting method, the first rock heating, so that the hardness decreased, in the other broken rock method for crushing operations.

General heating methods are two kinds of current heating and microwave heating, according to the study shows that microwave heating can be rock to 1800 degrees Celsius, and then the hardness of the rock will drop sharply. This method of auxiliary rock breaking is not common in the country, mainly because of the limited scope of application, and can replace the method is also more. But it provides an effective method for rock breaking rock, which is of great significance for the future development of new methods.

![Figure 1. Carbon dioxide fractures](image-url)

1-Filling valve; 2- Heating pipe; 3- Steel Pipe; 4- Gasket; 5- Cut slices; 6- Vent head
5. Conclusions
There are many kinds of non-blasting broken rock way, more selective than blasting method rock breaking. General mechanical rock breaking rock blasting method is small, high safety, suitable for part of a rock breaking and secondary rock breaking, especially for rock breaking requirements of the project, with mechanical rock breaking more, but because of mechanical presence Wear, maintenance problems, etc., and the efficiency is not as high as the explosives. Materialized work class In addition to metal combustion, the small range of rock breaking costs are relatively low, for a large range of rock breaking project, the use of materialization method is not realistic rock. Electrical equipment is currently a small range of applications, but its development potential is higher, the main energy from the power to make it more environmentally friendly and energy-saving, with the development of technology, electrical equipment improvement, which may become the main way to break the rock.

| Types                  | Economy | Application scope                                      | Advantage                                      | Disadvantages                                   |
|------------------------|---------|--------------------------------------------------------|-----------------------------------------------|-------------------------------------------------|
| Mechanical broken      | Normal  | Mines, precious stones and so on Municipal engineering, mountain, ice, demolition and so on | Safe, weak vibration, environment protection   | Mechanical wear, low efficiency                  |
| Hydraulic splitting    | Normal  | Coal mines, tunnels and so on                          | Safety, environment protection, into Lane efficient and good quality | Mechanical wear, medium hard rock should not be used |
| Hydraulic breaker      | Normal  | Quarrries, coal mines, concrete and so on              | No fly stone, no vibration, environment protection | Lithology and climate impact, low efficiency, Lack of standardization, there is a certain security risk |
| Boring machine         | Higher  | Precious stone mining                                 | No throwing, no toxic gas                     | Waste metal, lively metal prone to danger        |
| Static expansion agent | Low     | Quarrries, concrete and so on                          | High safety, small vibration                  |                                                 |
| Carbon dioxide cracker | Low     | Quarrries, coal mines, concrete and so on              | High safety, small vibration                  |                                                 |
| Metal burners          | Higher  | Precious stone mining                                 | No throwing, no toxic gas                     |                                                 |
| Plasma blasting        | Normal  | Dismantling Municipal engineering                      | High safety, small vibration, no throwing     | Equipment requirements are high, broken rock volume is small |
| Heat splitting rock    | Normal  | Auxiliary rock breaking                                | Hard rock effect is significant                | Only applies to auxiliary rock breaking          |
6. Looking ahead

After years of development of non-blasting rock burst is showing a diversified development. First of all, in the choice of broken rock way, often using multiple methods of mutual cooperation. Mechanical method of rock breaking and physical and chemical work class combination, explosive blasting method and the combination of non-explosive blasting methods are often used in the project. Many of the key projects in foreign countries have also adopted a variety of ways to co-break rock.

In the study of the principle of rock breaking and the development of products, there is an interdisciplinary form, often a rock-breaking method development, may involve mechanical, electrical, chemical engineering, mathematical calculations, computer simulation and other disciplines, It is also a huge challenge.

From the current non-bursting rock development direction, the way to break the rock from the mechanization of information, intelligent, computer modelling will be a good choice. In the country has been the use of intelligent early warning to non-blasting demolition, and achieved good results. Abroad in this regard has done a lot of research, such as intelligent rock cutting machine, simulated pressure measurement, etc., are the domestic scholars of the research work have some reference.

From the current blasting industry, non-blasting method although there are many advantages, but because of technical and practical reasons it is difficult to do a wide range of use. On the one hand to increase the existing non-explosive blasting method of improvement, and the development of new rock breaking method; the other hand, non-explosive blasting rock blasting and explosive blasting rock combined with the road, more in line with realistic requirements, The division of the area and the optimization of the rock breaking method, the use of non-explosive blasting detonation of low-sensitivity explosives is also a good choice. Low-sensitivity explosives than the general explosive power is relatively small, and more secure, with non-explosive explosive detonation way (such as: laser, arc), with the feasibility and economy. Similar to the way to take a number of road coordinated development, blasting industry will be an opportunity to develop.

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