**Academic Journal of Science and Technology**
ISSN: 2771-3032 | Vol. 12, No. 1, 2024

# Design and Application of a Composite Grouting Equipment in Coal Mines

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**Abstract:** In recent years, with the development of the coal mining industry, the underground broken surrounding rock grouting process in mines has played a vital role in the safe production of coal mines. At the same time, in order to adapt to the needs of intelligence and unmanned operation, a new process is urgently needed to assist grouting work.At present, among the many broken surrounding rock strengthening control methods in mines, drilling grouting is a widely used rock stratum modification technical measure, but with the continuous deepening of coal mining, the underground geological conditions are becoming more and more complex, and the stability of its roof and floor is seriously threatened. In order to ensure the safe production of mines, the broken surrounding rock grouting reinforcement technology has become an important support means. However, traditional grouting equipment has problems such as low work efficiency and complex operation. Its method of dealing with broken surrounding rock mainly relies on manual drilling and grouting. Especially when the drilling depth is large and the position is high, the workload of pushing the grouting pipe into the borehole is large, the labor intensity is high, the safety hazards are large, and the efficiency is generally low. Therefore, this paper studies and discusses the design principle, structural characteristics and working principle of an integrated composite grouting equipment for underground movement, delivery, mixing and injection in coal mines, and verifies the feasibility and effectiveness of the equipment.

**Keywords:** Coal Mine; Composite Grouting Equipment; Innovation; Design Research.

## 1. Overview of Underground Grouting Technology in Coal Mines

### 1.1. The Role and Importance of Grouting in Broken Surrounding Rocks in Underground Coal Mines

Due to the complex geological conditions of coal mines, the strata are mostly weak, broken, and poorly cemented, and there are many structural broken zones, which leads to great difficulty in underground construction and low safety. Complex geological conditions such as fault zones, broken zones, and collapse columns restrict the efficiency of coal mining. Therefore, it is necessary to first grout and reinforce geological abnormal areas such as fault zones and broken zones. Pre-grouting is the main technical measure to improve the mechanical properties of broken rock mass, ensure the stability of shaft and tunnel construction, and improve construction efficiency [1]. Currently, there are two commonly used methods: ground drilling and underground drilling. This article mainly discusses underground drilling grouting technology.

### 1.2. Traditional Methods and Existing Problems of Underground Grouting in Coal Mines

At present, the main methods of traditional underground grouting in my country are: first locate the broken zone, then use the directional drill to reach the location to drill holes, and use special mixing equipment to configure the grouting materials outside the construction surface, and then use the trolley to transport or manually transfer the slurry to the construction site, and then use the grouting equipment at the construction site to carry out the grouting operation.

Due to the complex underground conditions and unknown road conditions; in addition, the drilling positions are changeable, the height fluctuations are large, the grouting equipment is difficult to operate and inconvenient to use; the overall process of grouting work is scattered, the number of work types is large, the work continuity is poor, and it is difficult to cooperate well. These problems have caused serious construction problems and time waste, and ultimately led to low overall work efficiency. At the same time, in the traditional manual grouting process, the mixing work is subject to the factors of materials and water sources, and is usually far away from the drilling working surface. It is often easy to cause the slurry to solidify or even fail due to the long transportation distance or bumps on the way, which increases the difficulty of construction and reduces the grouting effect. It cannot effectively meet the needs of grouting operations and may even cause serious failures or even damage to the grouting equipment.

## 2. Equipment Principle and Design

### 2.1. Introduction to Equipment Principle

At present, the main method of underground grouting is guided by the study of the injectability of permeation grouting, which was first proposed by Burwell Jr E B in 1958. Later generations conducted research on this basis. Generally, due to its different components, the slurry is suitable for different environments, and the benefits of different proportions are also different. However, due to its overly complex evaluation criteria, it is currently mainly simplified to use the injectability ratio as the evaluation criterion for the grouting effect.

At the same time, some scholars believe that in the grouting process, the slurry is a fluid, and under its own compression, the rock mass will undergo splitting changes, thus turning to the study of its splitting principle. In geotechnical engineering, a large number of engineering practices have shown that splitting-compaction is the main mode of the above-mentioned sand layer grouting diffusion process. During the splitting-compaction grouting diffusion process, the slurry forcibly splits the sand layer under the action of a high grouting pressure to form a splitting channel. During the expansion of the splitting channel, the sand layers on both sides of the splitting channel are compacted. Finally, the slurry exists in the sand layer in the form of splitting slurry veins. The slurry vein skeleton and the compacted sand layer jointly improve the overall performance of the sand layer [2]. It is undeniable that it is mainly developed from the principle of hydraulic splitting and has great similarities with hydraulic splitting. At present, the research on the mechanism of splitting grouting mainly focuses on the two aspects of splitting pressure and starting conditions, mainly based on experimental research and theoretical derivation [3]. The third is the compression grouting principle, which is also being widely studied. The compression grouting principle means that after the slurry is introduced into the formation by a high-pressure pump, there is not only expansion of the slurry near the grouting hole, but also continuous expansion of slurry bubbles, that is, the mixture of slurry and air. The combined effect of these bubbles squeezes the nearby formation and generates radial squeezing force [4], thereby achieving the result of compacting the bottom layer and improving the stability of the formation.

## 2.2. Overall Structural Design of the Equipment

In order to cope with and improve the underground grouting system, a composite grouting equipment is proposed here, which has all the functions of "moving, delivering, stirring, and injecting". The main body includes a mobile device, a suction device, a stirring device, a grouting pump, a mechanical arm, a grouting pipe and a control device. It combines the functions of absorbing materials, stirring and mixing, transporting slurry, positioning drilling, intelligent grouting, etc., orderly planning of working hours, and greatly reducing the loss of time caused by manual chaotic operations.

### 2.2.1. Mobile System Design

First of all, facing the complex environment underground and the objective requirements for large-mass transportation, the movement and turning design of the robot is proposed: good adaptability to the environment, and compatible with the requirements of speed and stability. After the lateral multi-claw, four-wheel, crawler and other solutions, the crawler chassis has good adaptability to the environment, strong transportation capacity, and takes into account speed and steering capabilities, and has the possibility of operation during operation.

### 2.2.2. Design of Suction System

Underground tunnels generally use anchor spraying or masonry tunnels, and water, gas, drainage and other pipelines are placed on the supported walls. However, since this grouting generally occurs in the development tunnels and preparation tunnels, the tunnel completion degree is not high, and the use of water, gas, and materials are affected. Transportation by manpower or locomotives will lead to confusion in the process, waste time, and easily cause danger. Therefore, this equipment uses a suction pipeline made based on the principle of auger, which has good pertinence for fluids such as dust, water, slurry, or similar fluid items. In order to reasonably control the feed quantity and ratio, a flow meter and an electrical gate are installed at the end of the suction device. When the appropriate ratio or excess suction is achieved, the suction device can be closed.

### 2.2.3. Design of Mixing System

In general, the main component of the slurry used in grouting reinforcement technology is silicate cement for coal mines, which has better applicability and strength than general cement slurry. In comparison, once ordinary carbonate cement slurry solidifies, it is difficult to change its shape. This effect of general cement slurry is applied to the ground. Its foundation is stable, the stress change is small, and it can have a good reinforcement effect. Therefore, it does not require high anti-caking and transportation issues, but it cannot adapt to the application scenarios of underground reinforcement or support technology in coal mines with variable stress conditions. Unsupported tunnels in coal mines change quickly and deform greatly, requiring the slurry to have a certain elasticity or creep. Practice has shown that ordinary cement slurry will break in a short time after the stress in the tunnel changes suddenly, causing serious casualties and property losses. However, coal mine silicate cement materials contain a large amount of limestone and gypsum, which have good strength and certain elasticity, are less likely to solidify, have good adaptability and practicality, and are more suitable for mixing with other slurries. However, the complex environment underground weakens its advantages, and its transportation conditions are often not optimistic.

In view of the characteristics of coal mine silicate cement materials and the objective needs of underground, when moving, the mixing system will actively enter a low-speed operation period to ensure that the slurry is constantly disturbed by external factors, so as not to cause solidification, and effectively integrate the concept of secondary mixing to cope with complex situations such as soft rock reinforcement [5]. The overall mixing system is placed on a mobile base and connected to the upper end surface of the mobile device through a bearing frame. At the same time, at least one inspection port, a water inlet and a feed port are provided on the top of the mixing bin, and a discharge port is provided at the bottom, wherein the water inlet and the feed port are respectively connected to the suction device through a guide pipe, and the discharge port is connected to the grouting pump through a guide pipe. The stirring paddle is located in the mixing bin and coaxially distributed with the mixing bin, and the upper end surface of the stirring paddle is connected to the stirring motor through a transmission shaft. The stirring motor is located outside the mixing bin. At the same time, in order to ensure safety and control components, at least one material level sensor is provided in the mixing bin to control the mixing quality of the material body and ensure the smooth operation of the equipment. The material level sensor is connected to the top of the mixing bin, and the stirring motor and the material level sensor are both electrically connected to the control device.

### 2.2.4. Grouting System Design

Underground tunnels often have different shapes, sizes, investments, and stability due to geological reasons, that is, the different environments, locations, and requirements. Grouting is therefore divided into different types such as top plate grouting, bottom plate grouting, anchor spraying stabilization, and broken rock grouting. Because of the requirements for the length and placement space of the grouting pipeline, it is preferred to adopt the method of having a pipeline outside the mixing system, and the pipeline is connected to the top grouting mechanical arm. In order to cope with different geographical and geological environments and requirements, and take into account manual operation control, an infrared sensor is installed on the top of the grouting arm. Since the heat of the hole after the drilling rig is completed is difficult to dissipate completely, the heat of the hole is higher than the outside world, so it can be detected. Taking the arched tunnel as an example, there is a broken zone exposed on the arched roof, which requires grouting. The drill rig drills holes first, and the instrument head control system receives instructions to extract and mix. When it returns to the working surface, the drilling is completed, and it moves to the position of the drill rig, lifts the grouting arm, detects the position of the hole, and then sets up the grouting arm. The mixing system twists the outer wall, introduces the grouting pipe and return grouting pipe into the hole, and pumps in the slurry. The deformation of the grouting pipe is detected by the end head, and it stops when the rated pressure is exceeded. Then the motor reverses and the pipeline is recovered. To ensure the cleanliness of the equipment, the preset program can automatically absorb water and clean the body before the next round of grouting to ensure the safe and stable operation of the machine.

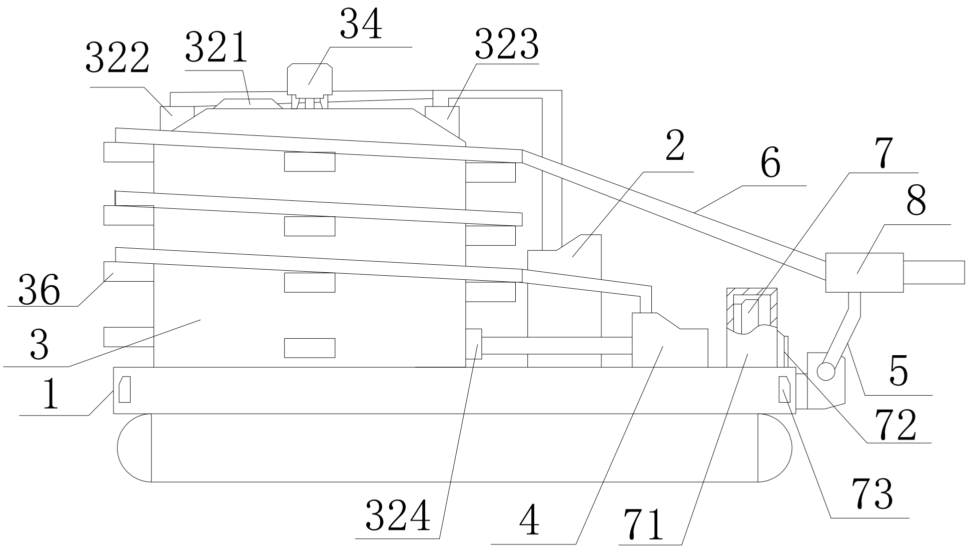

**Figure 1.** Equipment side view

# 3. Advantages and Disadvantages of the Equipment and Future Development Direction

## 3.1. Advantages of the Equipment

The innovation of this equipment lies first in that it realizes the integration and intelligence of loading, feeding and grouting, which greatly reduces the time and labor costs required for this process. Secondly, it avoids and prevents the major problem of slurry slab stratification. There is no situation where the slurry condenses due to the distance, which reduces the equipment loss. Finally, it has a large capacity, large storage, and expandable body. It can carry slurry required for more than ten drilling holes at a time, and can autonomously drag the raw materials to the working surface.

## 3.2. Limitations and Room for Improvement of the Equipment

Unfortunately, due to the high requirements of the drilling rig on the base, this equipment failed to achieve the integration of the overall function. The most labor-consuming drilling link failed to be incorporated into the overall structure, and the intelligent unmanned operation of all links failed to be realized. But in the foreseeable future, it is believed that there will be truly integrated intelligent drilling and grouting equipment, which can realize comprehensive and overall intelligent inspection, control, drilling, grouting, and reinforcement equipment.

# 4. Conclusion

With the orderly advancement of coal mine intelligence, the proportion of intelligent machinery in each link of the underground mine will gradually increase. The machinery provided in this paper has a certain role in promoting the intelligence of the grouting link, improving the work efficiency and accuracy of the grouting operation, and effectively reducing the labor intensity of the grouting operation and the equipment maintenance and management costs, optimizing the process layout, and improving the overall benefits.

# Acknowledgments

Funded by Anhui University of Science and Technology Undergraduate Research Innovation Fund Project (S202310 361184).

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