International Core Journal of Engineering Volume 11 Issue 7, 2025
ISSN: 2414-1895 DOI: 10.6919/ICJE.202507_11(7).0016

# Research on the Application Scenario of Intelligent Method in Underground Mine Mining Operation

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## Abstract

**With the acceleration of global industrialization, the demand for mineral resources continues to grow, but the traditional underground mining methods are facing problems such as low production efficiency, prominent security risks and serious environmental pollution. In this context, the application of intelligent methods to underground mining operations has become a key path for industry transformation and upgrading. This study focuses on the four core processes of underground mining: ore deposit development, ore block preparation, cutting and mining, and systematically analyzes the application scenarios and potential advantages of intelligent technology in these links. It is found that the technologies such as 3D geological modeling, intelligent shield machine, machine learning to optimize ore block division, automatic drilling robot, laser cutting and intelligent mining method selection can significantly improve production efficiency, ensure operation safety and reduce environmental impact. Taking a large copper mine in China as an example, after intelligent transformation, the daily average ore yield increased by 50%, the efficiency of mining preparation increased by 58%, the utilization rate of equipment increased by 24%, and the comprehensive cost per ton of ore decreased by 28.4%. However, the development of mine intelligence still faces technical difficulties such as limited data acquisition, high cost of intelligent equipment, difficult system integration and shortage of compound talents. In the future, we should deepen technological innovation, promote multidisciplinary integration, expand the whole process and life cycle management, strengthen personnel training and team building, and promote the transformation and upgrading of mine intelligence to a green, efficient and safe direction.**

## Keywords

**Underground Mine Mining Operation; Application Scenario; Intelligent Method.**

## 1. Introduction

With the acceleration of global industrialization, the demand for mineral resources continues to grow, and at the same time, the requirements of society for safe production and environmental protection are getting higher and higher. In this context, the challenges faced by traditional underground mining methods are increasingly prominent, such as low production efficiency, prominent safety hazards and serious environmental pollution. In order to meet these challenges and achieve sustainable development, the application of intelligent methods to underground mining operations has become the key path and core driving force for industry transformation and upgrading [1].

This study focuses on the four core processes of underground mining: ore deposit development, ore block mining, cutting and mining. The purpose of this paper is to systematically analyze the application scenarios of intelligent technology in these different links, and to deeply explore its actual effects. Through the study of typical cases, this study will further reveal the difficulties existing in the current technology application, and put forward the prospect for the future development direction.

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This study can provide theoretical support and technical reference for promoting the intelligent construction of underground mines, thus promoting the green, efficient and safe development of mining industry.

## 2. Overview of the Core Process of Mining Operation in Underground Mines

(1) Development of ore deposits

The development of the deposit is to establish the passage to the ore body by digging the shaft, and to construct the transportation, ventilation, drainage and other systems to create conditions for the subsequent mining [2]. Its main tasks include roadway engineering, development system design and initial support, involving the excavation of vertical shaft, inclined shaft or drift, the determination of development mode and transportation system, and temporary support to ensure construction safety. This stage directly affects the production efficiency and economic benefits of the mine and needs scientific planning and design.

(2) Ore block mining preparation

Ore block mining is a stage of further dividing ore bodies and preparing for ore block mining on the basis of ore deposit development, which mainly includes ore block division, mining preparation engineering and secondary support [3]. Mining contour and transportation channel are formed by cutting groove and drawing mine, and permanent support is carried out to ensure safety. This stage is very important for the safety and efficiency of mining, which depends on accurate exploration and reasonable design.

(3) Cutting

Cutting is a key step after the preparation of ore blocks, aiming at pre-cutting the top or one side of ore blocks to form a free surface, which is convenient for subsequent blasting or mechanical mining. In this process, it is necessary to select the appropriate cutting method (such as shallow hole, deep hole blasting cutting or mechanical cutting) according to the nature of ore and rock, and determine the cutting parameters such as hole spacing and charge, so as to ensure the safety and effect of operation. The cutting operation shall be carried out according to the design parameters, and the waste rock shall be treated in time. Fine operation and strict management are very important to ensure the efficiency and safety of subsequent mining.

(4) Backstoping

As the final link of mining operation, after the ore block is cut, the ore is mined by blasting or mechanical equipment and transported to the designated place. This stage involves the selection of mining methods (open stope method, filling method, caving method, etc.), the implementation of blasting or mechanical mining, ore transportation and ground pressure management [4-5]. Scientific management and strict safety measures are the key to ensure efficient and safe mining, which is directly related to the economic and social benefits of the mine.

## 3. Application Scenario Analysis of Intelligent Method in Core Process

With the rapid development of AI, Internet of Things, big data, robotics and other technologies, intelligent methods are more and more widely used in underground mining operations. In this section, aiming at the four core processes of underground mining operations-ore deposit development, ore block preparation, cutting and mining, the application scenarios and potential advantages of intelligent method are analyzed respectively, and its potential in improving production efficiency, ensuring operation safety and reducing environmental impact is discussed.

### 3.1 Application Scenario of Intelligent Method in Mineral Deposit Development

In the stage of ore deposit development, the application of intelligent method covers intelligent planning and design, automatic excavation, real-time monitoring and early warning, intelligent support and so on. Through three-dimensional geological modeling and optimization algorithm to improve the efficiency and economy of the development scheme, intelligent shield machine and

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automatic drilling rig are used to realize efficient and safe tunnel construction, with the help of sensor network and data analysis technology to monitor the construction status in real time and warn the safety risks, and at the same time, machine vision and mechanical analysis are used to realize the intelligent design and automatic construction of the supporting structure, thus comprehensively improving the supporting effect and safety [6].

### 3.2 Application Scene of Intelligent Method in Ore Block Mining Preparation

In the stage of ore block mining, geostatistics and machine learning technology are used to improve the accuracy and efficiency of ore block division, automatic drilling equipment and robots are used to realize efficient and safe construction, and intelligent design and construction of supporting structure are combined with machine vision and mechanical analysis [7], and sensors and data analysis technology are used to monitor the construction status and in-situ stress changes in real time, so as to warn the risks in time and comprehensively improve the efficiency and safety of mining and preparation work.

### 3.3 Application Scene of Intelligent Method in Cutting

In the cutting stage, intelligent optimization of cutting mode is realized by machine learning and optimization algorithm, automatic cutting operation is promoted by intelligent drilling robot and laser equipment, intelligent optimization of blasting parameters is carried out by combining numerical simulation technology, and real-time monitoring of operation status and in-situ stress changes is carried out by using sensor network and data analysis, so as to warn risks in time, thus improving cutting efficiency and safety.

### 3.4 Application Scene of Intelligent Method in Mining

In the mining stage, intelligent methods are mainly used in intelligent mining method selection, automatic mining, intelligent ore transportation and intelligent ground pressure management, etc., and intelligent selection of mining methods is realized through machine learning, optimization algorithm and other technologies to improve mining efficiency and safety [8]; Introducing automation equipment to realize efficient and safe construction of mining operations; Using the Internet of Things and other technologies to realize the automation and intelligence of ore transportation, and improve the transportation efficiency and safety; And with the help of sensor network, data analysis and other technologies, real-time monitoring of ground pressure changes ensures mine safety and stability.

## 4. Typical Case Analysis

**Table 1.** Intelligent technology application scheme

| Core process | Intelligent technology application | Key indicators to improve the target |
|---|---|---|
| Development of ore deposits | 3D Geological Modeling+Intelligent Shield Machine | Driving speed increased by 30% |
| Ore block mining preparation | Machine learning optimization of ore block division+robot support | The division accuracy reaches 98% |
| Cutting operation | Laser scanning guided blasting+in-situ stress real-time monitoring | Blasting efficiency increased by 25% |
| Mining transportation | AGV Unmanned Transportation System+Internet of Things Ground Pressure Monitoring | Energy consumption of transportation is reduced by 18% |

The annual output of a large copper mine in China is 8 million tons, and there are some problems such as low mining efficiency (60m³/ shift) and frequent ground pressure accidents (3 per year). Through the introduction of intelligent mining technology system, the transformation covers the

ISSN: 2414-1895 DOI: 10.6919/ICJE.202507_11(7).0016

whole process of deposit development, mining preparation, cutting and mining. See Table 1 for the application scheme of intelligent technology.

The transformation data in 2022 showed that the production efficiency was significantly improved after the intelligent upgrading of the mine. As shown in Table 2, the average daily ore yield increased from 22000 tons to 33000 tons, an increase of 50%; The mining efficiency increased from 60m³/machine shift to 95m³/machine shift, an increase of 58%; The equipment utilization rate increased from 72% to 89%, an increase of 24%.

**Table 2.** Comparison of production efficiency indicators (data in 2022)

| Index | Before transformation | After transformation | Lifting range |
|---|---|---|---|
| Average daily ore output | 22,000 tons | 33,000 tons | +50% |
| Mining efficiency | 60m³/ shift | 95m³/ shift | +58% |
| Equipment availability | 72% | 89% | +24% |

As shown in Table 3, the economic benefits after the transformation are remarkable, and the comprehensive cost per ton of ore has dropped from 34.5 yuan to 24.7 yuan, a decrease of 28.4%. Among them, the labor cost decreased from 18.5 yuan/ton to 12.3 yuan/ton, a decrease of 33.5%; The energy consumption cost decreased from 9.2 yuan/ton to 7.5 yuan/ton by 18.5%; The equipment maintenance cost is reduced from 6.8 yuan/ton to 4.9 yuan/ton, which is 27.9% lower, showing a comprehensive cost saving effect.

**Table 3.** Comparison of economic benefits

| Cost item | Before transformation (yuan/ton) | After transformation (yuan/ton) | Drop |
|---|---|---|---|
| Cost of labour | 18.5 | 12.3 | -33.5% |
| Energy consumption | 9.2 | 7.5 | -18.5% |
| Plant maintenance | 6.8 | 4.9 | -27.9% |
| Comprehensive cost Per ton of ore | 34.5 | 24.7 | -28.4% |

## 5. Technical Difficulties and Future Development Direction

### 5.1 Current Technical Difficulties

The development of mine intelligence faces multiple technical difficulties. First, the underground environment is complex, and data acquisition is limited by equipment compatibility and signal transmission stability, which leads to different data quality and difficult fusion of multi-source heterogeneous data, which affects intelligent decision-making; Second, intelligent equipment is expensive and difficult to maintain, and it is easily affected by dust, vibration and other factors in harsh environment, and its reliability is insufficient; Third, there are problems such as incompatible interfaces and inconsistent protocols among multiple intelligent subsystems, which makes system integration difficult and affects the overall intelligent collaboration; Fourth, the industry lacks compound talents who know both mining engineering and intelligent technology, which restricts the application and innovation of technology.

### 5.2 Future Development Direction

In the future, mine intelligence will focus on deepening technological innovation, such as optimizing AI algorithm and developing Internet of Things and robotics. Promote multidisciplinary integration

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and improve the level of support design and equipment control; Expand to the whole process and life cycle management to realize collaborative optimization and intelligent decision-making; Strengthen personnel training and team building, and cultivate compound talents through cooperation between universities and enterprises; At the same time, the government will improve laws and regulations and standardize the development of the industry. Despite the challenges, technological progress and industrial synergy will promote the transformation and upgrading of mine intelligence to a green, efficient and safe direction, with broad prospects.

## 6. Conclusion

In the development stage of the deposit, the application of intelligent planning and design, automatic excavation, real-time monitoring and early warning, intelligent support and other technologies has effectively improved the efficiency and economy of the development plan. In the stage of ore block preparation, the introduction of geostatistics and machine learning technology has significantly improved the accuracy and efficiency of ore block division. At the same time, the use of automatic drilling equipment and robots has also ensured the safety and efficiency of construction. In the cutting stage, through machine learning and optimization algorithm, the intelligent optimization of cutting mode is realized, and the use of intelligent drilling robot and laser equipment promotes the automatic cutting operation. In addition, the cooperation of numerical simulation technology and sensor network further improves the cutting efficiency and safety. In the mining stage, intelligent methods are mainly used in intelligent mining method selection, automatic mining, intelligent ore transportation and intelligent ground pressure management. The application of these technologies not only improves the mining efficiency and safety, but also realizes the automation and intelligence of ore transportation, which improves the transportation efficiency and safety. Through the case analysis of a large copper mine in China, this study further verified the effectiveness of intelligent methods in underground mining operations. The data shows that the production efficiency and economic benefits have been significantly improved after the intelligent upgrading of the mine. Although the current development of mine intelligence faces multiple technical difficulties, such as complex underground environment, high cost of intelligent equipment and difficult maintenance, the future development direction is clear, including deepening technological innovation, multidisciplinary integration, whole process and life cycle management, personnel training and team building. Therefore, technological progress and industrial synergy will promote the transformation and upgrading of mine intelligence to a green, efficient and safe direction, with broad prospects.

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