Efficiency analysis of intelligent equipment in mining complex environment operation

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Abstract: As the basic industry of the national economy, mining industry faces complex working environment and high safety risks. The application of intelligent equipment in mining industry faces the complex underground geological environment and harsh surface climate, and sometimes the high pressure and darkness of deep-sea mining. Complex environment brings challenges to the reliability of intelligent equipment. This paper analyzes the characteristics and technical challenges of complex mining environment, points out the multi-source characteristics of intelligent equipment operation efficiency, and finds that the efficiency of intelligent equipment in complex environment effectively changes the problems of low efficiency and high safety risk of traditional manual operation, and explores a new path for the application of intelligent equipment in mining industry.

Keywords: Intelligent equipment; Complex mining environment; Operation efficiency; Spatiotemporal synergy

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1 Mining complex environmental characteristics and technical challenges

The complexity of the mining operation environment presents multi-dimensional characteristics. The operation of intelligent equipment in the complex mining environment needs to analyze its efficiency from three typical scenes: underground, open-air and deep sea.

1.1 Uncertainty of geological conditions

Mining operations face complex geological factors, which run through the whole life cycle of mine design, construction and production, and pose a fundamental challenge to the adaptability of intelligent equipment. In underground mines, the ore body is easy to fragment and lack stability, so it is difficult to efficiently recover resources in the mining process. With the increase of mining depth of underground mining, the in-situ stress continues to rise, and the risk of dynamic disasters such as rock burst and spalling has increased sharply. Intelligent equipment needs to adjust mining parameters at any time, and can sense the change of stress state in real time. The geological uncertainty of open-pit mine is also prominent. The spatial variability of ore grade distribution, the heterogeneity of slope rock mass structure, and the sudden exposure of water gushing at the bottom of the stope and weak interlayer all directly affect the implementation of the mining and stripping plan. In coal mining, the complexity of geological conditions is reflected in multiple factors such as the change of coal seam thickness, the sudden change of roof lithology, the distribution of gas enrichment areas, and the difference of hydrogeological conditions. Due to the uncertainty of geological conditions, intelligent equipment is required to be equipped with multiple sensors, and the geological model is built to dynamically update and adjust the mining model in time. Only in this way can the equipment accurately execute the instructions and ensure the high reliability of the whole mineral mining.

1.2 Constraints of workspace

Different from ground operation, mining space is limited, and strict requirements are put forward for the size, trafficability and mobility of equipment. In underground operation, the roadway, as a mine transportation, ventilation and pedestrian pipeline, can only meet the basic traffic requirements, which requires the maximum compression of the size of intelligent equipment. At the same time, the radius of the roadway curve is small and the slope changes frequently, so the equipment must have excellent steering Trafficability and climbing ability. The spatial constraint of open-pit mine presents different forms. Factors such as road transportation, terrain gradient and working face strength directly affect the efficiency of working space. In the underground space, with limited lighting, dust and water mist will further reduce visibility, which poses a severe challenge to the intelligent equipment relying on visual sensors and affects the operation efficiency and safety. Deep sea mining is faced with complex terrain, and floating objects on the seabed will also reduce visibility and interfere with navigation and positioning. The design of intelligent equipment should adopt modular design and compact layout. At the perception level, multi-source sensing data should be fused to ensure sensitive situational awareness. At the executive level, it is necessary to achieve precise motion control and complete complex actions such as turning, obstacle avoidance and alignment in a narrow space.

1.3 Interference of environmental perception

Intelligent equipment relies on sensors to sense the environment. The complex mining operation environment interferes with the perception ability of intelligent equipment. Problems such as dust, water mist and insufficient illumination will interfere with lidar and optical camera. Open air environment also has interference problems, which is dynamic and multiple. Dust, extreme rainfall, ice and snow and other weather will affect the sensor, reduce the detection accuracy, and make the intelligent equipment unavailable in serious cases. The interference factors of deep-sea environment mainly focus on complete darkness, high pressure, low temperature and sediment suspension. The sunlight cannot penetrate the water depth of kilometer, so the traditional optical camera must rely on artificial light source for illumination. The flow of seawater causes the diffusion of suspended particles and reduces the image definition. In addition to lidar, multi-sensor fusion is a common strategy to deal with perceptual interference. Millimeter wave radar can penetrate dust, rain and fog better than laser radar and camera, and can be used as a redundant sensing source under adverse conditions; Infrared thermal imaging is not affected by light, and can effectively

identify personnel and heating equipment in the dark environment; Ultrasonic radar is stable in short-range detection and can be used to assist parking and obstacle avoidance.

2 Efficiency of intelligent equipment in mining attached environmental operation

2.1 Greatly improved operation accuracy

Precise operation is the basic premise for intelligent equipment to replace labor. In mining operations, intelligent equipment is widely used in shearers, transportation, drilling and other links. The planned cutting rate of shearer controlled by digital technology is more than 85%. In the transportation link, the lateral parking accuracy of the unmanned mine car shall not exceed 0.15 meters, and the longitudinal error shall not exceed 0.4 meters. With the further improvement of navigation and positioning accuracy, the positioning error can be reduced to less than 0.1M in the future. In the drilling process, the intelligent rotary drill can automatically find holes, level, perforate and depth, and the hole depth error is controlled within 10 mm. The operation accuracy has been greatly improved to centimeter level, which depends on the application of sensors and high-precision positioning technology. The Beidou high-precision positioning system developed by China is deeply integrated with laser radar, millimeter wave radar and camera, so that the intelligent equipment can build a 360 degree environment perception model without dead angle, correct the trajectory in real time during the operation, and ensure the centimeter accuracy throughout the operation.

2.2 Man machine cooperation breaks through the bottleneck of efficiency

The application of intelligent equipment in mining operations should also measure its efficiency, so as to be economical. At present, some intelligent equipment has been close to manual operation in terms of operation efficiency, and has achieved anti overstepping in some fields. Taking the unmanned transportation in the mine as an example, the comprehensive efficiency of the mine car with unmanned driving is more than 85% of that of manual driving. It can realize the safe transportation of minerals under complex terrain conditions, so as to avoid the safety risk of Tramcar Transportation. Intelligent equipment has broken through the bottleneck of traditional manual operation in some fields. For example, in the process of ore blending, the optimal ore blending plan is dynamically generated through the multi-metal multi-objective intelligent ore blending model to maximize the use of low-grade ores and ensure the balance and stability of raw ore grade. Compared with traditional manual operation, the degree of refinement has been significantly improved. In addition, in man-machine cooperation, intelligent equipment can work continuously. Unmanned equipment does not need to shift, is not limited by fatigue, and can continue to operate in harsh environments. The application of new energy power and fast charging technology further ensures the endurance of the equipment.

2.3 Improving personnel safety in complex environment

The contribution of intelligent equipment to safety is the core value of the intelligent transformation of mining industry. Its role is mainly reflected in the following three aspects: first, the personnel are separated from the high-risk operation area, and remote control is adopted to enable the front-line production personnel to evacuate from the mining face, slope bottom, goaf and other dangerous places to the centralized control center. For some hazardous production processes, intelligent equipment such as exploration robot dog can also be used instead of technicians to avoid personnel safety risks from the source. Second, it has the function of multi-dimensional situation awareness and active risk avoidance. Intelligent equipment such as unmanned mine card is equipped with laser radar, millimeter wave radar and camera to identify obstacles, personnel and other vehicles in real time and realize safe obstacle avoidance and emergency braking. Electronic fences are used in hazardous areas to provide early warning in case of abnormal conditions and prevent personnel from entering by mistake. The third is environmental monitoring and early warning. GNSS monitoring, AI identification and other technologies are used to build a three-dimensional monitoring matrix to realize the comprehensive prevention and control of geological disasters, equipment crossing, vehicle injury and other risks.

2.4 Intelligent equipment synergy

The intelligence of single equipment is only the starting point. In the face of the complex mining operation environment, only the cooperative operation of multiple equipment is the key to the efficiency release. In practice, through the global wireless positioning network in the mine operation, the multi equipment collaborative scheduling of key processes such as rock drilling, charging, shoveling and transportation is realized, and the ore flow and equipment flow are deeply integrated. In open-pit mining, taking the driverless truck as an example, it no longer waits passively, but dynamically adjusts the running rhythm according to the state of the shovel, and cancels the parking and waiting link. In the underground fully mechanized mining face, the acquisition machine and hydraulic support are precisely coordinated and automatically operated to improve the underground mining efficiency. The improvement of intelligent equipment synergy means the integration of existing decentralized intelligent equipment, the reconstruction of the entire production system, the exertion of system power, and the improvement of equipment efficiency.

Summary: the application of intelligent equipment in key processes such as mining perforation, shovel loading, transportation, crushing and exploration has changed the traditional operation mode. Through multi-sensor fusion, precise control and collaborative scheduling, intelligent equipment can achieve centimeter accuracy in complex mining environment, replacing manual operation, and eliminating personnel safety risks from the source. However, the efficiency of intelligent equipment in mine operation is still facing challenges, and the perceived interference, collaborative complexity and virtual measurement reliability are still the current technical problems. Looking forward to the future, intelligent equipment is not only a tool to replace people, but also a core carrier to reconstruct the mining knowledge system and production mode.

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