Development and Application of ZMK5200QJY40 type Mining Rescue Vehicle for Hoisting

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Abstract.ZMK5200QJY40 type Mining Recovery Vehicle for Hoisting was designed for quick borehole rescue. In this paper, the traits between underground rescue and ground borehole rescue were analyzed, technical principle of the vehicle was introduced, the technical parameters of rescue capsule and hoisting control system were listed. Of the 11 key parts in the vehicle, the rescue capsule design and the design of hoisting winch with large rope capacity were introduced in detailed. It was tested in Pingshang Coalmine of Qinxiu Coal Co., Ltd in Jincheng, Shanxi. It was validated that the vehicle is useful for normal borehole or sleeve with the diameter of 580mm to 620mm. With the help of the vehicle, the miners trapped in 900 meters underground can be rescued quickly and safely. ZMK5200QJY40 type Mining Recovery Vehicle for Hoisting was developed successfully; it can be used for vertical rescuing in large borehole. Matching with the new-designed rescue drilling rig, a package of emergency rescue technology and equipment were formed.

1. Introduction

China is the largest coal production and consumption country, coalmine disasters seriously threaten the safety of production. When the underground disaster occurs, traditional rescue methods will be limited by the harmful gases and the secondary accidents. Because of many uncertain factors and the highly dangerous underground, it is difficult to drill life rescue channels in a short time to provide life support for trapped personnel. And it is very easy to miss the best rescue time which has limitations in application. The ground borehole rescue is a way to build large diameter holes on ground and lift the trapped personnel from underground to the ground through lifting equipment. This is the most effective means of mine accident rescue. It has the characteristics of high efficiency, avoiding large-scale collapse area and preventing secondary accidents during rescue [1,2]. At present, many coal mines are building rapid rescue channels from ground to underground emergency refuge chambers [3]. China has already had the drilling technology and equipment for large diameter holes, and has successfully completed the construction of several rapid rescue operations, but the mature rescue lifting and supporting equipment is deficiency.

In order to satisfy the actual needs of mine rapid rescue, the Xi’an Research Institute raised its own funds and based on the Shaanxi Provincial Industrial Science and Technology Project and the National Science and Technology Major Project to develop the ZMK5200QJY40 type mining recovery vehicle. It was tested in Pingshang Coalmine of Qinxiu Coal Co., Ltd in Jincheng, Shanxi. It was validated that the vehicle is useful for normal borehole or sleeve with the diameter of 580mm to 620mm. With the help of the vehicle, the miners trapped in 900 meters underground can be rescued quickly and safely.
2. Technical Principle

ZMK5200QJY40 type Mining Recovery Vehicle including the following parts which is shown in Fig.1. Special rescue vehicle, Lifting hoist, Hoist arm, Rescue hoist, Rope arranger cable, Wire rope, Lifesaving capsule, Landing gear, Rescue remote control, Control table, Turntable. The equipment can meet the dual needs of lifting loads and onsite rescue. It can achieve rapid transition and can arrive at the well site at first time when underground accidents occur. After adjusting the stable legs and the hoist arm, the rescue remote control station can realize the lowering and lifting function of the rescue capsule.

During the rescue process, the video and voice communications with high definition can be maintained between the operator and the rescue capsule to facilitate the guidance and rescue from ground personnel. The rescue capsule has a buffer device, rope breaking protection device, bottom escaping device, oxygen support system, gas detection device in the rescue cabin, etc. By controlling various functional electromagnets, the electro-hydraulic control system collects the characteristics of the pressure, flow and speed of each function node, so as to realize the stability, attitude adjustment and rescue function of the recovery vehicle. At the same time, the rescue capsule's lowering and lifting speed, the loading of wire rope and the real-time location are displayed online, so as to ensure the safety of the lifesaving capsule during lifting and lowering.

![Figure 1. The Constitute of ZMK5200QJY40 type Mining Recovery Vehicle](image)

3. Technical Parameter

ZMK5200QJY40 type Mining Recovery Vehicle can not only meet the vertical rescue requirements of the large diameter hole, but also can provide a safe and rapid service for the trapped personnel in the mine emergency rescue. And it can meet the daily lifting requirements. The main technical parameters are shown in Table 1 and Table 2.

| Items                | Parameters                      |
|----------------------|---------------------------------|
| Maximum Lifting      | 40 kN                           |
| Applicable Aperture  | φ580mm-φ620mm                   |
| Outer Diameter       | φ550mm                          |
| Effective Space      | φ540mm×1900mm                   |
| Lifting / Lowering   | Maximum 2m/s                    |
| Safety device        | Anti-Break Rope                 |

![Table 1. Life Capsule Parameters](image)

It adopts electro-hydraulic proportional control technology, integrates CAN bus communication, and has graphical data display interface. The system has high precision, fast response speed, and is safe and reliable.
Table 2. Hoisting Control System Parameters

| Function          | Characterization                                      |
|-------------------|-------------------------------------------------------|
| Tension and Speed | Tension Range: 0 ~ 4t; Speed                          |
| Overload protection| Rated load: 4t                                        |
| Depth of Wire Rope | Initial Position and Preset Depth                     |
| Over volume       | Heavy Punch Height Limit                              |
| Attitude of Hoist | The Angle between Hoist Arm and                       |
|                   | The horizontal Plane, The Length of                   |
|                   | The Arm, etc.                                         |
| Manual/Automatic  | Automatic Lift/Drop Action                            |
| Fault Alarm/Query | Display Fault Code and Can Be                         |

The development process of ZMK5200QJY40 type Mining Recovery Vehicle involves the reconstruction of automobile chassis, the design of lifting hoist, the research of safety lifting device with large rope capacity, the development of electronic cable system, the trial-manufacture of wire rope with central cable, the integration of control and display, video and audio system, the on-line detection and transmission of gas in lifesaving capsule, etc. This article focuses on the design of lifesaving capsule and safety lifting device with large rope capacity.

4. Design of Lifesaving Capsule

To realize the needs of large diameter borehole rescue, the shape of the lifesaving capsule is designed as a cylindrical structure. It is made up by the following parts: 1. Cabin, 2. Guide Device, 3. Break Prevention Protector, 4. Signal Transmission Equipment, 5. Slow Down Machine, 6. Camera in Cabin, 7. Intercom Earphone, 8. Safety Pin, 9. Disconnect Device, 10. Camera at Bottom of Cabin, 11. Buffer Device at Bottom of Cabin [4]. The diagram of lifesaving capsule is shown in Figure 2.

![Diagram of Lifesaving Capsule](image-url)

1-Cabin; 2-Guide Device; 3-Break Prevention Protector; 4-Signal Transmission Equipment; 5-Slow Down Machine; 6-Camera in Cabin; 7-Intercom Earphone; 8-Safety Pin; 9-Disconnect Device; 10-Camera at Bottom of Cabin; 11-Buffer Device at Bottom of Cabin

**Figure 2.** Diagram of Lifesaving Capsule

The cabin is divided into upper guide section, equipment compartment, staff compartment and lower guide section. The upper and lower guide section has been guided to facilitate the promotion and decentralization process. The guide device is divided into two parts, the upper and the lower parts, all equipped with buffer rollers, which can effectively reduce the impact between the wellbore and the
cabin during lifting and lowering. The buffer device can reduce the impact of the rescue capsule when decline to the bottom of the tunnel.

The break prevention protector is based on the principle of cam. When the wire rope breaks, the reaction force of the cam will push the protective rod out, and keep the rescue capsule in the wellbore to prevent the secondary injury. If the rescue capsule is trapped in the wellbore, the personnel can release the safety pin, step off the disconnect device and return to the bottom of the well with the help of the slow down machine. And waiting for the secondary rescue. The communication system is formed by the signal transmission equipment, the camera in cabin, the intercom earphone and the camera at bottom of cabin. And it can guarantee the real-time communication between the personnel in capsule and on the ground.

5. Design of Safety Lifting Device with Large Rope Capacity

The ZMK5200QJY40 type Mining Recovery Vehicle can meet the rescue within 900meters, so the design of the large capacity rope is particularly important. The winch system adopts a modular high-intensity planetary reducer structure, and the hydrostatic winding reducer is directly installed inside the reel to save space. The input of the reducer is equipped with normally closed multi-disc parking brake which is normally closed. The parking brake is opened by hydraulic pressure and running in wet-type. The plug-in motor can be directly installed inside the reducer to make the structure more compact. The drum adopts the structure of Casting Single Step Double Fold Line Slots [5] [6]. It can improve the quality of rope, reduce the disorder of ropes, prolong the service life of wire rope, and avoid the danger when lifting and lowering the lifesaving capsule.

In order to ensure the communication connection between the moving parts and the stationary parts of the winch during operating. The cable in the wire rope passes through the rotating shaft of the hoist center and is drawn through the slip ring. The structure is shown in Figure 3 [7].

![Figure 3. Cable Drawing Diagram](image)

1- Wire Rope ; 2- Signal Inner Lead ; 3-Slip Ring ; 4- Signal Outer Lead

In the design of the safety protection for the internal brake of the winch, the winch system adopts the structure of the normally closed safety clamp and the constant open type work clamp, which plays a double insurance function [8-10]. Normally closed safety clamp can automatically close when the hydraulic system stops working, and play a role of safety protection with internal brakes simultaneously. The function of the constant open type work clamp is to reduce the speed of the winch when it is running too fast. The working clamp is closed by hydraulic lifting, and the speed of winch will be reduced. When the electrohydraulic system is broken down or the hydraulic system stops working, the rod cavity is often closed under the action of the accumulator. And the winch is brake at the same time with the internal brake and the normally closed safety clamp, which plays the role of safety and protection. The double clamp structure of the winch is shown in Figure 4.
6. Field Application

20 to 28 October 2015, ZMK5200QJY40 type Mining Recovery Vehicle was tested in Pingshang Coalmine of Qinxin coal Co., Ltd. Figure 5 is a sketch map of the escape well in the refuge chamber. Figure 6 is the distribution of the rescue lifting system.

In the application process of ZMK5200QJY40 type Mining Recovery Vehicle in the field (as shown in Figure 7), no-load test (as shown in Figure 8-1), load test (as shown in Figure 8-2), life test (as shown in Figure 8-3) and manned test (as shown in Figure 8-4) were carried out successively. They were lifted and lowered more than 20 times. The maximum depth was 297.8 meters, and the speed of the rescue capsule under different conditions was simulated at the interval of 0 to 2m/s. The data communication, the video and audio communication of the cabin and the harmful gas concentration are shown to be normal. The test achieves the desired design effect. The application shows that the equipment is suitable for the casing or regular drilling between the diameters of 580mm to 620mm. It can meet the safety and rapid rescue needs in the depth of 900 meters, and also marks the successful development of the ZMK5200QJY40 type Mining Recovery Vehicle.
7. **Summary**

The ZMK5200QJY40 type Mining Recovery Vehicle is developed and applied successfully. Matching with the new-designed rescue drilling rig, a package of emergency rescue technology and equipment were formed.

While maintaining the advantages of underground rescue of Xi’an Research Institute of China Coal Technology and Engineering Group, we expand the drilling rescue business on the ground. It will help our institute to take the lead in the field of mine rescue for a long time.

Xi’an Research Institute of China Coal Technology and Engineering Group based on the development of coalbed gas and mine emergency rescue. The institute has accumulated a lot of construction and rescue experience in coal mine. The ZMK5200QJY40 type Mining Recovery Vehicle has been developed successfully after the ZMK5530TZJ60 drilling rig, which strongly supports the outstanding advantages of the Xi'an Research Institute in the emergency rescue field. And it has considerable economic and social benefits.

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