Research on a hydraulic manipulator arm of an automatic bottom laying robot for underground roadway in coal mine

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Abstract. This paper studies a robot with rapid bottoming technology that integrates the transportation, installation and removal of bottoming modules, and rapid road surface leveling. It is driven by explosion-proof diesel and is used for new application equipment with fine operation ability in high-risk environment of coal mine roadway. Research on the integrated design of equipment and research on automation control technology to realize the safe and rapid construction of the bottom laying module, so as to realize the automation of module laying and achieve efficient and safe laying of modules.

Keywords: Robot, Bottoming module, Hydraulic, Manipulator arm.

1 Introduction

As a remote-controlled high-power and automatic operation equipment, the robot is fundamentally different from ordinary construction machinery. It integrates bionic technology, communication technology, control technology, sensing technology, electromechanical-hydraulic integration technology, robotic arm motion the integration of control technology is the development and leap of robot technology from the field of pure kinematics to the field of engineering dynamics, which belongs to the technical integration of a specific field. The equipment system is mainly composed of mechanical body system, power system, hydraulic system, sensing and electro-hydraulic proportional control system, communication system, clamp claw components, modules, lighting system and other parts. As shown in Figure 1.

The robotic mechanical system includes: upper body assembly, module placement box, working arm, gripper assembly, four-wheel drive wheeled mobile chassis, etc. Upper body assembly: installation of power system (explosion-proof diesel engine), electrical control system, digital two-way wireless remote control system, wireless communication system, electro-hydraulic proportional hydraulic system, detection system and lighting system, etc.; module placement box is used to accommodate and carry The module has a limited position function for the module, which is conducive to the picking and placing of the module by the robotic arm; the boom assembly arm is used for the transfer and placement of the module.

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Lifting, horizontal rotation, pitching, and telescoping; the arm assembly rotates around the boom assembly according to the operation requirements, and the head is equipped with a claw assembly. Claw assembly: use hydraulic motor + reducer + absolute encoder + hydraulic clamp to grasp the module, which can complete the horizontal (-90°—+90°) rotation of the module, and the clamp opens and closes to grasp and self-lock to achieve stability The grab is a module installation and removal operation. At the same time, the leveling mechanism can complete the necessary road leveling work before paving the ground (you can carry rakes, or grinding tools, etc.). The mechanical arm is equipped with an absolute encoder to ensure the coordinated control of the arm joint and the jaw assembly, and to complete the spatial multi-dimensional movement operation under the conditions of different module specifications and sizes; the chassis is driven by a full hydraulic system, 4X4 drive structure (four drive + Double steering), the wheel steering adopts the oil cylinder and connecting rod method to ensure the consistency of the wheel steering. It has the advantages of strong environmental adaptability, wide operation range, flexible and convenient operation, safe and reliable work and so on.

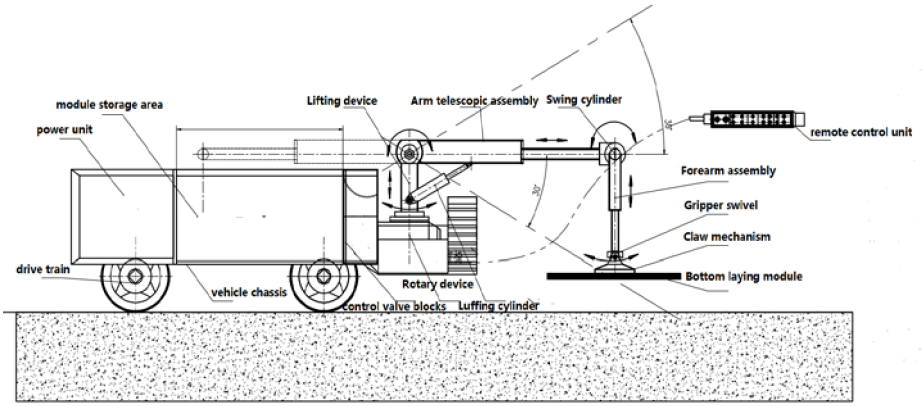

Fig. 1. An automatic bottom laying robot.

This paper introduces the design and research of the hydraulic manipulator for the robot to meet the laying conditions.

2 Design basis and performance requirements of robotic arm

The main task of the robot's hydraulic arm is to use a special gripper to hold a module with a size of L*D*H= 2m*1m*30mm for bottom laying work. After investigation, it is found that there is no vehicle-mounted robotic arm that can fully meet reprinting requirements. Either the maximum arm span is not enough, or the maximum reloading capacity is insufficient. Therefore, it is necessary to specially design such a vehicle-mounted hydraulic manipulator.

What the robotic arm needs to complete is to grab the module for laying work. In its design process, there are not only design parameters, but also its special performance requirements:

(1)Under the condition that the quality conditions are satisfied, there must be sufficient stiffness and strength to avoid plastic deformation during the transfer process and the loss of transfer ability after repeated work;

(2) Since it is installed on the chassis and the space is limited, the design should be as compact and small as possible;

(3) Hydraulic drive inevitably has hydraulic pulsation frequency. The structure design should avoid resonance phenomenon. At the same time, there should be no obvious vibration during the working process.

3 Design of key components of hydraulic manipulator arm

The main components of the hydraulic manipulator are an important part to ensure that it can achieve basic actions and complete the task of grasping and laying. The quality of the component structure design directly affects whether the transfer task of the manipulator can be successfully completed. This paper will adopt a group design method to design its components. The main components. According to the structural form, it is divided into three groups: base group, boom group, and jaw group for design research. Since the research on the rotary drive device and the hydraulic cylinder is quite mature, the standard selection can be found according to the needs, and the structure is no longer designed. There is no driving device at the rotating joint, which only serves as a connection. The pin shaft with a relatively simple structure is selected, and its structure is no longer designed separately.

3.1 Structural design of jaw assembly

The jaw assembly mainly includes the gripper attitude control hydraulic cylinder, the clamping hydraulic cylinder and the gripper. The structure design of the gripper should meet the following requirements:

Appropriate clamping force should be provided. The finger clamping force should be appropriate. If the force is too large, the power consumption will be large, the structure will be huge, uneconomical, and even the module will be damaged; if the force is too small, it will not be able to be clamped or will loosen or fall off.

The fingers should have a certain opening and closing range. The fingers should have a sufficient opening and closing angle to easily grasp or place the workpiece.

Compact structure, light weight and high efficiency are required. On the premise of ensuring its own rigidity and strength, the structure should be as compact and light as possible, so as to reduce the burden of the boom.

In order to realize the grasping of the L*D*H= 2m*1m*30mm module, according to the introduction of the classic structure of Industrial Manipulator, the module adopts the lap joint, combined with the module structure shape, as shown in the figure. 2, there are 4 through holes on the edge for connecting and fixing with other modules, the hole diameter is 36 mm. The thickness of the base module is reduced by half within a certain distance on both sides, and the surface is covered with anti-skid patterns. Each anti-skid pattern is 2m long, 8mm wide and 3mm high. When two bottom-laying modules are connected, the edges of the modules are overlapped together, and the thickness is exactly the thickness of the module, and then bolted and fixed by the matching pressure plate.

Fig. 2. Bottom laying module structure diagram.

According to the above module structure, the principle diagram of the jaw structure is formulated, as shown in Figure 3. Driven by hydraulic pressure, when the T-shaped tie rod moves laterally in the direction indicated by the arrow A, the fingers of the claw descend into the through holes on both sides of the module, and one end of the two fingers slides left and right in the directions indicated by B and C respectively, completing the alignment of the workpiece. On the contrary, when the T-bar moves in the reverse direction as indicated by the arrow A, the fingers move in the reverse direction as indicated by B and C, respectively, to release the clamping of the module.

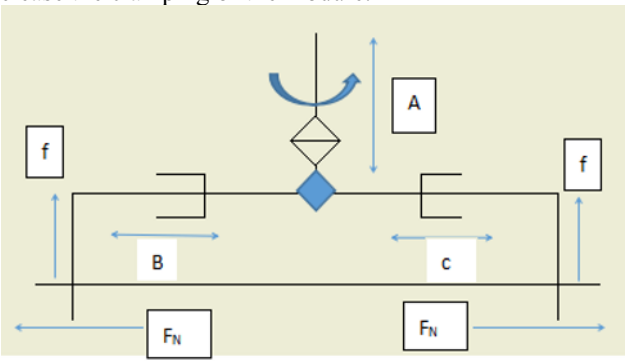

Fig. 3. Schematic diagram of jaw structure.

According to the design requirements of the gripper and the structural principle shown in Figure 3, this paper designs the structural shape of the gripper as shown in the figure 4. Consider the stroke and installation space of the clamping hydraulic cylinder, and at the same time reduce the size of the arm, the mounting bracket and the arm pull plate as much as possible without affecting the finger clamping and loosening the workpiece, and reduce the overall size of the gripper quality, to achieve the purpose of lightweight. According to the structure and shape shown in the figure, use the 3D modeling software to establish a 3D model to ensure that there is sufficient lateral distance in the clamping state (so that the arm can obtain a sufficiently large power arm and reduce power consumption), without affecting the BC direction expansion and contraction. On the premise that the oil cylinder slides on the mounting frame, the key dimensions are repeatedly verified, the model is modified, and the most reasonable dimension parameters are finally determined.

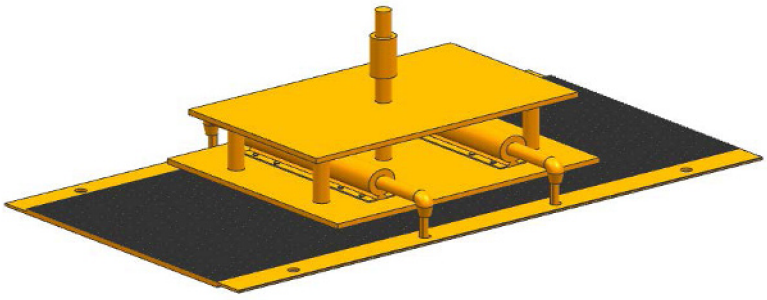

Fig. 4. The structural shape of the gripper.

After completing the selection of the hydraulic cylinder and obtaining the corrected 3D model of the whole machine, the size of the modified arm is repeatedly checked and corrected, and finally the structure of the mechanical arm and the basic size of the telescopic arm as shown in the figure are obtained.

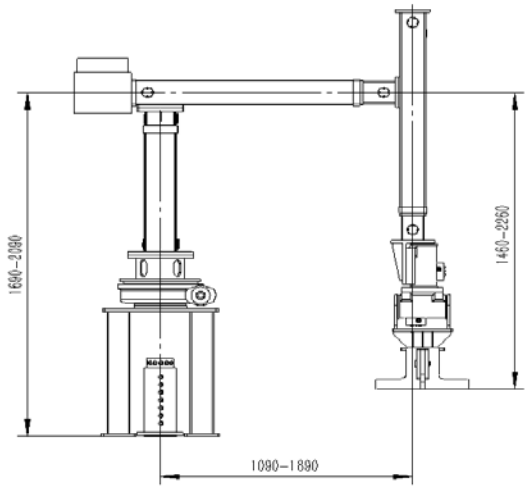

Fig. 5. The structural shape of the gripper.

3.2 laying method

When grasping the bottom laying module, adjust the posture of the grasping plate, align the four mechanical grippers with the four through holes on the edge of the bottom laying module, slowly lower the grasping plate, and insert the four graspers into the four holes reserved in the middle of the bottom-laying module. Then the hydraulic cylinder works, relying on the pressure provided by the two bidirectional hydraulic cylinders, the module is grabbed by the friction between the mechanical gripper and the hole wall of the bottom-laying module, and the angle of the bottom-laying module is slightly adjusted by the steering cylinder, and it is aligned and placed on the already laid module. the edge of the module, and then slowly move the gripping plate down to put down the bottom-laying module. After the laying is in place, the hydraulic cylinder releases the pressure and retracts the mechanical gripper. Finally, the two stacked and laid bottom-laying modules are fixed and connected manually with bolts. As shown in Figure 6

3.3 Recycling method

When recovering the base-laying module, first remove the fixing bolts manually, clean the installation holes of the base-laying module, move the mechanical gripper, and adjust the position to align the four mechanical grippers with the four through holes on the edge of the base-laying module. Slowly lower the gripping plate, insert the four grippers into the four holes reserved in the middle of the bottom-laying module, and then the hydraulic cylinder works, relying on the pressure provided by the two bidirectional hydraulic cylinders, using the friction between the mechanical gripper and the hole wall of the bottom-laying module Grab the module. Move the grab tray upwards slowly to lift the bottom-laying module, and put the bottom-laying module back into the hopper of the automatic laying equipment to realize the recovery of the bottom-laying module.

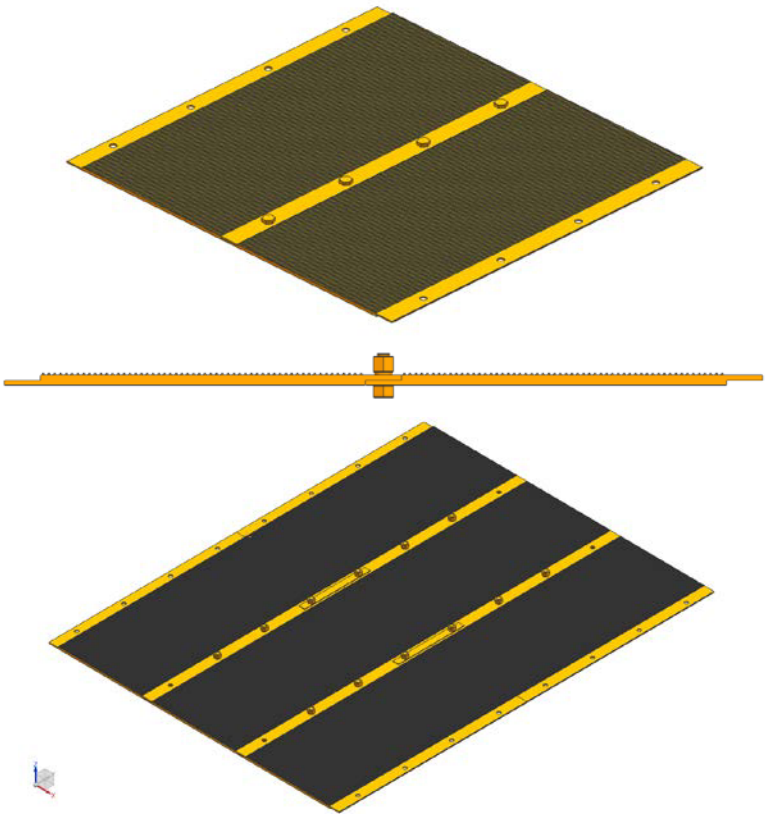

Fig. 6. Bottom layer module connection diagram.

4 Conclusion

In this paper, a fast installation and retraction manipulator driven by a fully hydraulic structure is designed and studied. According to the actual working conditions of the road surface in coal mines, the cooperation between the gripper mechanism and the modular structure of the key components of the manipulator is designed and studied. It solves the problem of stable operation and rapid completion of the installation or retraction of the bottoming module to meet the needs of rapid and safe construction. And the research on the structure of the bottom laying module suitable for mechanized and automated bottom laying equipment: including research on modules and modules, modules and equipment, and highly adaptable interfaces. The research on rapid bottom laying construction technology improves the roadway adaptability of the bottom laying robot.

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