Design and Research of Small Crawler Fire Fighting Robot

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***Abstract*—In view of the special working conditions and personal safety of firefighters in public places, houses and other fire scenes, the virtual prototype technology was used to conduct in-depth research on small crawler fire-fighting robots. The overall design scheme of the fire-fighting robot is proposed, and the independent suspension system with good shock absorption performance is designed. The explosion-proof waterproof shell of the special fire-fighting robot is developed, which realizes the accurate detection of the temperature and dangerous objects of the fire scene by the vision and temperature identification of the fire-fighting robot. Research shows that the small crawler fire-fighting robot has high detection intelligence and structural reliability, which is of great significance to the fire-fighting operations.**

Keywords—crawler, fire-fighting, robot, shock absorption

I. INTRODUCTION

With the development of social economy and the advancement of industry, various petrochemical enterprises are increasing, and the number of various inflammable and explosive chemical dangerous goods is also increasing, resulting in a significant increase in the probability of fire accidents. As a result, the importance of fire fighting robots is becoming more and more obvious. When a fire accident occurs, the harsh environment such as high temperature, dust, toxic gases and smoke poses a great threat to the safety of the firefighters. If the firefighters rush into the scene of the accident to carry out rescue, they cannot complete the task, but also increase casualties.

The fire fighting robot belongs to the category of the special robots. It has the functions of climbing, wading, obstacle crossing, high temperature resistance and heat radiation resistance, rainproof, explosion proof, chemical corrosion prevention, electromagnetic interference prevention, remote walking and self-defense functions. In the face of various dangerous and complex environments such as high temperature, toxic, anoxic and heavy smoke, the fire-fighting robots can be equipped with fire-fighting water cannon, fire-extinguishing sprinklers and other fire-fighting equipment, as well as cameras and sensors, to replace fire-fighting personnel to enter the scene of dangerous disasters and accidents for fire detection, detection of chemical dangerous substances, fire extinguishing, cooling, opening and closing valves, moving goods, plugging leakage and other operations, which can effectively solve the problems of personal safety and insufficient data collection faced by fire-fighting personnel in the above-mentioned places. On the basis of the feedback results, on-site commanders can make scientific judgments on the disaster situation in time and make correct and reasonable decisions on the disaster rescue work. Therefore, fire fighting robots can play a decisive role in fire fighting and emergency rescue.

In the research and development of special fire-fighting robots, the United States and the former Soviet Union carried out research in this area earlier, and then the United Kingdom, Japan, France, Germany, Italy, China and other countries also began to study such technologies[1-6]. At present, the practical fire rescue robot with different functions is in the initial stage of research and development, and has not yet been used on a large scale. For the first time, the Tokyo Fire Department used the "Rainbow 5" robot to extinguish the fire; the Thermite RS-T2 series commercial fire extinguishing robot developed by Howe and Howe, USA, has a crawler design, is smoke-resistant, and can work in harsh environments.

Many universities and research institutes in China are also engaged in the research on fire-fighting robots. However, there is still a big gap between domestic fire-fighting robots and developed countries in wireless remote control technology, visual inspection technology and other aspects. And there are not serialized products, so the function is relatively single. Most of them do not have explosion-proof function.

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II. OVERALL DESIGN OF FIRE-FIGHTING ROBOT

A. Requirements for fire robot operation

The fire-fighting robots are mainly used in various fire-fighting rescues such as oil, gas, gas leaks, explosions, tunnels, subway collapses, etc. Therefore, for the harsh working environment such as high temperature, corrosion, dust, smoke, etc., the body design of the fire-fighting robot is required to have high adaptability. For the complex ground conditions at the scene of the fire and the large recoil force during the water spray operation, the traveling mechanism and the body structure of the fire-fighting robot are required to have functions such as climbing, obstacles, steering, etc., and the stability requirements are high. For the detailed investigation of the accident scene, the fire-fighting robot is required to be equipped with a visual monitoring system to provide reliable information in real time. For different types of the fire rescue, it is necessary for the fire-fighting robot to replace the appropriate type of water gun conveniently, but also need to have a self-spraying device to cool the robot. For receiving high-quality feedback images of the scene, the wireless telemetry control terminal is required to have a long communication distance and strong anti-interference ability.

B. Overall design plan of the fire fighting robot

The fire-fighting robot is mainly composed of the body mechanical system, the carrying system and the control system. Among them, the robot body mainly consists of the explosion-proof shell, the walking device, the shock absorber and the auxiliary mechanical device. The carrying system mainly includes the water gun device and the on-line monitoring device, and the control system is mainly the remote control device. The hardware composition of the fire-fighting robot is shown in Figure 1.

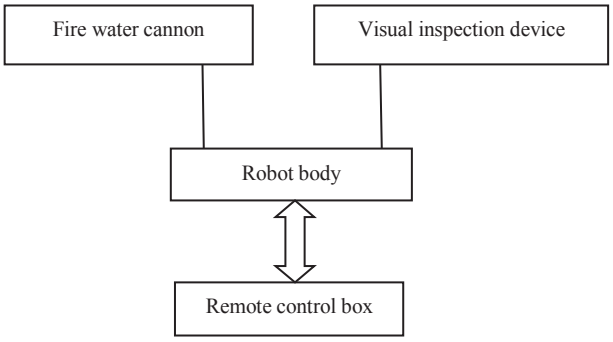
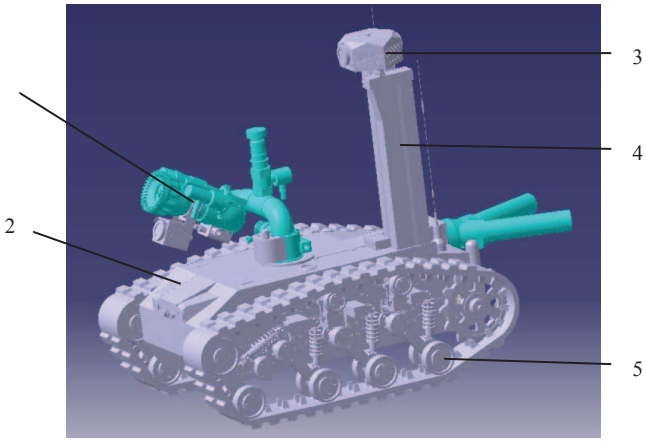


Fig.1. Hardware composition of the fire-fighting robot

Rubber crawler walking device is used on both sides of the robot body. Water gun device is installed on the front end of the robot body and water pipe is connected on the back end. The visual inspection device is installed on the elevator, which can collect information more accurately for different heights of fire scene. Inside the explosion-proof housing of the fire-fighting robot, there are drive motors, reducers, battery components and electrical control components. The total plan design of the fire-fighting robot is shown in Figure 2.



1-Fire water cannon;2- Explosion-proof shell;3- Video camera;
4- Lifting platform;5- Track walking mechanism

Fig.2.The total plan design of the fire-fighting robot

III. DESIGN OF THE FIRE FIGHTING ROBOT

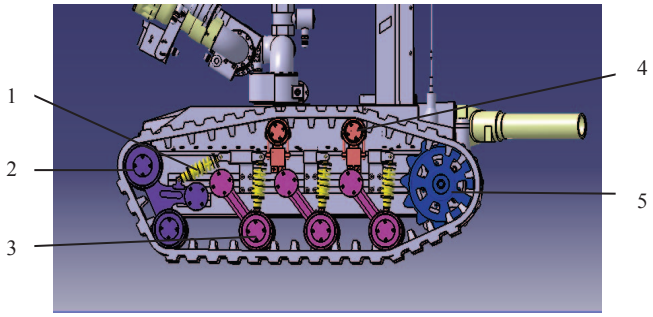
A. Mechanical system design of the fire fighting robot body

The body of the fire fighting robot is the core component of the robot and also the installation base of other systems[7]. For petrochemical, gas and other special environments that are flammable and explosive, robots are required to have explosion-proof and waterproof functions. Therefore, the main box of the fire-fighting robot adopts a explosion-proof shell, and all the components that need to be flameproof, such as driving motor, reducer and battery, are installed in the explosion-proof shell.

The walking mechanism of robot mainly includes wheel type, leg type, wheel leg compound type and crawler type[8].The advantage of the crawler type walking mechanism is that the landing area is larger than that of the wheel type, so the landing pressure is smaller, and the adhesion between the crawler and the road surface is stronger, so the driving force provided by the crawler is larger[9].Since the environment faced by the fire-fighting robot is very complicated and the ground conditions of the fire scene are also relatively variable, the crawler-type traveling mechanism is more conducive to the movement of the fire-fighting robot. Moreover, when performing sprinkler operations, the robot will be subjected to a relatively large recoil, and the crawler structure is more conducive to the stability of the work. In order to achieve greater moving speed, rubber track is adopted, so that the fire-fighting robot can reach the designated position more quickly and carry out rescue, minimizing casualties and property losses.

According to the requirements of oil, gas, gas leak, explosion, tunnel, subway collapse and other fire rescues on the robot's walking ability and obstacle-resistance performance, an independent suspension system with good damping performance is designed to protect the robot body from direct impact in the course of traveling, and to ensure that the robot has higher stability and reliability in the course of operation.

Figure 3 is the schematic diagram of the walking device for the fire-fighting robot. The damping system adopts an independent spring suspension structure, the connecting seat of the shock absorber is fixed on the box body, one end of the shock absorber is fixed on the connecting seat, and the other end is connected on the front wheel frame or the load-bearing connecting rod. The walking device is in the form of rear wheel drive, the bottom is three load-bearing wheels, and the upper part has two tightening wheels



1- Damping spring;2- Guide wheel;3- Load-bearing wheel;
4- Tensioning wheel;5- Driving wheel

Fig.3. The walking device

B. *Design of fire-fighting robot carrying system*

Fire water cannon is the core device in the process of fire fighting and rescue operation. The material of the gun body is made of 304 stainless steel, and the gun head is made of aluminum alloy. The fire water cannon has two rotational degrees of freedom, which can be rotated in both horizontal and vertical directions to achieve a change in the spray angle. According to the high temperature environment in which the fire fighting robot is working, the double-layer water curtain self-spraying and cooling device is used to effectively cool the fire-fighting robot itself to ensure the high adaptability of the robot in the special environment. During the fire-fighting and rescue, the fire-fighting robot has to drag the fire hose to move in the course of walking, which requires a higher load capacity. Therefore, high-power drive device is selected in the design and assembled in the interior of the explosion-proof shell. The power supply unit uses high energy density lithium battery, which can be charged and exchanged for sudden fire.

With the development of computer science and automatic control technology, the visual monitoring system of the fire-fighting robots has received more and more attention and become an indispensable subsystem[10]. When the fire occurs, the situation at the scene of the fire is more complex, if the firefighters rush into the scene to carry out rescue, the danger is very great. However, the fire-fighting robot equipped with the monitoring system can replace the firefighters to detect the gas, temperature, dangerous objects, obstacles and other situations at the scene of the fire, and then transmit the video image of the scene to the remote control system to help the operator take correct measures to further deal with, thereby reducing the loss of people's lives and property. The occurrence of fire is often accompanied by the generation of heavy smoke, which will cause inconvenience to the detection of fire-fighting robots, and the gas concentrations at different heights of the fire scene are also different. In order to collect the information on site more accurately, an explosion-proof lifting device is designed. The camera is installed on the lifting platform to realize the change of shooting height and improve the intelligence and practicality of the fire-fighting robot. The structure of the explosion-proof lifting device is shown in Figure 4.

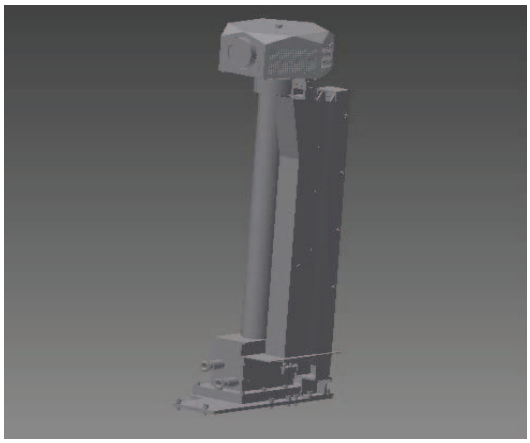


Fig.4. The structure of explosion-proof lifting device

C. *Design of remote control device*

The remote control device is the command center and control core of the fire-fighting robot, which is mainly composed of data processor, wireless terminal, display and operation Panel .The data processor is the core of the control terminal and is responsible for the processing of data and control instructions. Manipulators send instructions to the robot through the control panel, which can remotely control the robot's movement, information collection and fire extinguishing. According to the situation of the fire scene, the firefighters also can adjust the water spray angle through the control platform. The visual monitoring system can help workers get the environment around the fire scene.At the same time, the robot can collect various information from the fire scene which can be transmitted to the control terminal to help operators to operate scientifically and reasonably.

IV. CONCLUSION

Based on the characteristics of the disaster scenes in cities, this paper has developed a kind of fire-fighting robot that adapts to harsh environments such as high temperature, corrosion, dust, smoke, etc. It can replace firefighters into the fire scene for investigation and the fire-fighting tasks. And the fire-fighting robot has high reliability. The following conclusions are drawn:

- Aiming at the obstacle-surmounting problem of small crawler fire-fighting robot during walking, an independent spring suspension system with good damping performance is designed to protect the robot from direct impact during the walking process, which ensures the high reliability of the robot during working.
- In view of the special explosive environment such as petrochemical and gas, the explosion-proof and waterproof double design technology is adopted to develop the explosion-proof and intrinsically safe

shell of the special fire-fighting robot. According to the high temperature environment in which the special fire-fighting robot works, the double-layer water curtain self-spraying cooling device is used to reduce the temperature effectively of the fire-fighting robot to ensure high adaptability of robots in special environments.

- By using multi-sensor technology and image detection, visual recognition and other information fusion technology, the fire-fighting robot can detect the gas, temperature and dangerous substances in the fire scene sensitively and accurately to ensure the fire- fighting effect.
- An automatic lifting platform is designed, which is more conducive to information collection on fire scene.

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