Design of composite wall climbing robot combined with vacuum adsorption and hook climbing

Shangchun Liao¹, a *, Ruyi Ma¹, b

¹ Key Laboratory of Metallurgical Equipment and Control Technology, Wuhan University of Science and Technology, Ministry of Education, Wuhan 430080, China
a 2543861131@qq.com, b 982463279@qq.com

Keywords: Wall climbing robot; vacuum adsorption; hook climbing; compound type.

Abstract. With the development of society, human beings have more and more exploring spirit, breaking through one limit after another, building floors are getting higher and higher, underground development is getting deeper and deeper. The problems follow, such as the construction of high-rise buildings and the cleaning of exterior walls, the exploration of underground caves, the exploration and construction of complex terrain and dangerous areas, which are dangerous and inefficient. Using wall climbing robot can solve these problems very well. Nowadays, many research institutes at home and abroad have carried out research and development on wall climbing robot, and the technology adopted has its own merits. In this paper, vacuum adsorption and hook-and-claw climbing are combined to overcome the disadvantage that they can only climb on smooth and rough surfaces respectively. By combining the dexterous operation mode and force feedback, the two methods can be switched quickly and accurately, so that the wall-climbing robot can climb freely and conveniently on the wall with various roughness. It provides a safe and effective way for people to work in high-risk locations.

Introduction

Robots have been invented to replace tedious, repetitive and onerous tasks, and their high efficiency has made them more and more popular in manufacturing applications. Nowadays, more and more people need robots with special abilities to work in dangerous and special environments instead of humans. Especially in the construction industry, its work risk factor is high, and high-altitude operation is even more labor shortage, inefficient. This can not help but make people want to design a machine that can work at high altitude to replace people's work, wall climbing robot came into being. [1,5] In order to make the robot run on the wall, vacuum suction cup adsorption, magnet adsorption, fan thrust and other ways were designed; and by observing the crawling ways of animals such as gecko, spider, Oriental salamander, and chiroptera, the robot designed to use bristle adsorption, mucus adhesion, and hook and claw climbing. They all have their own advantages and disadvantages, such as vacuum suction cup adsorption, it adsorbs well on smooth wall surface, but it is easy to leak pressure on rough wall surface; hook claw climbing on rough surface is better, smooth surface is easy to hook; magnet adsorption can only be adsorbed on iron wall surface, other materials wall surface is then It can not be adsorbed, so it is more widely used in the ship shell; [10] fan thrust dependence noise, low energy utilization, but it is easy to operate fast; while the bristle adsorption is based on the interaction between molecules van der Waals force adsorption, its fine structure, bristle end disk diameter about 40 microns, thickness is about 2 microns m, the production is more complex, it is the current wall-climbing robot research hotspot, but the technology is not very mature, is still in the study [2]; mucus adsorption is by the end of the foot and wall contact, and fit the wall gap, thus
secreting mucus into the gap, adhesion, its disadvantage is slow. The application of wall-climbing robot in building mainly focuses on the cleaning work of high-rise building exterior wall, spraying of building material fire-proof layer, painting of wall surface, and tile attachment of wall surface. However, due to the limitation of the running environment, the insufficient adsorption capacity, the limitation of its own weight, and its running speed, all kinds of wall climbing robots have hindered their wider application. [11] In order to make it more widely and conveniently used, two or more kinds of adsorption methods are proposed, and their respective advantages are used to synthesize, which overcomes the shortcomings of their respective operation, so that wall-climbing robots can work in more complex environments. Known combinations include oblique wall-climbing robots with fan thrust and negative pressure; Stanford climbing maneuvering platforms with barbed antennas; omni-directional wall-climbing robots with negative pressure suction cups and hook-and-claw structures attached to smooth and rough surfaces; and building cleaners with airflow stability. Man and so on. In this paper, the true pressure suction cup and hook-claw combination of climbing mode, using four-legged climbing mechanism, each foot is equipped with suction cup and hook-claw can convert each other, each leg has sensors, constitute a feedback mechanism, when the pull force can not reach the required size, the adsorption mode conversion, so that the wall-climbing robot can be more complex. Running on the wall. The climbing robot built by this mechanism has higher mobility and higher safety factor.

**operation principle of vacuum wall climbing robot**

The vacuum wall climbing robot provides its adsorption capacity by atmospheric pressure. The vacuum pump creates a vacuum environment between the suction cup and the wall to form a negative pressure, so that the suction cup is adsorbed on the wall. This adsorption method requires strict sealing of the adsorption layer, and it is easy to leak pressure on the cracked wall. [7,8] The vacuum adsorption wall climbing robot consists of sucker foot, vacuum pump, solenoid valve, steering gear, large framework, power supply, control circuit, single chip microcomputer, wireless module, sensor and other components. [12] For example, a quadruped vacuum-absorbing wall-climbing robot moves on its own with four sucker feet. Each time it runs, one sucker feet runs steadily and the other runs, which ensures the stability of the operation. Four steering gears are connected with the sucker foot, and the steering gear has a larger moving angle. Each steering gear is equipped with a motor, which can ensure that the sucker foot has greater flexibility and has a certain ability to surmount obstacles. The vacuum pump is connected with the sucker through the pipeline to create a vacuum environment for the sucker. Because each sucker foot needs to move independently, four electromagnetic control valves are used to connect the vacuum pump and the sucker foot to realize the operation of the sucker foot. In order to make the quadruped vacuum wall-climbing robot run in harmony, the sensor is used to provide the running conditions of each sucker foot, and the data is transmitted to the single-chip microcomputer through the control circuit for unified and coordinated processing. The external power supply provides the required power, and the wireless module provides wireless control to facilitate the operation of the climbing robot. [4] its structure is shown in Figure 1:

**The running principle of the claw climbing robot.**

Compared with traditional wall-climbing robots, such as vacuum adsorption, magnetic adsorption and bonding of special materials, wall-climbing robots can only operate on smooth surfaces, iron surfaces and walls of special materials respectively, and are not suitable for rough walls, such as brick walls, cement walls, stone walls and other cracks, and the materials are general, and widely used on
the wall. The hook and claw climbing robot can effectively solve this problem. There are also some wall-climbing robots adapted to rough wall adsorption, such as negative pressure wall-climbing robots, which allow a certain gap between the suction cup surface and the wall, but its energy efficiency is low, whether crawling or stationary, need to provide a large amount of electricity to maintain its adsorption, [3] in addition to the use of high-speed fans to form a high-speed fan. In negative pressure environment, the noise is larger, while the hook-claw wall climbing robot has less noise. When it is stationary, the energy consumption is basically zero. The hook-and-claw wall-climbing robot adopts a parallelogram structure with four symmetrically distributed feet. Each foot runs independently. Each foot has more than one claw. Each foot is equipped with four steering motors and sensors. The steering motors are driven by motors to ensure the flexible movement of the foot and have a certain ability to avoid obstacles. The state, including the force information, is fed back to the single-chip microcomputer through the control system, which is processed by the single-chip microcomputer. The angle of rotation of the steering gear and the depth of penetration of the claws are related to the stability of the hook-claw wall climbing robot. Therefore, it is necessary to distribute the movement time of the foot reasonably. The material, length and bending of the claws need to be carefully considered. [6] Its organization is shown in Figure 2:

![Fig. 1 Composition of vacuum adsorption robot](image1)

![Fig. 2 construction of hook and claw wall climbing robot](image2)

**Vacuum adsorption and hook and claw climbing robot.**

Wall climbing robots, which are composed of different climbing methods, overcome the limitation of the environment when moving in a single climbing mode, and can run on the wall with different roughness or shape. The main representatives are building cleaning robot with stable air flow, Stanford climbing mobile platform, wall climbing robot with combined thrust and negative pressure adsorption, wall climbing robot with hook and sucker, etc. They have different structures and characteristics.

The wall-climbing robot which combines hook and claw with vacuum adsorption adopts two different adsorption modes. The wall-climbing robot adopts vacuum adsorption mode on smooth plane and hook and claw type on rough plane to climb. Strong adsorption. This paper designs a composite wall-climbing robot which combines vacuum adsorption and hook-claw climbing. It is composed of a vacuum wall-climbing robot in Fig. 1 and a hook-claw wall-climbing robot in Fig. 2. The quadruped structure is independently operated with suction cups and hooks on the feet. Smooth wall with vacuum suction cup adsorption operation, when a foot due to the wall is too rough to reach the vacuum environment, the sensor will feedback information to the microcontroller through the control system, so that the foot claws pop up and cling to the wall. [9] When the running hook-and-
claw device cannot grasp the wall because the wall is too smooth, the sensor feeds back the information to the microcontroller through the control system, so that the hook-and-claw on the foot can be retrieved, and the sucker can be used for vacuum adsorption and crawling. The claw's ejection and recovery are realized through the spring device at the end of the claw claw and the motor connected with the claw. When the robot moves forward, the microcontroller can arrange the running sequence of four feet and the running steps of each leg reasonably.

Conclusions

In recent years, people have conducted in-depth research on wall-climbing robots, and put forward a lot of wall-climbing robots based on different adsorption methods. These wall-climbing robots have their advantages, but because of their single adsorption mode, they more or less have some defects. If a variety of adsorption methods are used to combine. The method can effectively integrate their respective advantages and create a very convenient and practical wall climbing robot. In this paper, the combination of vacuum adsorption and hook and claw climbing is used as the operation mode of the wall climbing robot. With the unique transformation mechanism and force feedback structure, the wall climbing robot can easily climb on the complex rough plane. It has certain reference significance for the future research and development of the combined wall climbing robot.

References