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A New Cleaning Robot for Glass Curtain Wall of City

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Abstract. To solve the problem of artificial scrubbing the glass curtain wall, such as large investment, high risk, high difficulty, based on the structure of telescopic fence, this paper has designed a new glass curtain wall cleaning robot, with a simple structure, convenient operation, safe, reliable and high efficiency. The robot can scrub the plane with no dead angle. we also analyzed the operational path and motion control, confirmed the feasibility of system movement

Keywords: Cleaning Robot, Glass Curtain Wall, Simple Structure, High Efficiency

INTRODUCTION

In view of the advantages of beautiful and light transmittance in the city, the glass curtain wall is mostly used on the wall, which brings some trouble to the cleaning. The glass curtain wall is generally large, mostly at the height of dozens of meters or even hundreds of meters, and there is no climbing support around it. That makes the cleaning of the glass curtain wall a complex. Heavy, dangerous, expensive work. Under this background, the high-rise building cleaning robot came into being.This kind of robot belongs to a kind of climbing robot, Research institutes around the world are actively carrying out this research work.

Since the first vertical wall mobile robot was developed by Professor Xi liang from the University of Osaka Prefecture in Japan in 1966, the wall climbing robot has flourished in Japan.Professor Nishi from Miyazaki University in Japan developed "a flying robot "with two rotating blades[1].Japan Chemical Machinery Technology Service Co., Ltd. developed a wall climbing robot called "Walker"[2].In 1992, Daifuku company of Japan successfully formulated the single suction wheel drive wall cleaning robot[3].In 1982, Professor Sun Liang of Miyazaki University in Japan developed the biped climbing robot[4].After that, many kinds of climbing robot prototypes have been developed in Britain, Spain, the United States, Germany and Russia.In 1990, the Russian Academy of Mechanical Sciences developed a single sucker wall climbing robot for cleaning operations [5-8]. The American International robotic company developed a wall climbing robot "Skywasher" for cleaning skyscrapers[9]. After developing a four foot wall walking robot Robug II, the British South Bank University developed Robug III wall climbing robot[10-11].In 1994, B.Bahr at the State University of America developed the ROSTAM- III vacuum adsorption wall climbing robot[12-13].Since 1980s, many Chinese universities and scientific research institutes have also made great progress in the field of wall climbing robot. Many types of wall climbing robots have been developed.For example, Shanghai Univer's special robotics technology research laboratory has developed multi-storey frame and multi vacuum suction wall climbing robot series [14].Two types of wall climbing robots have been developed by Harbin Institute of Technology: single sucker wheel driven wall climbing robot and magnetically

adsorbed crawler wall climbing robot[15].However, as a whole, the application of cleaning robot in China is basically undeveloped.It can be said that it is a blank field, and most of the high rise buildings in China are still using the hanging basket to complete the cleaning work at present. Therefore, the cleaning robot will have a very broad application prospect.

OVERALL STRUCTURE DESIGN OF CLEANING ROBOT

The main function of urban glass curtain wall cleaning robot is to complete the work of cleaning exterior glass wall instead of people.So the working environment of equipment is in the height of ten meters or even a hundred meters.That has high requirements for the weight, adsorption performance and flexibility of the device itself.

The curtain wall cleaning robot system is divided into three main parts:vacuum adsorption combined with permanent magnet，path planning of telescopic connecting rod，distribution of the cleaning device.The cleaning equipment mainly adopts the intersecting connection mode. Through this way, the equipment can be moved more flexibly and lightly. It is mainly set to lighten the weight of the equipment itself.

Because of the large area of glass, It’s slow for the robot to move back and forth,so as to improve the efficiency and reduce the cost, The two ends of the device are fixed by the way of He Yongci adsorption and vacuum negative pressure.At the cross connection of brackets, a clean cloth magnetic force angle is installed to increase the pressure on the wall to achieve the expected cleaning effect.The small type motor drives the cleaning mop to complete the cleaning work on the glass wall under the expansion of the support arm.In addition, a simple modular design structure is adopted in the structure, as shown in Figure 1.

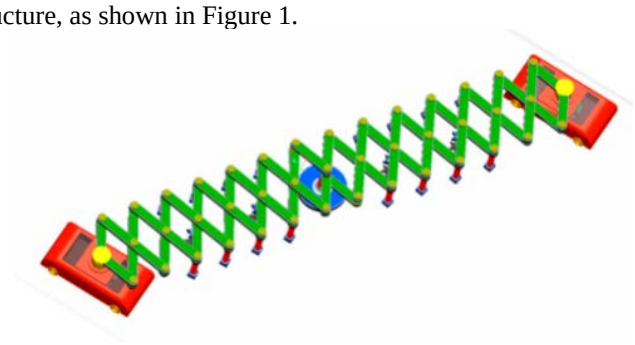

FIGURE 1. Overall structure of the cleaning robot

THE ADSORPTION MOVEMENT MODE OF THE ROBOT

The centrifugal fan is adopted as the negative pressure generator of the adsorption system,which is shown in figures 2 and 3. That is, the centrifugal fan is installed inside the cleaning robot. As the motor rotates highly,the air in the inner cavity is derived in the radial direction, so that a certain pressure difference is formed inside and outside the cavity, and the negative pressure on the wall surface is generated on the outer surface, and the friction force of the wheel and the wall can be produced to overcome the gravity ,and achieve the purpose of adsorption. The principle of negative pressure adsorption is shown in figure 4.

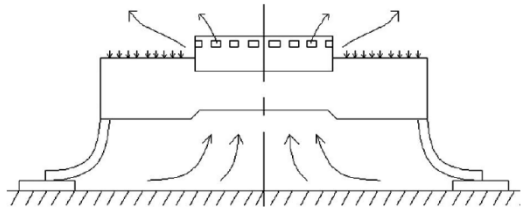

FIGURE 2. Principle diagram of negative pressure adsorption

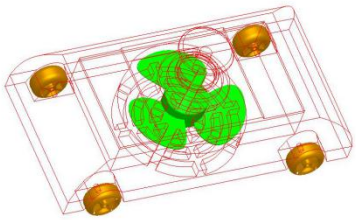

FIGURE 3. Centrifugal fan

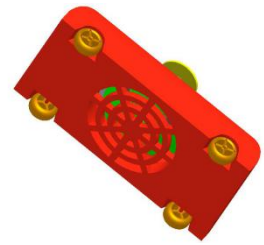

FIGURE 4. Negative pressure adsorption device

The curtain wall cleaning robot should have a certain adsorption capacity. The negative pressure produced by the centrifugal fan must be greater than the weight and load of the cleaning robot to prevent falling, and it should also keep a certain driving force to make the robot move forward.

It must be satisfied:

$$F \geq Mg + Ma = m_1 g + m_2 g + Ma \quad (1)$$

In the form:F is the negative pressure generated by the fan, M is the sum of the weight and load of the robot, m_1 is the weight of the robot, m_2 is the weight of the cleaning brush, and a is the acceleration.

PATH PLANNING OF "FENCE" TELESCOPIC CONNECTING ROD

The expansion device of cleaning robot is mainly composed of telescopic frame and motor.The telescopic frame uses plastic material with good elasticity and toughness.The plastic material has ductility, the force can be deform-able.,and the quality of plastic material is lighter, which can reduce the weight of the equipment itself.According to the setting procedure, the telescopic frame is telescopic controlled by servomotor.The outer end of telescopic bracket is provided with a absorbent sponge, mainly to dry the glass wall .In addition, the magnetic attraction point is mainly designed to increase the positive pressure of the sponge on the glass wall, so that the water can be better absorbed .Generally, the size of the glass curtain wall is 1.0~1.5 meters wide and1.2~1.6 meters height1. The telescopic brackets can drive the clean mops to expand to all parts of the glass.

THE CLEANING DEVICE FOR THE ROBOT

The cleaning device is composed of main rotary mops and auxiliary cleaning devices.Besides, the cleaning liquid supply of the cleaning device is transported by VPF.In this way, the cleaning efficiency can be improved, and the self weight of the cleaning robot can also be reduced.The motor rotates to drive the main rotary mop (Figure 5), and its flexible brush is used to rub and clean the glass curtain wall.In the process of telescopic swing of telescopic connecting rod, auxiliary cleaning device (Figure 6 is cleaned by adsorption force.

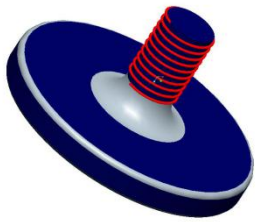

FIGURE 5. Main revolving mop.

FIGURE 6. Auxiliary cleaning device.

In order to reduce the weight , the telescopic arm is equipped with a hose, the water is introduced from outside to wet mop.Meanwhile, in order to increase the cleaning effect without adding water marks on the glass, the absorbent sponge is also designed on the telescopic boom, which greatly improves the cleaning effect.

STATIC ANALYSIS OF THE ROBOT IN THE VERTICAL GLASS CURTAIN WALL

When the robot is stationary on the vertical wall, as shown in Figure 7, The robot is subjected to the gravity, the support force of the wall and the static friction force of the wall to the adsorption device. According to the Cartesian coordinate system, the forces of the robot body can be decomposed into the X axis and the Y axis.

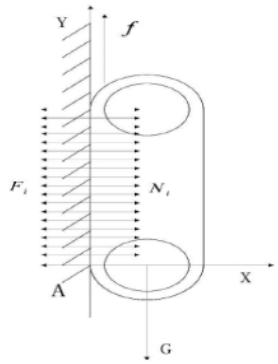

FIGURE 7. The force analysis of the robot on the vertical wall

The robot is supported by the wall face adsorption device and the adsorption force of the adsorption device in the horizontal X direction.In vertical direction Y, subjected to gravity and friction of the wall.According to its static equilibrium, it can be obtained:

The force balance in the X direction:

$$\Sigma x = 0 \tag{2}$$

$$\sum_{i=1}^{n} F_i = \sum_{i=1}^{n} N_i \tag{3}$$

The force balance in the Y direction:

$$\Sigma y = 0 \tag{4}$$

$$f = \frac{G}{2} \tag{5}$$

Among them,

F_i——The attraction of each adsorption device to the adsorption surface.

N_i ——The support of each corresponding adsorption device

i—— The number of adsorption devices, the maximum is 2;

f —— The static friction of the vertical wall.

G ——The gravity of the robot (including the load).

When the robot moves on the wall, No matter what posture the robot is in, The torque of the driving axle is the power source of the robot.Considering the critical condition of robot overturning at A point, the torque balance condition of robot is:

$$\sum M_A = \sum_{i=1}^{n} F_i a_i - \sum_{i=1}^{n} N_i a_i - \frac{G}{2} \times \frac{h}{2} \tag{6}$$

Among them,

a_i——The distance from each adsorption unit to the A point;

a——The center distance of the wheel;

h ——The robot’s height .

CONCLUSION

In view of the current cleaning situation of modern high-rise glass curtain wall,to solve the problem of large investment, high risk and high difficulty in artificial high altitude scrubbing glass,a glass curtain wall cleaning

equipment with simple structure, convenient operation, economy, safety, reliability and high efficiency is designed.The device is supplied with external water by hose to reduce its weight.The air curtain wall is scrubbed by man-machine control.The vacuum suction is applied ,the 360 degree without dead angle scrub in the plane can be realized.

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