The Innovation Design of the Magnetic Adsorption Climbing-wall Flaw Detection Robot

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Abstract: In order to reduce the surface flaw detection cost and time consuming of large area steel iron surface (such as the surface of large storage tank or ship, etc), solve the existing wheeled magnetic adsorption technology problems of wall climbing robot, a kind of wheeled magnetic wall climbing robot is designed. Unique adsorption unit and innovation design of magnetic circuit make the wheeled wall climbing robot has a large carrying capacity. The robot uses LPC1768 chip as the control center. Divided into walking control, camera control, the other action control. Robot users through wireless handle to control the robot walking and action in the surface of steel vertical and accept the robot feedback information through a ground station. This paper mainly introduces the design of each module, gives the concrete design scheme of mechanical structure, hardware circuit and software.

Key Words: Teleoperator, Permanent Magnetic Wheeled Adsorption, Image Real-time Transmission, Flaw Detection

1 INTRODUCTION

The oil tank and ship hull is common in large iron and steel surface. Because of the pressure and the erosion of rain water and oil, the wall may have pits, cracks, internal defects. These defects are easy to cause the risk of accidents. It must be regularly tested. At present, the surface detection of large tank ship by artificial realization. It need of scaffolding. It's efficiency is very low and high risk. In the circumstances that Nuclear leakage or leakage of toxic gas, a safe and reliable magnetic adsorption robot is particularly useful. With the rapid development of industry, the detection technology which enterprise require for is become more and more high. It is imperative to develop automated test equipment.

At present the domestic magnetic adsorption robot are mostly in the stage of research. It is hard to be practical application. Magnetic adsorption robot can be roughly divided into tracked and wheeled. Tracked type wall climbing robot most have complicated structure, low efficiency.Its walking is not flexible and high cost. Besides it is difficult to repair[1]-[2]. Wheel type wall climbing robot, due to the distance between permanent magnet and the adsorbed surface , the adsorption capacity is not strong.It is difficult to work safely on the working face or carry other equipment. This caused a gap in the market in China about magnetic adsorption wall climbing robot. This paper designed a new type of wheel type magnetic wall climbing robot . The innovative and unique design of magnetic circuit adsorption unit let the robot has high practical value and broad application prospect[3].

2 STRUCTURE DESIGN

2.1 Design of Adsorption Unit

2.1.1 The Selection of Permanent Magnet

Because of NdFeB has high coercivity, energy product,rich resources and cheap, it become the most widely used magnetic materials. Using NdFeB as wall climbing robot's permanent magnet materials has the advantages of compact structure and plot ratio [4].

Table1. The performance parameters of the NdFeB N52

Br	mT	1430-1480
	KGS	14.3-14.8
Hcb	KA/m	≥796
	KOe	≥10
Hcj	KA/m	≥876
	KOe	≥11
BHmax	KJ/m^3	398-422
	MGoe	50-53
TW	□	60

2.1.2 Permanent Magnetic Adsorption Unit Magnets and Magnetic Circuit Design

Adsorption unit should be as close as possible to the adsorbed surface, so the adsorption unit as the robot's

wheels can achieve better adsorption effect. As shown in Figure 1, the adsorption unit consists of an annular permanent magnet 1, an annular steel plate 2, nylon sleeve 3. The annular steel disc is on the ragged edge of adsorption unit. It effectively protect the strong magnets. Besides it has a magnetic guiding role.

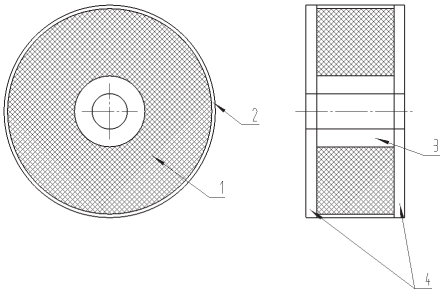


Fig 1. The adsorption unit. The adsorption unit consists of an annular permanent magnet 1, an annular steel plate 2, nylon sleeve 3.

The strong magnet is magnetized the thickness direction. Its N pole touch a steel sheet phase. S pole close with another steel sheet phase.It forming magnetic dipole on the wheel and the wheel below and the sucked surface contact. So it greatly enhanced the adhesion of robot.

2.2 The Driving and Driven Wheel Distribution Design

In order to develop a reliable, flexible climbing wall robot mobile platform, the design of robot motion system as shown in Figure 2. Robot system mainly comprises two driving wheels and two driven wheels. Driving wheels flank the robot. Driven wheel falls on the front and back.

Fig 2. The design of robot motion system. Robot system mainly comprises two driving wheels and two driven wheels.

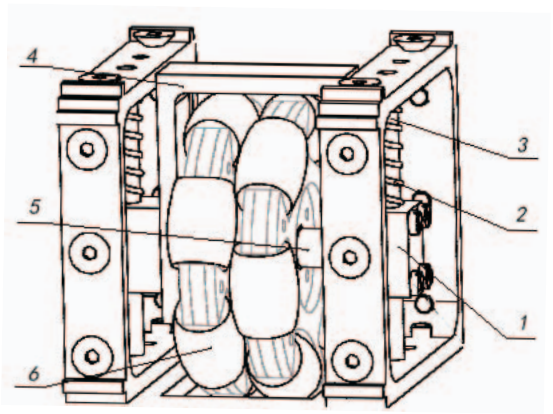


Fig 3. The driven wheel sketches. 1.Floating block 2. Floating spring 3. Floating guide rod 4. The fixed frame 5. Driven shaft 6. Driven wheel.

The two driving wheels are concentric.They are drove respectively by a DC motor. It can realize forward, backward, steering motion by controlling the two motors' speed. Omnidirectional wheels are made by Non-metallic materials. They are in the front and tail end of robot. Each driven wheel has floating mechanism design to enhance adaptability to wall surfaces. The kinematics model of this robot can be equivalent as shown in Figure 4.

2.3 The Kinematics Analysis of Wall-climbing Robot

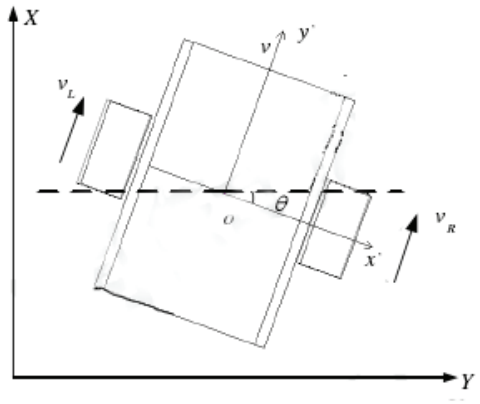
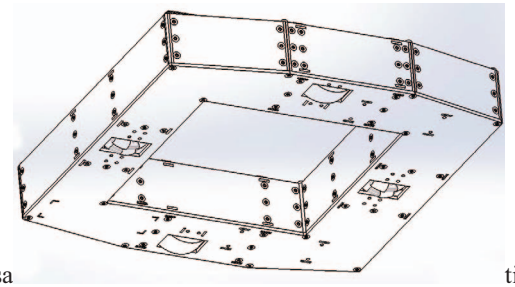


Fig 4. Climbing robot's motion diagram.

The robot motion model is in the center of the equivalent of two driving wheel axis point O. The motion state of this point



satisfy the following expressions:

$$\begin{cases} x_0 = v\sin\theta \\ y_0 = v\cos\theta \\ \theta_0 = \omega \end{cases} \tag{1}$$

The motion control of robot should ultimately rely on the control of the driving wheel on both sides of therelationship, therefore asked the robot velocity of center of mass and on both sides of the driving wheel speed.

$$\begin{cases} v = (\omega_L + \omega_R)R/2 \\ \omega = (\omega_L - \omega_R)R/B \end{cases} \tag{2}$$

Among them, v- translational speed of robot center of mass; ω −rotating angular velocity of the robot; ω_L- robot left drive wheel rotation speed; ω_R- robot the right driving wheel rotation speed; B- distance between two wheel; θ −robot pose angle.

Put (2) into formula (1) get (3), then we obtain the relationship between robot velocity of center of mass and the two driving wheel speed.

$$\begin{cases} x_0 = (\omega_L\omega_R)R/2\sin\theta \\ y_{0'} = (\omega_L\omega_R)R/2\cos\theta \\ \theta_0 = (\omega_L\omega_R)R/B \end{cases} \tag{3}$$

When the robot steering, robot's instantaneous turning radius is R0. Relationship between robot velocity of the

center and the angular velocity of robot is shown as follows:

$$v = R_0\omega \tag{4}$$

When the left and right wheel speed is equal.w =0, and V -the robot velocity is not zero. The robot's turning radius R0. The robot's motion in a straight line. When the driving wheel speed equal in number but opposite in direction, according to the formula of V is zero, while W is not zero. So that R0=0 and robot has ability to do rotary motion with zero radius. We can control robot's speed, steering rotational speed and turning radius by controlling both sides of the driving wheel[5].

The trajectory of a robot can be obtained by integrating the center of mass velocity and angular velocity. The complete expression of position information of the robot at any time as follow[6].

$$\begin{cases} x_0(t) = \int v(t)\sin\theta dt \\ y_0(t) = \int v(t)\cos\theta dt \\ \theta_0(t) = \int \omega(t) dt \end{cases} \tag{5}$$

2.4 The Main Body Frame Design

The main frame is made of aluminum alloy and carbon fiber. They are have low density but high hardness. With the premise of robot mechanical structure reliability, it reduce weight and increase the load capacity of the robot.

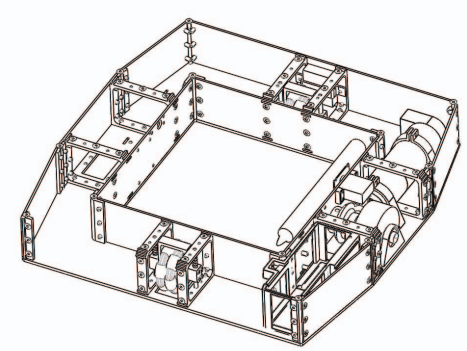


Fig 5. The main frame of the robot. The main frame is made of aluminum alloy and carbon fiber.

2.5 The Selection of Motor

Robot design weight is 6kg, the maximum speed is 0.5m/s, without considering the intermediate transmission loss, the power required for no-load:

$$p_n = mgv = 6\times 9.8\times 0.5 = 29.4w$$

Considering the robot design maximum carrying capacity of 7kg, the maximum power at full load needed for:

$$p = (m+m_f)gv = (6+7)\times 9.8\times 0.5 = 73.5w \tag{6}$$

Power considering the motor speed can not reach the rated and loss of energy, for the sake of safety, the total power of motor:

$$p_z \geq 2p = 2\times 73.5 = 147w \tag{7}$$

The motor torque:

$$M \geq \frac{1}{2}Rmg \tag{8}$$

The motor rotate speed:

$$n \geq 60\frac{v}{\pi d} \tag{9}$$

The motor shall be selected to meet the above 3 requirements(7-9). With comprehensive consideration, we choose the domestic 90w motor.

3 HARDWARE STRUCTURE DESIGN

The whole control process of the robot is shown in figure 6.

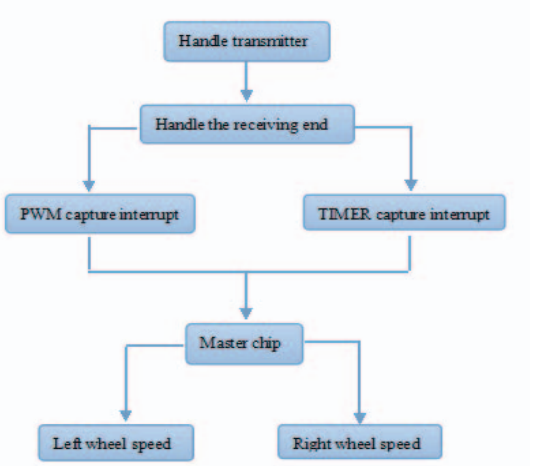


Fig 6. The whole control process of the robot.

3.1 Design of Control Circuit

The main control chip is LPC1768. We control motor by using self-made driver. Smart battery using STM32F103C8T6 as the control chip. The main control chip LPC1768 control driver through the CAN communication. LPC1768 and the two rudders is directly connected to control rudders by PWM wave. LPC1768 communicate with handle by transceiver[7].

In addition, the main control board also includes control chip peripheral circuit four capacitance and resistance of the right size, and circuit which convenient for program download.

3.2 Remote Control Handle

We use Tiandifei 6 as our radio handset. Operator rock trigger button to make the handset launch ppm wave. Than PPM signal will be modulated and become six way PWM signal. By the capture function of the PWM module and timer module (PWM signal acquisition level jump) to enter the interrupt. Than deal with the received signal, and according to the received signal change the speed of corresponding wheel to complete controlling robot.

3.3 The Image Transfer Process

Using 5.8 G figure, system is divided into transmitter and receiver respectively which need 12v power supply. Turn

camera connected hdmi av module hdmi port, figure and transmitter connect the av port; The ground receiver directly connected av display to show the image.

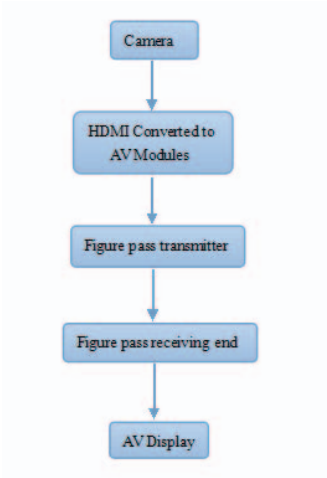


Fig 6. The flowchart of image transfer process.

3.4 Power Supply Mode

The power of this circuit for the power supply is two piece of Intelligent battery. Intelligent battery comprises rechargeable batteries and some monitoring circuit. Intelligent battery can output 24V voltage and the maximum stable current is 10A and the maximum output power is 240W. Built-in electric detection module and power detection module can detect the status and show you by some indicator lamps.

The circuit adopts LM2576-5.0, LM2576-ADJ, MP2482DN, AMS1117-3.3 as step-down voltage stabilizing chip and output 12V, 5V, 3.3V voltage we need.

4 CONCLUSIONS

(1) The magnetic adsorption climbing robot we design is different from the traditional wall climbing robot. It effectively overcomes the problem that poor of robot adsorption capacity and load capacity.

(2) Put forward specific solutions for wireless remote control wall climbing robot.

(3) It integrate wall climbing robot technology, wireless remote control technology and wireless image transmission technology.

(4) Based on the embedded technology, low cost, low power consumption using the embedded technology, low cost, compared with the price so hundreds of thousands of domestic and foreign, low cost.

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