Structure design and type selection of a crawler manipulator chassis

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Abstract: The crawler robot chassis is intended to be used in dangerous places, complex environment and other operations, the machine can work on complex ground, with good environmental adaptability, good crawler grip, no slipping. This paper briefly introduces the structure design, control system design and motor selection of the new crawler manipulator chassis.

1. Introduction

In recent years, robot technology advances by leaps and bounds, the development of robot has penetrated into all walks of life, has a wide range of applications in people's daily production and life, robot is also moving towards the direction of high intelligence. Intelligent mobile robot is a multi-functional integrated system including environment perception, dynamic decision and planning, behavior control and execution. It concentrates the research achievements of sensor technology, information processing, electronic engineering, computer engineering, automation control engineering, artificial intelligence and other disciplines, represents the highest achievement of mechatronics, and is one of the most active fields in the development of science and technology.

At present, most of the mobile robots we can see are wheeled, because the wheeled structure is more convenient to move, and can move anytime and anywhere, and with the man-machine control system, the operation is more simple and easy to complete various tasks. However, wheeled mobile robot also has some disadvantages. For example, when a wheeled robot walks on soft land or in the desert, it will slip, which makes the encoder calculation error and cannot be controlled; moreover, the turning radius of the wheeled robot is very large, so when considering the control mode, it will directly affect the size of the walking parts of the wheeled robot.

2. Structural design

The structure of crawler manipulator chassis is shown in Figure 1, which is composed of five parts: vehicle body, walking device, telescopic device, swinging device and end effector.

The crawler robot chassis has the following advantages:

(1) Be able to work on complex ground in different environments, even in soil, desert, gravel and other environments;

(2) It has a good ability to adapt to the environment, can realize the change of pose in a variety of terrain, and can recover quickly after the change;
(3) Crawler good grip, no slip, can maximize the effectiveness of the motor.

![Telescopic device](image1)

![End effector](image2)

![Frame](image3)

![Walking device](image4)

![Swing device](image5)

Figure 1 Crawler manipulator chassis

3. Control system design

The crawler manipulator chassis adopts four crawler structure, double differential travel, both sides of the crawler do not affect each other, can adjust their rotation, independent operation. From the control point of view, the crawler manipulator chassis uses a low-voltage regulated power supply to control the movement of the motor, so that the chassis can run stably. Because there is a voltage regulator, it will not affect the movement of the chassis due to the unstable voltage. The motion control system not only includes motor and crawler, but also includes encoder, rotary steering wheel, motor driver, motor control motherboard and core control board. With the good writing of control program, it forms a good control system with mechanical equipment. The specific control system is shown in Figure 2.

![Encoder signal feedback](image6)

![Communication I/O](image7)

![PWM signal](image8)

![Circuit feedback](image9)

![PMW power converter](image10)

![Left motor](image11)

![Left front rotary motor](image12)

![Right front rotary motor](image13)

![Right motor](image14)

![Crawler manipulator or chassis](image15)

Figure 2 Chassis control system of crawler manipulator

3.1. regulated power supply module

According to the needs of chassis power configuration hardware system, 3.3V, 5V and 15V regulated power supply are provided respectively to ensure the normal operation of all components. Lm2575hv-adj chip is used for voltage regulation module. Under the premise of input of 24 V, the output voltage can be changed by adjusting the resistance with a screwdriver to obtain the required stable voltage value. By using the voltage regulator module, the voltage can be stabilized in a certain range, so that each power module is independent of each other and can work normally without affecting each other.
3.2. **AT Mega328(UNO) core control board**

The technical parameters of the control board are as follows:

- **Size**: 70 * 54mm;
- **Input voltage**: no external power supply or external 7V ~ 24V DC input when connected to USB;
- **Output voltage**: 5V DC output, 3.3V DC output and external power input, support USB interface protocol and power supply (without external power supply), adopt at mega328 (UNO) MCU;
- **Flash**: 32KB (2 kb for bootloader);
- **SRAM**: 2KB;
- **EEPROM**: 1KB;
- **Speed**: 16mhz;
- **Support ISP download function**;
- **Support single chip TX / RX terminal**;
- **Support aref terminal**;
- **Digital I / O digital input / output 0 ~ 13 in total**;
- **Analog I / O has a total of 0 ~ 5 analog input / output terminals, 6 and 7 reserved), and supports six groups of PWM terminals (PIN3, pin5, pin6, pin7, pin9, pin10);**

This control system adopts AT Mega328(UNO) control board. Because the control board is easy to operate and has complete functions, it is convenient to control the crawler chassis, so it is considered to use the control board comprehensively.

3.3. **Motor drive module**

The motor controller adopts rmds-107 DC servo motor driver, and the specific parameters are as follows:

- **Overall weight**: 120g;
- **Body size**: 98*67*25 with plug;
- **Continuous current**: 10A;
- **Peak current**: 25A;
- **Communication interface type**: can bus,RSA232, PWM /PPM pulse direction;
- **Encoder type**: incremental encoder, single ended ABZ or AB voltage output is appropriate, also support NPN output, PNP output, long line output, differential output.

4. **Motor selection**

In this walking structure design, chain drive plays a connecting role and is the key device to connect the inner and outer wheels. Through the connection of chain wheel, that is to say, through the connection of chain wheel chain, four tracks are connected in pairs. One of the motors on the same side controls the forward and backward of the track, and the other DC servo motor controls the rotation of the track.

If the friction coefficient between the track and the ground is set \( \mu = 0.5 \), the weight of the machine body is set 50Kg, and the traction force and friction force \( f/2 \) of the motor are equal, then

\[
F_o = \frac{f}{2} = \mu \frac{mg}{2} = \frac{0.5 \times 50 \times 10}{2} = 125N.
\]

According to the design parameters, the walking speed of the whole tracked robot chassis is \( v = 0.4 \sim 0.8 \text{m/s} \), and the maximum value of \( v \) is 0.8m/s.

So the power of the tracked robot chassis is \( P_o = F_o \times v = 125 \times 0.8 = 100 \text{W} \). The required power of DC servo motor for walking is \( P_m \), as follows:

\[
P_m = \frac{P_o}{\eta}
\]

Where: \( K \)- safety factor, take \( K = 1.5 \); \( P_o \)- power of the designed chassis; \( \eta \)- total transmission efficiency of the transmission device; and because the total transmission efficiency is \( \eta = \eta_{\text{motor}} \times \eta_{\text{Chain drive}} = 0.97 \times 0.96 = 0.9312 \). Therefore, the actual output power is:

\[
P_o = \frac{100}{0.9312} = 108.17 \text{W}
\]
Because the prime mover of the crawler type mechanical arm chassis needs to bear the weight of the whole chassis and cooperate with the use of the crawler and other mechanical structures, the DC servo motor with high precision, large torque and flexible operation is adopted. The DC servo motor can not only operate accurately, but also operate offline, so it is very convenient to use. Through calculation, the actual output power of crawler manipulator chassis is 161.08W, so Maxon DC servo brushless motor of Swiss brand is selected, and its model is ec-4pole 30. The specific parameters are shown in Table 1 below.

| Motor parameters  | 305013 | 305014 | 305015 |
|-------------------|--------|--------|--------|
| Rated voltage (V) | 24     | 36     | 48     |
| Maximum speed (rpm) | 17000   | 17000   | 16500  |
| Maximum current (mA) | 885     | 590     | 422    |
| Rated speed (rpm) | 16200   | 16200   | 15800  |
| Maximum current (N.m) | 114     | 119     | 120    |
| Starting current (A) | 9.21    | 6.39    | 4.70   |
| Antiviral group (A) | 236     | 171     | 124    |
| Antiviral group (Ω) | 0.102   | 0.210   | 0.386  |

5. Conclusions
In this paper, through the introduction of the crawler robot chassis, the structure design, control system composition and motor selection of the robot chassis are finally determined. The next step is to complete the specific structure design, strength design and verification of the tracked robot chassis. By designing a reasonable chassis structure of tracked robot and cooperating with robot or manipulator, the task can be completed in a variety of complex environments to meet the established work requirements.

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