# Permanent magnetic climbing robot design and calculation of adsorption

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## Abstract

**Designed a permanent magnet adsorption climbing robot, established four rectangular permanent magnet adsorption model by ANSYS, calculated the air gap suction force of the permanent magnet, provided a reference for the follow-up.**

## Keywords

**Climbing robot; permanent magnetic; ANSYS.**

## 1. Introduction

Many special industries exist altitude, toxic, flammable, explosive and other dangerous work environment and serious threat to the lives and safety of the staff. Development of special robots to replace human work is urgent need. Therefore, the development of special automated robot instead of doing physical labor is the future trend of social development [1-3]. In recent years, wall-climbing robots in the nuclear industry, petrochemical industry, construction industry, shipbuilding industry, power industry and other fields has been in-depth study and the rapid development, especially adapt inclined or vertical wall and capable of spider climbing robot[4-10]. Because of its inspection, cleaning, descaling, coating thickness measurement and other functions, it can reduce the risk of manual operations, improve operational efficiency, reduce operating costs and in the research and application of widely.

This paper presents a new wheel permanent magnetic wall-climbing robots structural design, including adsorption system and motor systems and power systems, for the second adsorption system permanent magnet material selection and arrangement of analysis design, finally that variation of suction force at different gap conditions between the air gap and the permanent magnet.

## 2. Climbing robot structure design

In this paper, wall-climbing robot structure design shown in Figure 1, which includes adsorption systems, motion systems and power systems. Adsorption system consists of four groups of high-strength neodymium magnets square, four square magnets around the center of gravity position of the robot base plate is symmetric. Motion system composed of four wheels, in which hub of the wheels from light quality high strength aluminum alloy and attached to the outer rubber tires. Power system consists of the DC motors, the lithium batteries and a controller. There are four DC groups and are distributed in the bottom position of the robot, through the shaft and linkage with the corresponding wheels. The controller controls the motor speed to control the four wheel speed to achieve climbing robot forward, steering, and other back position and posture change.

## 3. Modeling and Simulation

Establishment of Permanent Magnetic Wheel climbing robot three-dimensional model, shown in Figure 2. The robot has a good wall surface adsorption capacity, strong obstacle ability, turn more flexible ability, better adapted to the wall and over capacity, and it can be used as a variety of special purpose wall climbing robots good carrier. The following will be part of the permanent adsorption modeling and simulation.

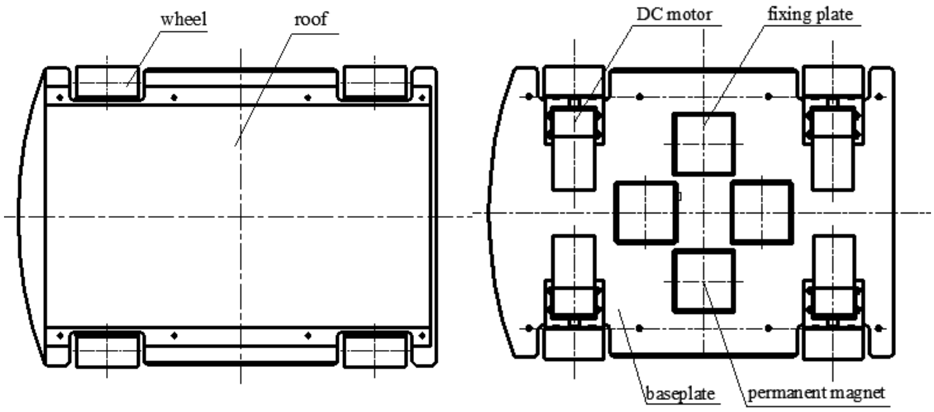


Fig. 1 Climbing robot two-dimensional map

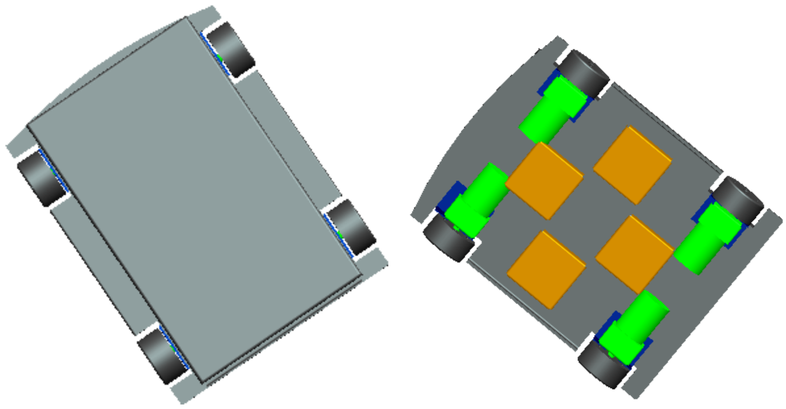


Fig.2 Climbing robot three-dimensional map

Adsorption unit select NdFeB as permanent magnet material, the advantage of this material has a very high energy product and coercive force and also has the advantages of high energy density. In the same volume, its magnetic field strength generated the equivalent of 5-10 times ferrite magnets, alnico magnet 5-15 times. It is currently the most widely used permanent magnets. Considering the economic costs and material properties the final choice grades for N52 NdFeB and magnetized in the thickness direction, the performance parameters are shown in Table 1.

Table 1 N52 material parameters

| Br | H cb | H cj | BH |
|---|---|---|---|
| 1.43-1.48 T | ≥796 kA/m | ≥876 kA/m | 398-422 kJ/m3 |
| 14.3-14.8 kGs | ≥10.0 kOe | ≥11 kOe | 50-53 MGOe |

According to the parameters in Table 1 to obtain the relative permeability of the permanent magnet ur:

$$u_r = \frac{B_r}{u_0 \cdot H_{cb}} \quad (1)$$

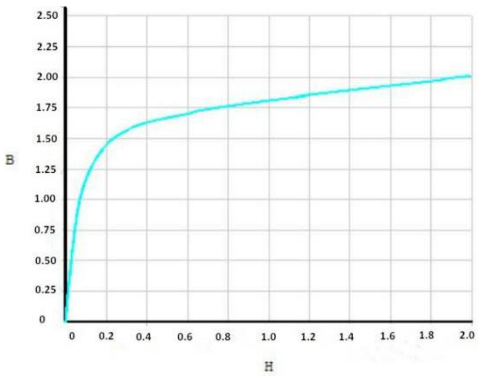
In which for a conservative calculation, Br take 1.43T; u0 is a constant 4π × 10-7 T.m/A; Hcb coercive force, its value is 0.796 × 106A/m.

$$u_r = 1.43$$

Yoke material is Q235 steel non-linear material, its material parameters are shown in Table 2 and B-H curve (hysteresis curve) shown in Figure 4. Air relative permeability ua=1.

Table 2 Q235 material B-H parameters

| H/(A/mm) | 50 | 100 | 250 | 500 | 750 | 1000 | 1500 |
|---|---|---|---|---|---|---|---|
| B/(T) | 0.8043 | 1.1618 | 1.5159 | 1.669 | 1.7487 | 1.81 | 1.913 |



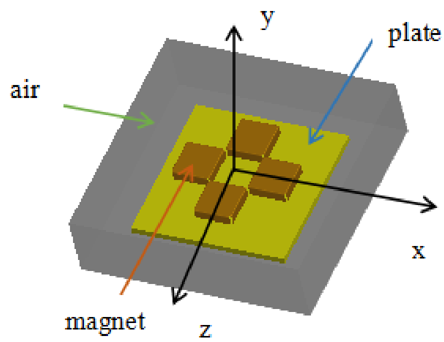




Fig.3 Q235 B-H curve Fig.4 Schematic simulation model

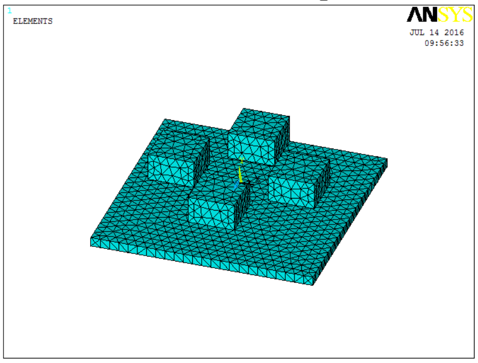
Establish an air gap-type permanent magnet adsorption model, shown in Fig.4, the geometric parameters are shown in Table 3.

Table 3 Permanent magnet geometry

| Contents | Length(mm) | Width (mm) | Height (mm) | Sum |
|---|---|---|---|---|
| magnet | 50 | 50 | 30 | 4 |
| plate | 240 | 240 | 10 | 1 |
| air | 360 | 360 | 140 | 1 |

Establish a magnetic field model in ANSYS. Permanent magnets and air bases are being wrapped and model building process should consider the role of the air gap. Therefore, the air gap-type permanent magnet adsorption model shown in Fig.4. Its magnetization direction is Y direction, Q235 steel thickness of the wall is 10mm, ignore the air magnetic flux leakage factor.

Enter the above calculated relevant material properties modeling in ANSYS, the properties of different material attached to the respective models, according to the actual shape of the entities to a reasonable mesh, as shown in Fig.5. And applying boundary conditions and loads in the vertical direction of the wall, as shown in Fig.6.



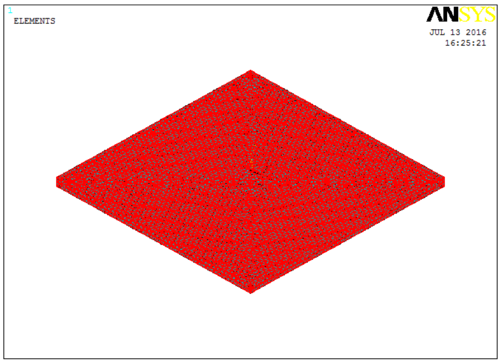




Fig.5 Meshing Fig.6 Boundary conditions

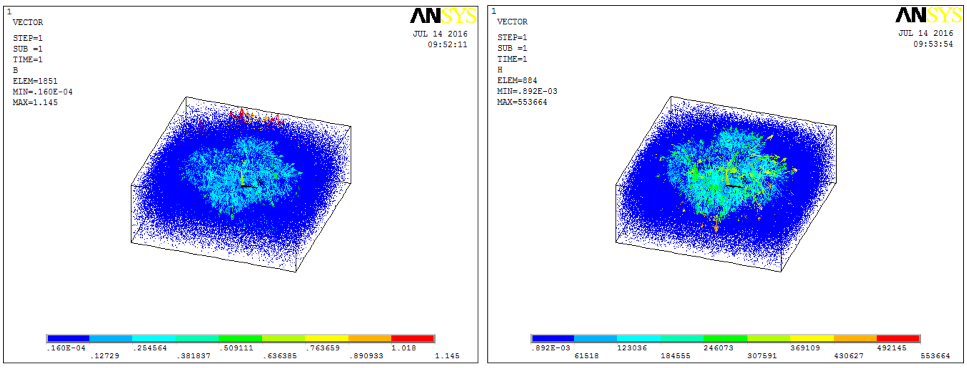



Fig.7 Magnetic induction and magnetic field intensity

Establish air gap of 10mm, 15mm, 20mm, 25mm and 30mm of simulation models. Obtained each adsorption model Y direction simulation data, as shown in Table 4. After the simulation is completed, also obtain the magnetic flux density and magnetic field strength of each model vector, Figure 7 shows the air gap is 20mm flux density and magnetic field strength model vector.

## 4. Data analysis

In accordance with the different conditions of the air gap of the permanent magnet attracting force model described above, obtain the size of the force in the Y direction and establish a data table, as shown in Table 4.

Table 4 Y-Force

| Gap(mm) | 10 | 15 | 20 | 25 | 30 |
|---|---|---|---|---|---|
| Forces by virtual work(N) | 628.79 | 285.50 | 179.61 | 113.25 | 75.60 |
| Forces by maxwell stress tensor(N) | 652.94 | 355.76 | 205.10 | 123.87 | 80.20 |

Analysis the data in Table 4 available: Y directions with an increase in air suction force decreases rapidly and the decreasing trend as the air gap increases leveled off.

## 5. Conclusion

This paper proposed the permanent wall-climbing robot design, obtained the dates by ANSYS simulation of suction force at Y direction of the air gap and the permanent magnet magnetic field intensity distribution. This article provides a reference for subsequent engineering applications.

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