Permanent magnetic climbing robot based on ANSYS gap-type adsorption analysis

Jigang Liu [a], Donglin Tang [b], Liyuan Xie [c], Xu Chen [d]

School of Mechatronic Engineering, Southwest Petroleum University, Chengdu 610500, China

[a]startljg@163.com,[b]tdl840451816@163.com, [c]ljxxlyxzz@163.com, [d]chenxuyoutian@163.com

Abstract

Designed a permanent magnetic climbing robot for testing requirements of tank wall. Proposed gap-type adsorption way of rectangular permanent magnets for the poor load capacity and poor adsorption of the permanent magnetic climbing robot. Conducted a magnetic field analysis of the permanent magnet in ANSYS electromagnetism environment and obtained magnetic variation and suction force under different conditions of air gap.The results showed when climbing robot and the wall distance less than 21mm Y direction maxwell stress was greater than 300N, meet the minimum requirements for adsorption and able to meet the actual needs of the project.

Keywords

wall-climbing robots; permanent magnets; adsorption

1. Introduction

The common adsorption of climbing robot is magnetic attraction, vacuum suction, vacuum adsorption, bionic adsorption and vibration absorption etc[1-4]. In which the advantages of magnetic attraction has high safety factor, load capacity and good adaptability of walls. Magnetic attraction divided permanent magnetic and electromagnetic adsorption. Where the former relative to the latter has the advantages of simple structure, independent of supply, high reliability etc. Therefore in vessel weld inspection, ship wall rust etc the wall of permeable material the wall-climbing robot with permanent magnet adsorption. The movement pattern of permanent magnetic wall climbing robot divided into wheel and crawler and multi-legged etc. Advantages of wheel is flexible and easy to control, but the contact areas between wheels and walls is small, lead to poor absorption edge and load capacity.

This paper for the problems of wheeled permanent magnetic wall-climbing, design the air gap-type permanent magnet adsorption. Obtain the variation under different gap conditions of suction force by adjusting the gap between the wall surface and wheels and provide the basis for climbing robot permanent magnetic follow-up study.

2. Climbing robot mechanical design

In this paper, the wall-climbing robot uses a permanent magnet adsorption and wheel movement, detecting device is the wheel ultrasonic probe, as shown in Fig.1. The basic operating principle is as follows: each wheel independently connected to the same model DC, controller control the motor speed, control each wheel speed to achieve pose changes in crawling. Ultrasonic probe located in crawling front and located in rubber wheel full of coupling agent. When crawling move the probes do not move and the rubber wheel move and achieve the wall ultrasonic testing.

To improve the adsorption properties of crawler, adsorption device uses high energy product of NdFeB permanent magnetic material. The climbing robot permanent magnetic structure design based on the above overall design ideas as shown in Fig.1. Permanent magnets using a size of 160mm×100mm×30mm of NdFeB permanent magnets.

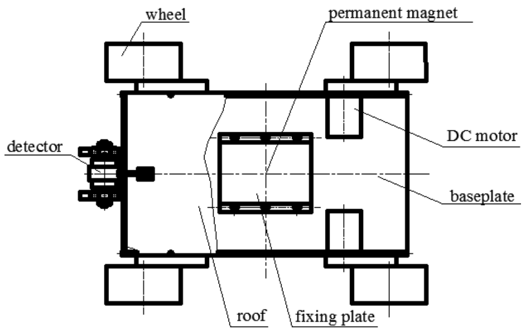


Fig.1 Mechanical structure design plans

3. Modeling and simulation of permanent magnet

Permanent magnet NdFeB material used in this paper, it has a very high magnetic energy product and coercive force, but also has the advantages of high energy density, long-term stability and to protect the crawler work. Select the grades 50M NdFeB magnets, the main performance parameters shown in Table 1.

Table 1 50M performance parameters

Br	H cb	H cj	BH
1.40-1.45 T	≥1033 kA/m	≥1114 kA/m	382-406 kJ/m3
14.0-14.5 kGs	≥13.0 kOe	≥14 kOe	48-51MGOe

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

$$u_r = \frac{B_r}{u_0 \cdot H_{cb}} \tag{1}$$

In which:for a conservative calculation, B_r take 1.4T;u_0 is a constant $4\pi \times 10^{-7}$ T.m/A;H_{cb} coercive force, its value is 1.033×10^6A/m. Thus obtained $u_r = 1.0785$.

Air relative permeability u_{air}=1, Q235 material parameters are shown in Table 2, the B-H curve shown in Fig.3.

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

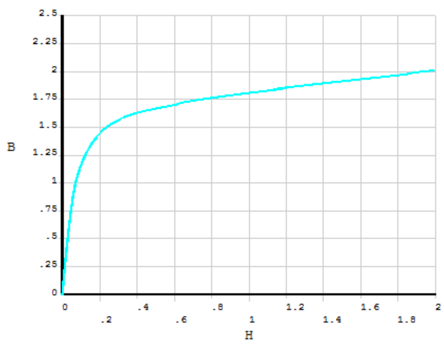


Fig.3 Q235 B-H characteristic curve

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

Model	L=160mm	W=100mm	H=30mm

Establish a magnetic field model in ANSYS. Tank wall compared to the climbing robot is very large. 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.

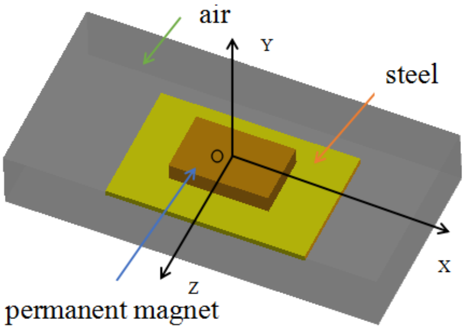


Fig.4 Adsorption model

Enter the relevant material properties modeling, the properties of different material attached to the respective models, according to the actual shape of the body 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.

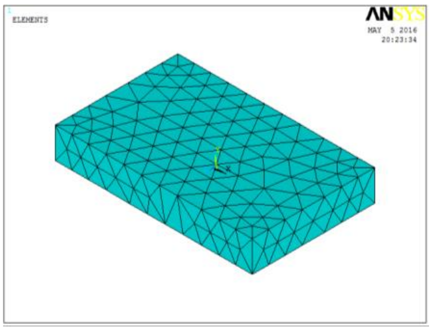


Fig.5 Meshing

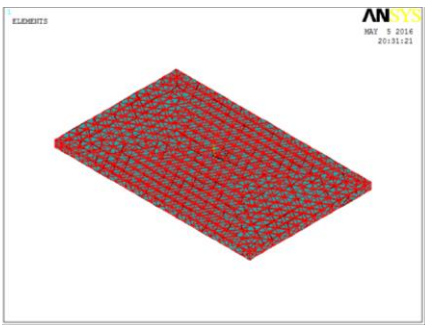
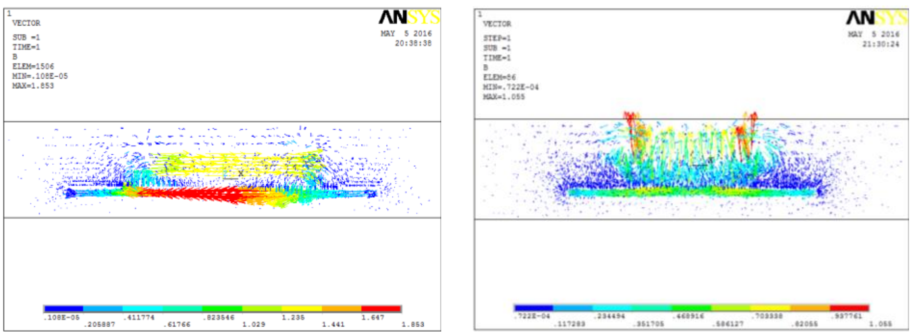


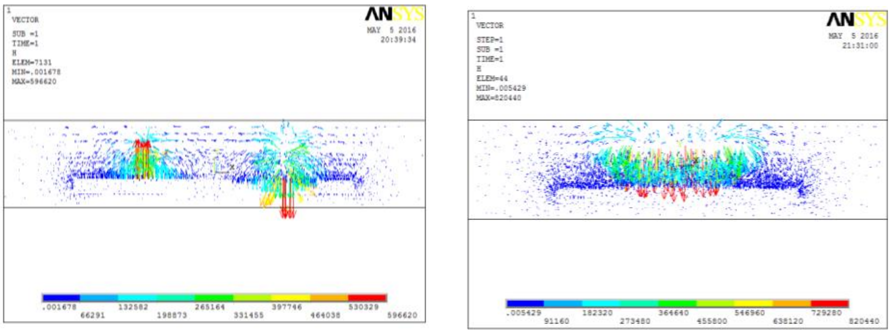
Fig.6 Applying boundary conditions and loads

Establish air gap of 1mm, 1.5mm, 2mm, 2.5mm and 3mm of simulation models, meshing and solver. Solved for each model Y direction adsorption data, as shown in Table 4. Solving completed each model to obtain the magnetic flux density and magnetic field strength vector diagram, as shown in Fig.7 and Fig.8. In which, figure (a) and (b) are the magnetic flux density vector when the air gap is1mm, figure (c) and (d) are the magnetic field intensity map when the air gap is 3mm.



(a) (b)

Fig.7 The magnetic flux density vector



(c) (d)

Fig.8 The magnetic field intensity map

4. Data analysis of permanent model

Solve the permanent magnet adsorption model under different conditions of the air gap, get the size of the force in the Y direction, establish the data table, as shown in Table 4.

Table 4 Y-Force

Gap（mm）	10	15	20	25	30
Forces by virtual work(N)	638.80	511.95	332.01	217.89	239.82

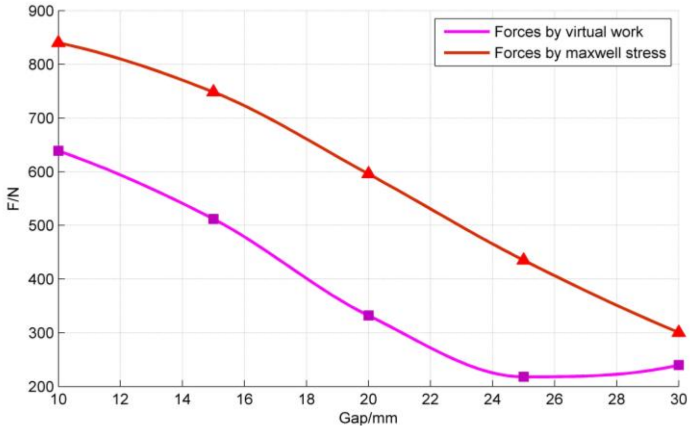


Fig.9 Air gap and Y direction of the force versus

Analysis the data in Fig.9 and combined the data in Table 4 available: model 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 adsorption design of permanent magnetic climbing robot, by ANSYS electromagnetics simulation inferred the permanent magnet magnetic field strength distribution of the air gap and suction force in the Y direction. By varying the air gap distance got Y direction of the suction force and the relationship with the distance.When climbing robot and the wall distance less than 21mm Y direction maxwell stress was greater than 300N, meet the minimum requirements for adsorption and able to meet the actual needs of the project. This article provides a reference for subsequent engineering applications.

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