Investigation of Magnetic Field and Force on a Maglev Supporting Structure of Vertical Axis Wind Turbine

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Abstract: Vertical Axis Wind Turbine (VAWT) is a type of important electric equipment. A hybrid maglev supporting structure in shaft system of VAWT is mentioned in this paper. The simulation has been conducted to study the magnetic field and force on this structure. The working condition is classified by four different length and magnetic isolated condition, three kinds of exciting currents compound modes is studied at the same time. Through the contrastive analysis of ANSYS simulation, the computed results reveal that the magnetism of pole terminals need to be isolated and face-to-face or back-to-back excitation is appropriate for magnet units in differential mode. The magnetic field and magnetic force are also emulated when the rotor working the position of equilibrium.

Keywords: Vertical Axis Wind Turbine, Maglev Suspension, Magnetic Field, Magnetic Force

Intoduction

The research and development of Wind Turbines is important in the New Energy Strategy. The VAWT, which plays an important role in it, is receiving more and more concern [1-2]. Some useful methods are proposed to improve the performance of VAWT. As concerned in [3-8], the permanent magnetic outloading system is introduced,which with the purpose of optimizing the energy utilization and reducing the start-up wind speed. In this paper, a kind of hybrid levitation bearing structure used in the VAWT spindle system is studied, and some correlative problems are discussed.

The Principle Of Maglev Suspension Used In VAWT. Compared to the Horizental Axis Wind Turbine(HAWT), the main rotor shaft of a VAWT runs vertically. The sketch of a VAWT is shown in Fig. 1.

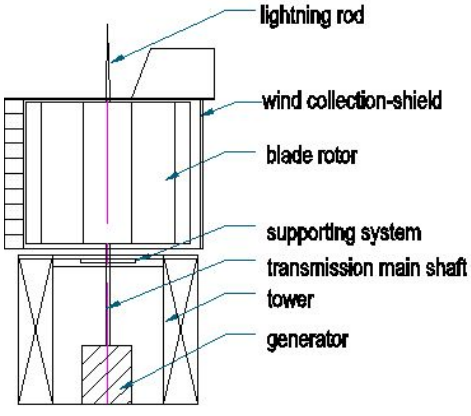


Fig.1 Sketch of a VAWT

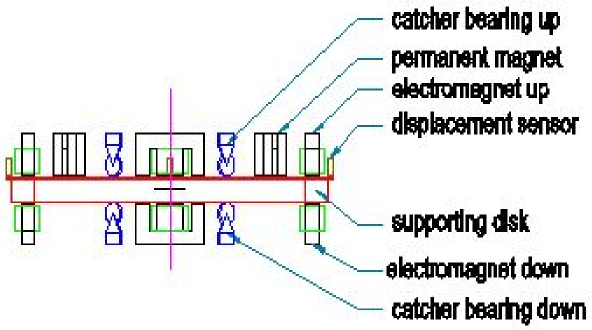


Fig.2 Schematic of a maglev supporting structure

The supported body in axial maglev supporting structure in Fig. 1 is of disk shape, and the schematic of it is shown in Fig. 2. Permanent magnets provide the supporting disk with suction lift while electromagnets can regulate the lift force with the turbine regular working. When supporting disk deviates from balance position, electromagnets in differential mode regulate the location of disk with bidirectional force if needed. Catcher bearings confine the maximum deviation of disk to avoid its impact on permanent magnets or electromagnets, and support the main shaft system axially when the turbine shut down.

Magnetic Field And Magnetic Force Analysis

Working Condition. Four permanent magnets are symmetrically located, supporting the main shaft system of turbines. The force acting on each permanent magnet is 1750N at lowest to meet the bearing loads demands. E-type electromagnets work in differential mode and are located symmetrically. They produce a zero resultant force on supporting disk when they are in the same biasing current with the disk balanced.

Then taking the following hypothesises for granted, such as uniform air-gap flux, ignoring the magnetic resistance of iron core、the leakage flux and eddy current loss etc, the resulting force of the permanent union can be expressed as:

$$F_y = \frac{B^2 S_y}{\mu_0} \tag{1}$$

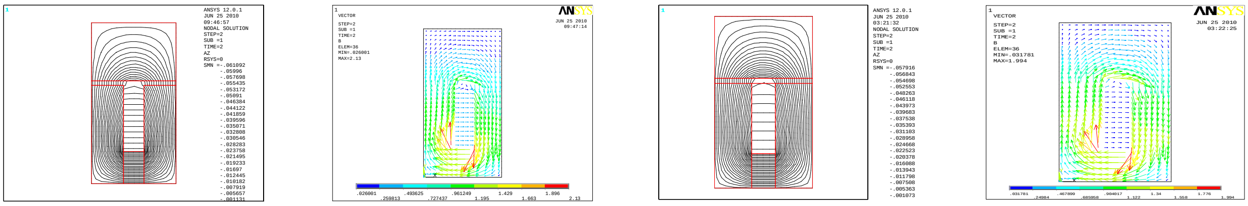
$$B = \frac{\mu_0 H_c h_{pm}}{2x_y + h_{pm} / \mu_r} \tag{2}$$

where, F_y is the magnetic force of permanent magnet that acted on supporting disk in up direction, with a nuit of *N*. B-the resulting magnetic flux density in air gap, with a unit of T. μ_0 is the permeability of air，$\mu_0 = 4\pi \times 10^{-7}$, with a unit of H/m. μ_r is the relative permeability of permanent magnet. h_{pm} is the length of permanent magnet that along the magnetic circuit, with a nuit of m. x_y is the gap between the supported body and permanent magnetic union, with a nuit of m. S is sectional area of magnetic circuit in permanent magnetic union, with a nuit of m^2. The permanent magnet is NdFeB, $H_c = 1158.789\ kA/m$ and the h_{pm} is 28.33 *mm*.

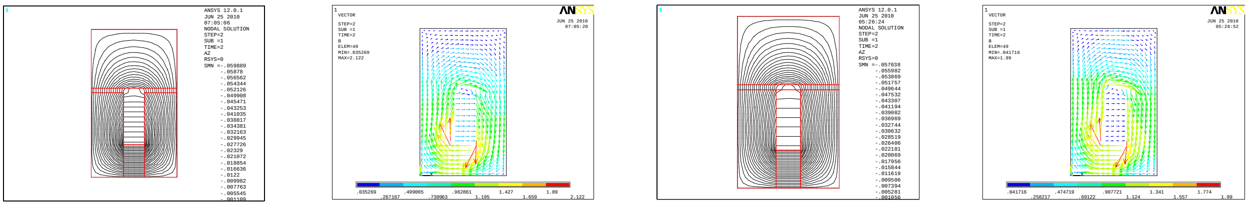
Analysis For Magnetic Field And Force in Permanent Magnetic Union. To verify the force of permanent magnetic union and find the influence of leading poles with different length, the simulations are classified according to the different length and working conditions. The first working condition is defined as μ_{rx}=1 when the gap between the magnetic leading poles is filled with air. The second working condition is defined as μ_{rx}=0.5 when the gap between the magnetic leading poles is magnetic isolated. By useing ANSYS12.0, the magnetic forces are computed and listed in Table 1, while the magnetic flux density vectors are shown in Fig.3.

Table 1 Comparison of magnetic force in different situations

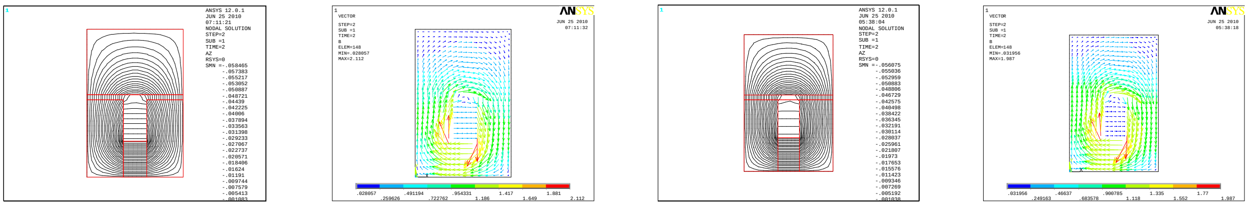
The length of magnetic length [mm]	Compared item	$\mu_{rx}=1$	$\mu_{rx}=0.5$
135	FVW-Y（N）	-803.30	-1194.20
	FMX-Y（N）	-796.74	-1183.431
125	FVW-Y（N）	-948.77	-1321.10
	FMX-Y（N）	-941.06	-1309.05
115	FVW-Y（N）	-1137.39	-1468.30
	FMX-Y（N）	-1129.59	-1458.11
105	FVW-Y（N）	-1386.64	-1638.50
	FMX-Y（N）	-1383.05	-1633.58



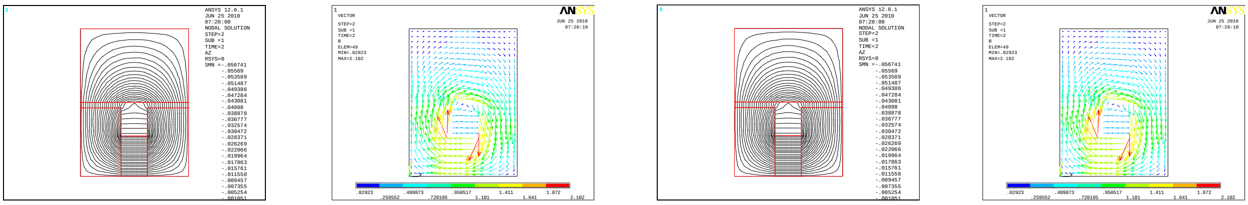
a11) wh=135mm a12) wh=135mm b11) wh=135mm b12) wh=135mm



a21) wh=115mm a22) wh=115mm b21) wh=115mm b22) wh=115mm



a31) wh=95mm a32) wh=95mm b3) wh=115mm b4) wh=105mm

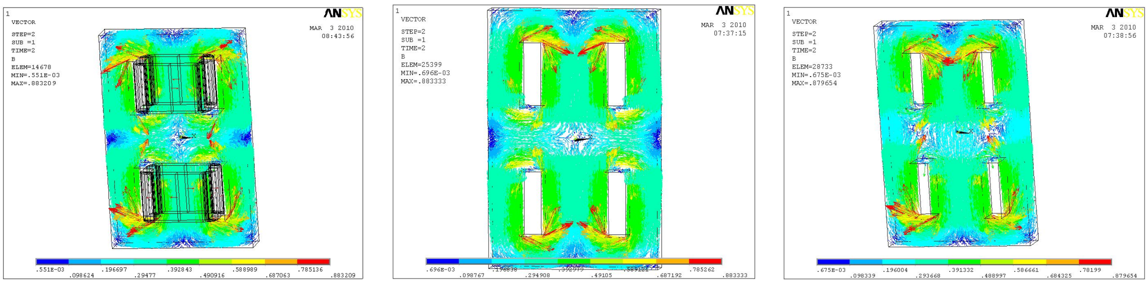


a41) wh=75mm a42) wh=75mm b4) wh=105mm b4) wh=105mm

Fig. 3 The comparison magnetic field and induction indensity distribution

Taking the data in Table 1 and graphs in Fig.3 as consider, the gap between the magnetic leading poles needs to be magnetic isolated as the comparative analysis of horizontal direction shows.The length of magnetic leading poles should be as shorter as possible to reduce the magnetic flux leakage and enhance the levitation force as the comparative analysis of vertical direction shows.

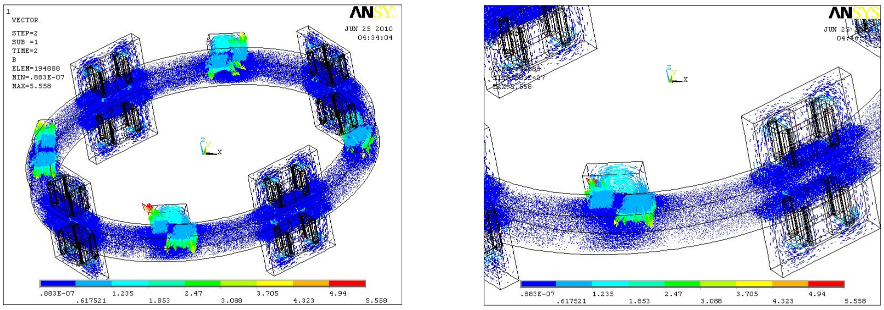
Excitation effect analysis of electromagnetic unit. E type electromagnets are used in the mentioned supporting structure. This type of electromagnets have also been studied and used in many instance. The force expression of these electromagnets have been studied and verified[9]. A electromagnetic unit contains two E type electromagnets, which are placed in two sides of the supporting disk. The two components work in pairs of differential mode. Three compound modes of the exciting currents are compared as following. Corresponding to the three kinds of compound modes, three kinds of magnetic actions are reached. The difference between the actions are base on the relative direction of magnetic flux that pass through the dominant leading pole. If they flows in the same direction, the compound mode can be named drawing form temporarily. If they flows face to face, the compound mode can be named face-to-face form. While they flows back to back, the compound mode can be named back-to-back form.



a) Back-to-back form b) Face-to-face form c) Drawing form

Fig. 5 Coupling simulation of the integral magnlev structure

Through the comparison of dirrerent graphs shown in Fig.4, both the magnetic actions in the face-to-face form and in back-to-back form have no mutual coupling,urrent situation is similar to the current, and paired electromagnet without magnetic flux density of the cross, mutual coupling between no influence. However, there is mutual coupling between the pairs of electromagnets in drawing form, which is shown in the graph c). So the former two forms of exciting currents are better for the application.



a) Global map b) Partial enlargement map

Fig. 5 Coupling simulation of the integral magnlev structure

Magnetic Analysis of Integral Maglev Supporting Structure. There is only little magnetic flux leakage along the supporting disk as shown in Fig.5. The order of magnitude of flux leakage density is about 10^{-4} level, while that of main magnetic flux density is 10^{-1} level. The magnetic induction density hasn't been strengthen. So the mutual influence can be ignored. The computed result shows:FVW_X=5474.7 *N*, FMX_X = 5714.7 *N*. Compared with the oretical calculation 7000 *N*, the deviation is about 18.36% ~ 21.79%. Therefore, some allowance should be given in actual structure design.At the same time, the gap between the magnetic leading poles should be magnetic isolated.

Conclusion

As the rusults of ANSYS simulation show, the magnetic levitated supporting system mentioned in this paper can offer effective force for VAWT.

The length of leading poles, which is used to constitute the magnetic circuit, should be setted as shorter as possible. At the same time, the space around the magnetic leading poles, especially the gap between them, needs to be magnetic isolated.

The exciting currents for the two components of electromagnetic unit should be coordinated. The compound mode can be face-to-face form or back-to-back form.

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