Analysis of Structure and Mechanics Feature of Axial Permanent Bearings Based on ANSYS

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Abstract: This paper analyzes a single axial permanent bearing and two kinds of symmetrical-mounted axial permanent bearings by ANSYS solving method of magnetic field. The effect of axial dimension and air gap length between two magnetic rings on axial restoring force and stiffness of bearings is calculated, which provides the foundation for further designing and guiding suggestion for application of permanent magnetic bearing constructed by magnetic rings.

Keywords: Axial Permanent Bearing, Structural Parameter, Axial Restoring Force, Stiffness

Introduction

Magnetic suspension bearings are the modern bearings which suspend by magnetic force. Magnetic bearings are divided into active magnetic bearing, passive magnetic bearing and hybrid magnetic bearing. Passive magnetic bearings can also be subdivided into two types: permanent magnetic bearing (PMB) and superconducting magnetic bearings (SMB) [1-2]. Because that PMB do not need any external energy when it works, it is concerned by many experts. Ever since a long time ago, experts in the field of permanent bearing have done a lot of research in the structure and the mechanics feature of PMB. Due to various reasons, the research about complete permanent magnetic bearings still do not form an integrated system[3-7]. This paper uses ANSYS to analyze the structure and the mechanics feature of axial permanent bearing in order to obtain the effect of different structual parameters and relative mounting location to PMB. It provides the foundation for further axial PMB designing.

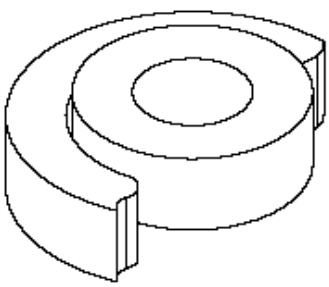

Fig.1a) the appearance of a axial permanent bearing

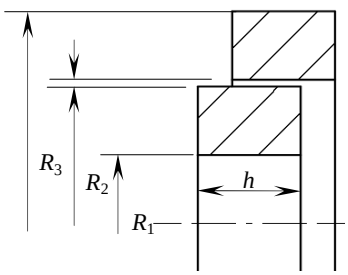

Fig.1b) the dimensions of a axial permanent bearing

Model Of A Single Axial Permanent Bearing

The axial permanent bearings in this paper are composed by two concentric permanent

magnetic rings. One is static (the big ring) and the other is dynamic (the small ring). (As figure 1a shows.) They are magnetized axially in the same condition. (The magnetized dimension is marked in figure 1b.) And the magnetization feature is identical. When the two rings overlap in axial direction, this location is defined as basic location and the center of the rings is the origin of the coordinates. Radical direction is r and axial direction is y. Then the properties of bearings are calculated when the small ring moves along y.

Because the bearings are symmetrical in axial direction, they are calculated in 1/2 model. The model shows in figure 1. In the figure 1, x is the air gap length in radical direction, R_1 is the internal radius of the small ring, h is the axial dimension of the bearing. This paper uses permanent magnetic material with following parameters: H_c=500 kA/m, B_r=1.231T, μ_r =1.9597.

ANSYS Solving Method For Axial PMB

ANSYS solving method of mechanic field has three steps: 1) Preprocessor. It includes model creation, definition of element type, real constants and material property and meshing; 2) Solution. It includes definition of load, boundary conditions and solution of magnetic potential equations; 3) Postprocessor. It includes magnetic flux density, magnetic field intensity, distribution of magnetic lines of magnetic force.

The entity of axial PMB has three dimensions. It is reduced to two dimensions because of its axisymmetrical property. It is much easier to build model and to calculate in two dimensions. This paper uses 2D static model solving method based on nodal.

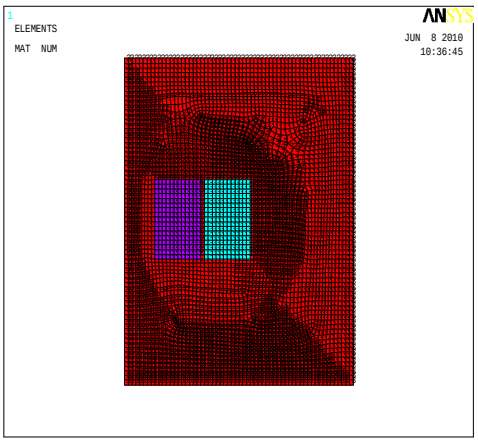

Figure 2 Finite Element Model of The Bearing

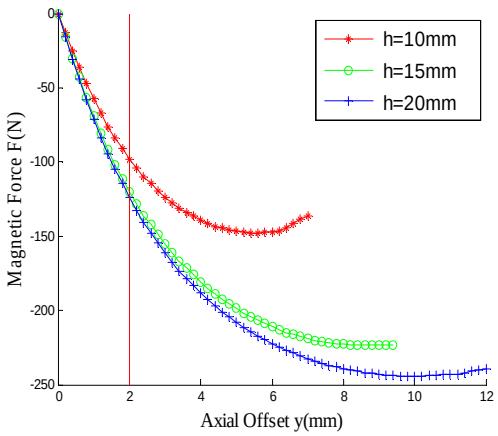

Figure 3 curves about axial dimensions and restoring force

Analyzing Structural Parameters Of Single Axial Permanent Bearing

The Effect Of Axial Dimension Of PMB. In order to obtain the calculating result of the effect of axial dimension to bearing, three situations are chosen, h=10mm,h=15mm, h=20mm. The dynamic ring is moved from basic location along y with 0.2mm per step. Usually the offset is not very large in practical application. So the range of offset is from 0 to 2mm in this paper.

In this part, the changing situation of magnetic restoring force is discussed when the axial dimension is different. The air gap length between two magnetic rings is *x*=1mm.

The model shows in figure 2 and the result shows in figure 3. According to figure 3, as the small rings move the same distance along axial direction, the larger the axial dimension is, the bigger the restoring force is. And the direction of restoring force is against that of offset. This means the bearing can return to the balance location, no matter what the axial dimension is. The restoring force is getting bigger and bigger with increasing offset. When offset reaches a half of axial dimension, restoring force is the biggest and after that it decreases. With the increase of axial dimension, increment of restoring force decreases, it does not have obvious effect to obtain big restoring force through increasing axial dimension.

In addition, before the restoring force reaches its peak value, the stiffness of force is negative. This means that the bearing can keep balance in this region. When the force exceeds the peak value, the stiffness of force is positive and the system will unbalance soon.

The Effect Of Air Gap Length Of Axial PMB. In this part, the axial dimension is *h*=10mm. The axial restoring force is analyzed through changing air gap length, x=1mm, x=0.75mm, x=0.5mm and other parameters are the same as above. The dynamic ring still moves from basic location with 0.2mm per step along y. The result shows in figure 4. As the small rings move the same distance along axial direction, the less the air gap distance is, the bigger the restoring force is. The direction of restoring force is against that of offset. This means the dynamic ring can return to the balance location. According to the above analysis, this kind of structure is proper to be used as a axial PMB.

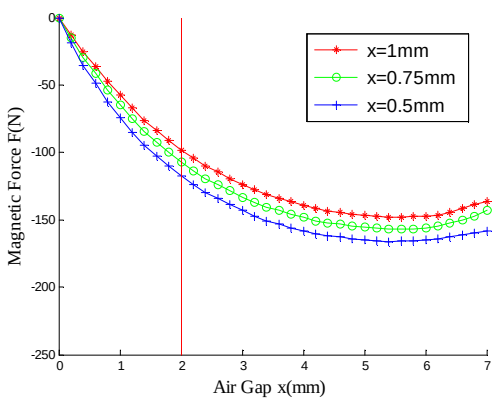

Figure 4 curves about air gap length and restoring force

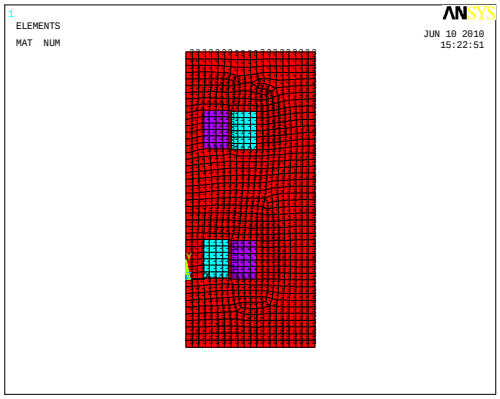

Figure 5 finite element model of two basic-mounted bearings

Analyzing Structual Parameters Of Two Axial Permanent Bearings

Based on above analysis, can property parameters doubt if axial PMBs are used in pair? Two different mounting methods of bearings will be discussed in this part. Structural and material properties of bearings are the same as above, axial dimension is *h*=10mm, air gap length is *x*=1mm.

A Pair Of Basic-mounted Axial PMBs. In this mounting method, all properties of two bearings can be overlapped simply. The initial location of two dynamic rings is at the basic

location as above and they move along y synchronously. The result shows in figure 7.

A Pair Of Biased-mounted Axial PMBs. Through above analysis, the restoring force of dynamic rings increases with increasing axial offset and then reaches the peak value. In this mounting method, the biased value of dynamic rings equals half of the offset value, at which the restoring force is the biggest. Two bearings mount symmetrically and two dynamic rings move along y axle synchronously. The result shows in figure 7.

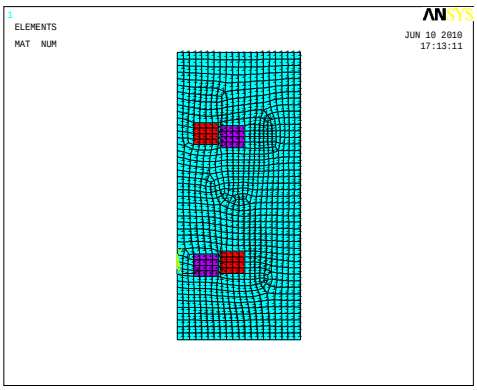

Figure 6 finite element model of two biased-mounted bearings

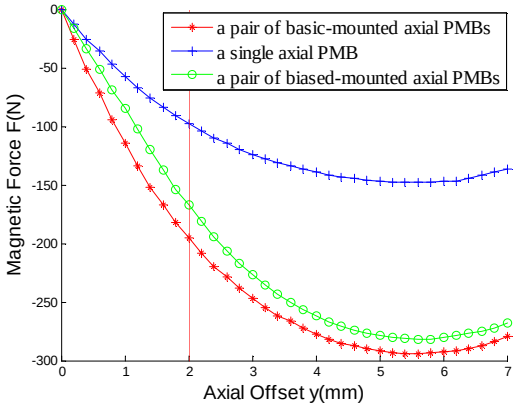

Figure 7 curves of three kinds of axial PMBs about restoring force and axial offset

The Curve About Axial Offset And Restoring Force. The curve shows in figure 7. In three kinds of bearings, all restoring forces increase with increasing axial offset and get the peak value when offset is a half of axial dimension of bearings. Then the forces decrease. The restoring force of a pair of basic-mounted bearings is almost two times than that of a single bearing; the force of a pair of biased-mounted bearings has the best linearity. So these different kinds can be used in different conditions.

Stiffness Properties Of Axial PMBs. Static stiffness properties show in figure 8. When dynamic rings are at the same offset, static stiffness of the basic-mounted bearings are the biggest and it can resist external interference best; static stiffness of the biased-mounted bearings keep correspondence basically in the range from 0 to 2mm.

Dynamic stiffness properties show in figure 9. When axial offset is below 1.6mm, the basic-mounted bearings have the biggest dynamic stiffness; static stiffness of the biased-mounted bearings keep correspondence basically in the range from 0 to 2mm.

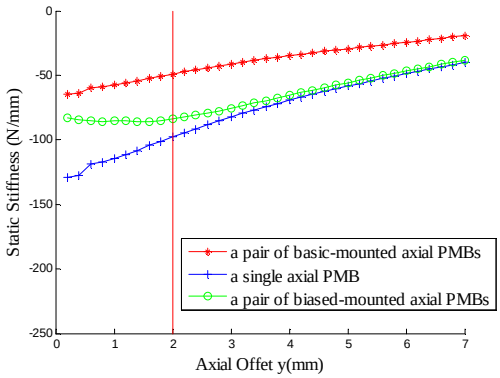

Figure 8 curves of three types of axial PMBs about static stiffness and axial offset

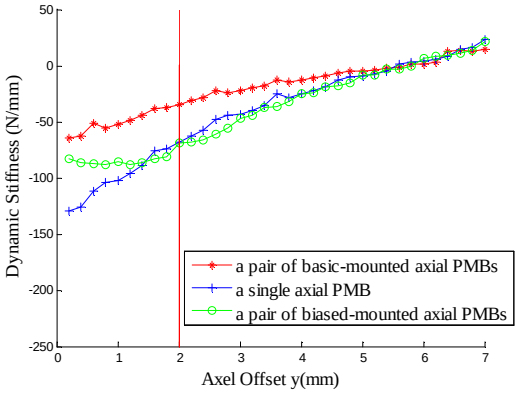

Figure 9 curves of three types of axial PMBs about dynamic stiffness and axial offset

Conclusions

The following conclusions are reached based on the above analysis:

1) The axial restoring force of bearings increases by increasing axial dimensions, but the increment decreases gradually. So it is not adaptable to obtain big restoring force by increasing axial dimensions; The axial restoring force can increase by decreasing air gap length.
2) When all property parameters of axial PMBs are the same, the restoring force of two basic-mounted bearings have two times than that of a single bearing. It infers that using multiple bearings can obtain the same effect.
3) The dynamic stiffness of the biased-mounted bearings is constant in specific region.

Thus, the application properties of axial PMBs are obtained. There are some requirements in practical application. Axial restoring force should be the biggest; axial stiffness should be the biggest; linearity of the properties should be optimal. According to these conditions, the ideal structure of axial PMBs can be obtained.

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