Simulation of 8 and 16 Polar Magnetic Bearings Operation using Finite Element

Hamed Nozari[1], Hasan Ghafori[2], Majid Ebn ali[3]
1- Department of Mechanical Engineering, Majlesi Branch, Islamic Azad University, Isfahan. IRAN.
Email: xlele50@yahoo.com
2- Advanced Engineering Research Center, Majlesi Branch, Islamic Azad University, Isfahan, IRAN.
Email: Hasangh28@gmail.com
3- Department of Electronic Engineering, Shahre kord University, IRAN
Email:ebnali-m@eng.sku.ac.ir

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ABSTRACT:
The growth of technology in suspension systems have led the magnetic bearings to a more powerful and economical design. Such bearings have lots of benefits such as performance capability in high speeds and the ability to perform action without lubrication in different performances that causes a decrease in the environmental and system pollution and makes it possible to work in vacant environments. Magnetic bearings work without friction and have little attrition. In This paper, the operation of magnetic bearing with 8 and 16 polar at a velocity rate at 30000 rpm and gap tolerance ranging from 2 to 0.5 mm are evaluated. The magnetic force condition is simulated based on finite element by optimizing the best mesh measurement.

KEYWORDS: Control and process, Magnetic bearing, Finite element, Optimization, Meshing.

1. INTRODUCTION

Active magnetic bearings are used in industrial applications. These bearings, during rotating, have lower vibration than other bearings and accurately control the shaft spot. There have been several studies done on magnetic bearings focusing more on winding of wires and the number of coils. There has been a little modification in different designs in a way that another electrical magnetic iron has been added as the second performance to the system [1], [2]. These bearing have many advantages including working ability at high speed and ability of performance without lubricating that results in omission of lubricating in various applications and finally reduction of environment and system pollution and offers working in vacuum for users. This bearing work without friction and have low erosion and have little vibration at the time of turning in compared of other bearing, they can control the location carefully, measure external force imposed on shaft and even draw working condition. Unique design and extensive abilities of magnetic bearing results in various applications for example in making thin layers of silicon, conductive bearing that are sensitive to vibration can increase inductance, since magnetic bearing have air distance are used for special biological tasks. Blood cells or other liquid can pass this air distance without any damages. Cold compressors are another sample of important applications of magnetic bearings. Magnetic bearings can work in high speeds that are requisite for new cooling tower, and despite usual bearing that cool with oil have no other effect on cooling tower regarding pollution.

Magnetic bearing can be insulated carefully and therefore are significant for processes that deal with destructive liquids [3].

In the active round magnetic bearing, the coils making valid magnetic flux are in the same axle as the rotor. The rotations of the rotor cause flux changes with turbulence time. Sometimes the cone coils are used to create radium-axle performance. The gap between rotor and stator is 0.3 mm to 0.1 mm [4]. In other designs the bearings with 8 windings have been ruled to make an electric.

Fig. 1. Radium magnetic bearing with 8 poles [5].

The main configuration of an electromagnetic bearing with feedback control is shown in figure 2.

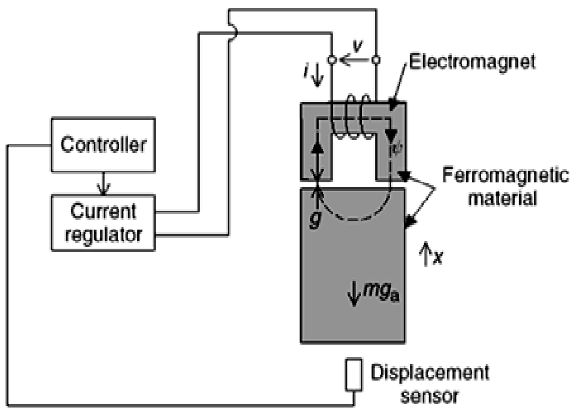


Fig. 2. The operation of magnetic suspension system [6], [7]

Magnetic bearings are of two kinds of active and inactive. In the present study the active kind was stimulated. Also to enhance the static capacity of the magnetic bearing, the effect of increasing the magnetic number of poles from 8 to 16 without any changes in area, the length and the number of windings were investigated.

2. FLUX DENSITY AND FORCE OF MAGNETIC CIRCUIT USED IN AMB

Magnetic power for suspension of rectangular iron part is produced from instillation of coil. The part is eight only in vertical axis.

Current i produce flux gravity between suspended part and nucleus c. The figure is function of current and the case that c is not saturated is appropriate to i square.

Magnetic power for suspension of rectangular iron part is produced from instillation of coil.

T Ampere circuital law which is an integral form may be stated as:

Where i is the current of the coil, N is the number of turns in the coil and H is the magnetic.

$$\int H.dl=Ni \quad (1)$$

Field intensity produced in the ferromagnetic core of the magnet by the current and L is the path enclosing a surface through which current flows [9].

$$Hi = Ni \quad (2)$$

$$B= \mu H \text{ or } B=\mu Ni/L \quad (3)$$

The flux ф is replaced by the current through the coil and the reluctance R also replaced by the resistance, there are magneto motive force (MMF) sources of strength Ni. In terms of the geometry of the bearing, the reluctance is:

$$R=2Z/\mu oA \quad (4)$$

Where z is the nominal air gap between the rotor and the pole face of the magnet of the bearing,
A is the cross-sectional area of each leg, and μo is the permeability of free space (4πX10-7 Tesla *Meter /Amp). The flux in the circuit may be represented as follows [9].

$$\Phi = \int B.ds = Ni/R \quad (5)$$

The flux density, B is given below

$$B = \Phi /A \quad (6)$$

The main goal of the AMB is to produce desired electromagnetic forces to levitate the ferromagnetic rotor (shaft) located in the bearing. The electromagnetic force generated by the electromagnet is the gradient of the magnetic field energy and depends on the air gap size [10].

$$F=-dw/dz \quad (7)$$

AND

$$W=1/2\int BHdv \quad (8)$$

Where F is the electromagnetic force, W is the magnetic field energy, and V is the air gap volume. The electromagnetic force is a nonlinear function of the coil current and the distance between the shaft and the electromagnet. The control algorithm produces electromagnetic force acting on the shaft using the power interface and electromagnet coil [9], [10].

$$F=B^2A/\mu_0 \quad (9)$$

Substituting in the expression determined for B yields:

$$L=N\phi/i \quad (10)$$

3. FINITE ELEMENT METHODS

Ansys is one collection of powerful modeling programs based on finite element methods and is able to solve problems from, one simple linear analysis to the most complex nonlinear modeler.

This software has very diverse elements that can model each geometrical type virtually by these elements.

It also has various engineering material that makes possible modeling every material with different properties and behavior. Although using Ansys software offer different capabilities for operator, primary modeling includes internal cycle off bearing, external cycle of bearing and coil dimension that is designing according to table1. In Ansys software, we start designing stator rotator and coil in graphical environment. Regarding appearance and dimension reference is shown in table1. [dimensions are based on improvement article in nuclear power industry] [8].

In this approach, complex models are divided into smaller parts and by combining results of each part, the answer of entire models in each point is achieved.

Table 1. The relevant parameters of the design of a polar bearing

Parameter	unit	8- pole
Air gap area	Ag(mm^2)	1966
Pole width	W(mm)	15
Axial pole length	L_{am} (mm)	130
Joarnal radial	Rj(mm)	65
Radial	Rp(mm)	65.5
Biasing ratio	B	0.314
Coil thickness	Tc(mm)	19.6
Coil height	Lc(mm)	7.9
Coil area	Ac(mm^2)	155
Stator inner- radius	Rc(mm)	78
Pole length	L p(mm)	12.7
Stator outer radius	R s(mm)	93
Stator outer diameter	D s(mm)	187
Stator axial length	L s(mm)	169
Calculated amplifier	VA_{max} (VA)	6674.24
Capacity of the picked amplifier	KVA	8
Peak amplifier current	I max(A)	100
Number of windings per pole	N	500
Biasing current	I_b (A)	31.4
Area of copper wire	A cu(mm)	7
inductance per electromagnetic	L(mh)	.997
RMS current	I rms	44.49

Table 2 shows the properties of the element including fabric and physical properties used in the bearings which include coil and bearing. In this simulation, there is an interaction between magnetic field and mechanical field.

In other words, this process includes two combinations of constituent and electromagnetic.

In this stimulation 3 different materials are used. Based on this assumption, there is no friction between rotator and stator.

Table 2. Fabric and physical properties of the materials

	Magnetic peatropriabiti(u)	Resistivetic(m)	Elastic module
Coil	2000	$3E^{-8}$	-
bearing	10	$70E^{-8}$	$2.3\ E^{9}$
Air	1	-	-

3.1. Loading

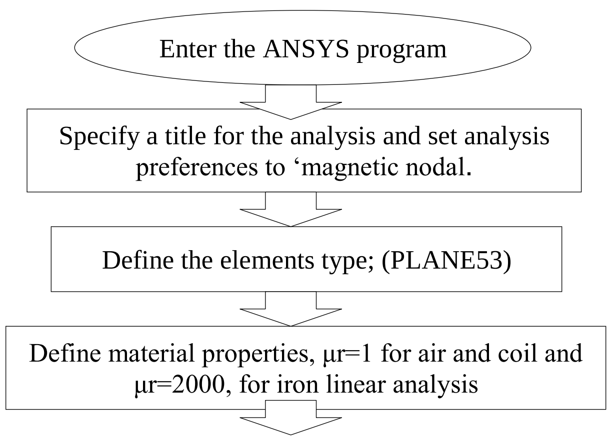
Static capacity (maximum force that magnetic bearings produce the hold shaft) is a sector/part of such variables as amplifying current, the area of magnetic poles, the number of coils, winding and the dimensions of air gap is shown in table 3.

Table 3. Loading of bearing magnetic

Calculated amplifier W	Tu	Coil area A(mm)	Rpm	Air gap area (mm)	Number of windings per pole (N)	I (A)
10000	650	155	30000	125	500	44.5

3.2. The analysis of transient bearing

Having used the proposed taps we tend the simulate modeling. To answer the algorithm, the ect physical properties, the amount of ect torch's turning, with 380V and 44.5 A, the force magnetic density flux will be calculated [8].



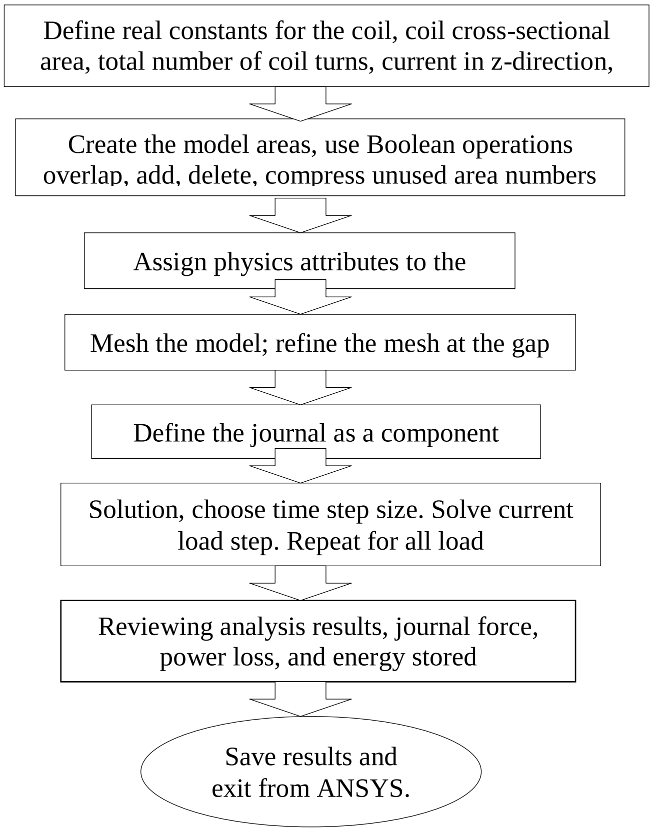


Chart. 1. The analysis of transient bearing.

3.3. Element selection and meshing

In finite element analysis, the elements dimension at the time of analysis and their results bear effective significance. So, the elements dimensions should be reduced as much as possible in order to get enough accuracy of results. So, it is attempted to make equilibrium among the elements dimension and the analysis time and to optimize the elements' dimensions. Also the distance gap ranging from 0-5 mm was investigated due to having direct relation with the applied force to the coils. As shown in picture 3 the magnetic bearing was meshed with the least element.

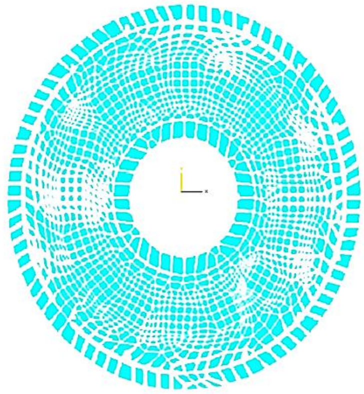


Fig. 3. Meshing 16 polar magnetic bearing.

4. RESULTS

After getting required results in external flux counter, we assess this situation regarding magnetic flux formula magnetic.

Property of magnetic H=I/2π field is independent of type of material that surrounds the wire.

In this software by ability of getting diagram of magnetic flux change in desirable cycle in air space between coil and ternary coil, changes are numerically evident. As it is shown in figure 4 and 5, all changes in air space is equal to 0.5 mm and 0.32 Magnetic bearing can control the maximum force that are explained in the following diagrams in 0.32 mm space. It can continue its turning in required cycle easily in rotator. As it is clear in 0.03 second the maximum flux of magnetic field is produced to turn the rotator.

Figure 4 and 5 are showing an overall view of the 8 and 16 poles bearings. Rey also shows the bearing velocity and all the force regarding the colored conditions showing the minimum to maximum levels of forces.

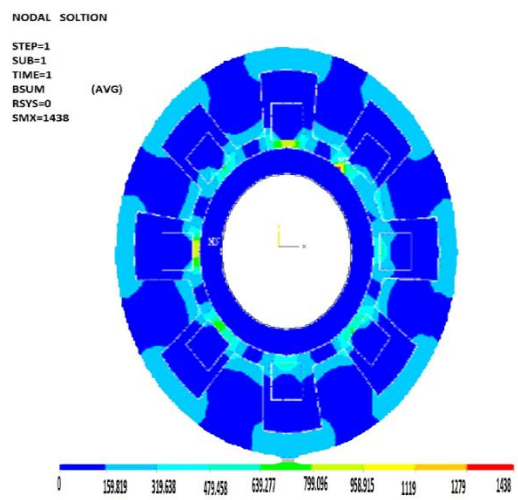


Fig. 4. 8 poles bearing simulation.

Different torques are depicted in rotational speed of 30000 rpm and based on picture 4, the maximum amount of force is between coils and rotor.

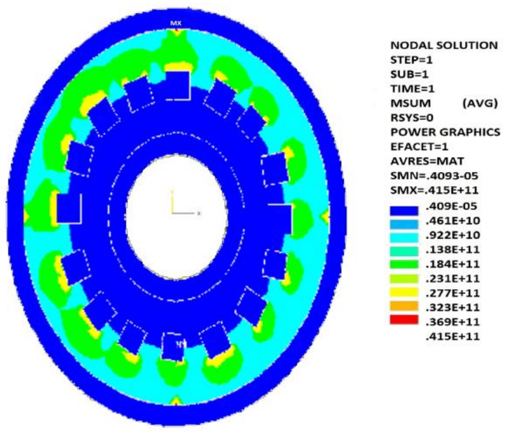


Fig. 5. 16 polar bearing simulation.

Investigating the effect of air gap in figure 6 and 7 shows the produced magnetic force in 0 - 5 air gaps for 8 and 16 polar bearings respectively. The 8 polar magnetic bearing showed to bear the highest amount of force in 1.8 and 3.6 mm air gaps.
In figure 6 the highest force in 3.3 mm air gap is made and the reflective force is 5938 M Pa- in 0.6 and 0.45 mm force fluctuations were made due to ups and downs of magnetic field and the produced density.

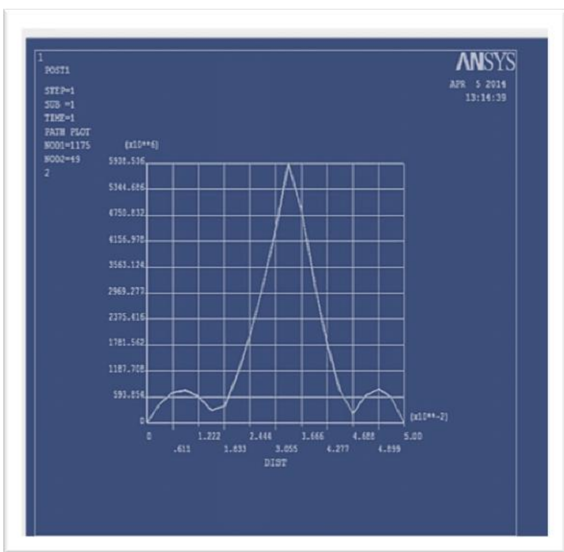


Fig. 6. Investigation the power in different air gaps in polar 8 bearing.

Figure 6 investigates the forces in different air gaps of 8 pole bearing. Based on figure 7, in the bearings with 16 polar and magnetic force in 0-5 mm air gap, in the magnetic bearing during 1.8 and .3.6 maximum magnetic force was made due to controlling the distance in the desired rotation.

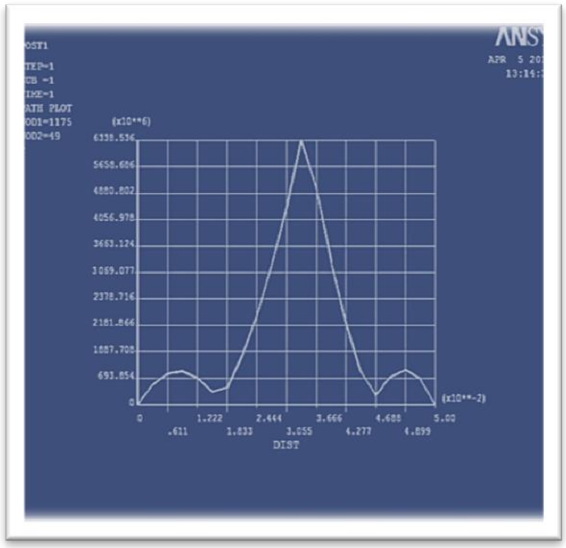


Fig.7. Investigation the power in different air gaps in 16 polar bearing.

In figure 7, the resulting maximum force in the air gap is created between the reaction force is 6338 M Pa.
Given figure, 8- output of changes in flow of magnetic field in air distance the gap of octagon bearing between 0-0.45 is evident. So that, it can be seen in each distance in desired turning measured density of flow. At the bearing in order to start, density of flow in magnetic field is maximized. Then by creating turning, torque by controller between 0.18 to 0.27 mm is set. By creating a flow of magnetic field to linear proportion, it continues its turn to 0.1 second.

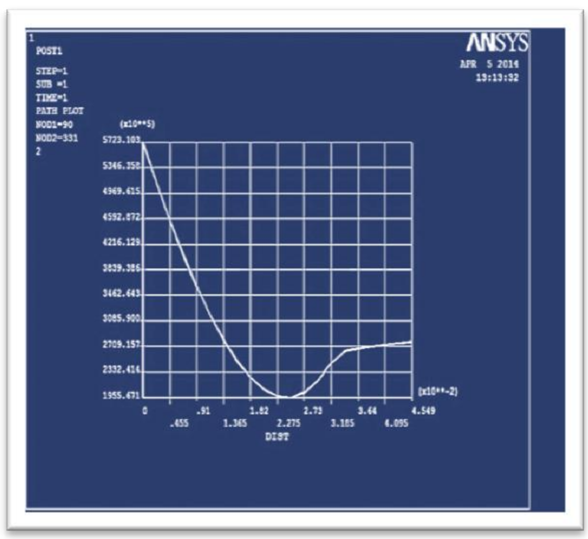


Fig.8. Diagram of density of flow in magnetic field of 8 polar bearing.

In desired diagram by considering observed asymmetry concluded that in air distance more than 0.25 mm condition changes in density of flow in magnetic field has change with mild gradient and by pay attention to coil volume and coil is normal in a moment of time. In contact with diagram in air distance of 0.25 mm is observable.

In flow of magnetic field of bearing with 16 poles, average of air distance is fixed to 0.22 mm. But the changes of flow in magnetic field have increased to 22 percent. It is possible to acquire changes of flow in magnetic field. By pay attention to condition in16 pole bearing, the balancing status is 0.22 mm and the contact of diagram with horizontal axis is less than octagon bearing, which these changes are because of increase in flow in desired air distance. In 16-pole bearings in air distance of more than average, vibration increase relative to octagon bearing that are more enduring. So 16-pole bearings have ability to control vibrating loads. In reviewing magnetic force it can be easily seen that change in forces shows that in magnetic bearing there is an indirect relationship between air distance and force. Also rise and fall in power is turning even in high speeds and no contact is created because of controlling status of bearing.

But through changes, air distance has a maximum and minimum. This force is increased in linear direction because of increase and decrease of air distance. It increases in one direction and decreases in other direction.

After getting the output in terms of the magnetic field at different nodes 8 and 16 bearing the desired output polarization can be seen in Table 4.

Table 4. The amounts of powers in different air gaps

16 pole Force (m Pa)	8 pole Force (m Pa)	Air gap (mm)	Air gap (mm)
6338.5	5938.5	3.3	3.3
5658.6	5366.6	3.1	3.5
4880.8	4750.5	3	3.6
4056.8	4156.9	2.8	3.8
3663.1	3563.1	2.6	4
3069.07	2969.2	2.5	4.1
2378.7	2375.7	2.4	4.2
2181.2	1781.5	2.1	4.27
1887.7	1178.7	2	4.3
693.8	593.8	.6	4.8

5. CONCLUSION

This article discusses application of magnetic bearing and their benefits in industry. Application of these systems in every part requires research on the level of economical use and value of using them in that part.

If its application is not acceptable because of costs, system can offer more exact services and increase speed in industry. According to the acquired results, it is observed that:

1 – The rotor deviation in eight pole bearing is equal to the 16 polar deviations and is equal to 0.001 mm.

2- Wear exists between 0 to 0.1 seconds, but the balance between internal and external cones in the bearing 16 samples can be observed.

3- The maximum sustainable power loss density of magnetic current of the field is about 0.1 percent, but the amount of force bearing toward the eight poles coercive force was 4 percent.

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