International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 11
November 2017

Magnetic Analysis of Single-Axis Active Magnetic Bearing using ANSYS base Environment

Jonathan Laldingliana, Pabitra Kumar Biswas , Sukanta Debnath
NIT Mizoram

ABSTRACT

The active magnetic bearing (AMB) is an integral part of the industrial rotational machine. In this paper magnetic analysis for a single axis, U type magnet based Active Magnetic Bearing (AMB) is presented. Here, the proposed AMB has a single actuator with two coils and a circular ball- type rotor which has to be levitated. ANSYS (Version-17.1) based software is used for analyzed the model. In this paper, finite element analysis is performed for finding out the different magnetic properties such as- magnetic field, flux pattern, magnetic flux density and magnetic force. The effect of different magnetic properties has been studied with the change in current, air gap and the number of turns. The electromagnetic field circulation and density analysis permit verifying the designed AMB and the influence of the shaft and coil current changes on the bearing parameters.

Keywords

Finite element Analysis (FEM), Active magnetic bearing (AMB), ANSYS, Electromagnetic field, flux pattern.

INTRODUCTION

A magnetic bearing is a system which used magnetic force to levitate a rotor without any physical or mechanical contact with the stator. A magnetic bearing system can be categorized into two parts active magnetic bearing and passive magnetic bearing. In case of passive magnetic bearing, the magnetic force produced to levitate an object is unstable, due to this problem research toward active magnetic bearing is increasing [1]. In AMB system, a rotor is levitated in the air gap between the stator without any physical contact with the help of controlled current flowing through the stator winding. In many engineering fields, AMB system plays a number of rolls over a conventional bearing system, since the spinning rotor is levitated in the air between the stator without any friction that usually exists in normal conventional bearing [2]. Therefore, the lifetime of the magnetic bearing system is longer. It has the ability to operate at a higher speed, less sound, low vibration level and high accuracy [3][4]. The building of magnetic bearing is difficult according to Earnshaw’s theorem and it is necessary to go for electromagnet with a good power supply. So, one of the perfect tool and method for analyzing the magnetic properties of active magnetic bearing system are a Finite Element Method (FEM). The diagram of a single axis, double coil with circular rotor is shown in figure 1.

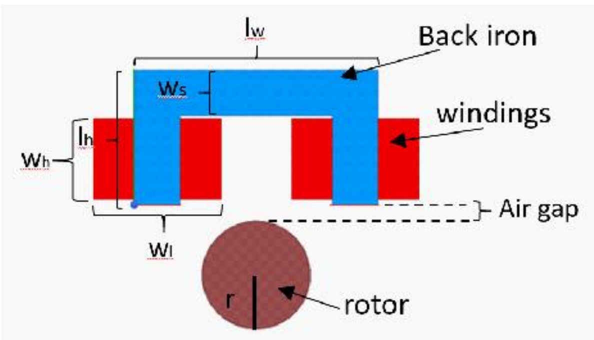

Figure 1: Single Axis Double winding AMB

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 11
November 2017

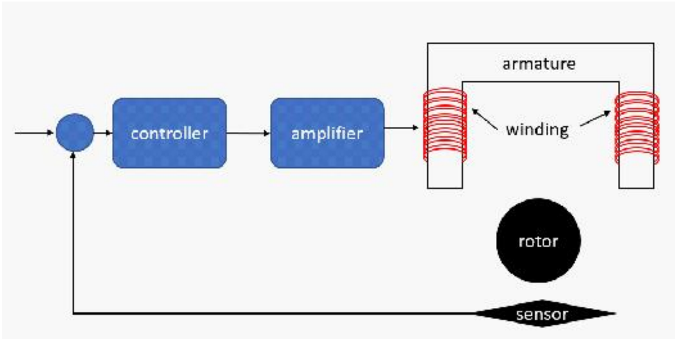

Figure 2: Block diagram of AMB system.

In AMB system the rotor is levitated due to the force of attraction between the ferromagnetic and the electromagnet. Control of a levitating object in open loop system is problematic, so closed loop system is considered in this paper. The closed loop system of a single axis double coil AMB is presented in figure 2. Here, the position sensor measures the air gap between the rotor and the armature and the signal is feedback to a comparator. The output signal of a comparator is supplied to a controller which produced a current set point. For obtaining a required actuator current, the signal from the controller is then amplified by the power amplifier.

In order to levitate a rotor for a single axis AMB, the force of attraction between the AMB and the earth force should be equal. The force equation is shown in equation- 1. Here, m is the mass of the rotor, 'C' is the magnetic constant 'g' is the gravitational force. The electrical equation of single axis AMB is given in equation-2. Where, E =voltage across the coil; L =coil inductance; R= coil resistance; x= rotor position.

$$F = m \quad - c\left(\frac{i}{x}\right)^2 \qquad (1)$$

$$E = R.i + L\frac{\delta i}{\delta t} - L_0 x_0 \frac{\delta x}{\delta t} \qquad (2)$$

It is necessary to find out the required magnetic force and magnetic field for levitating the -rotor in the air without any physical contact between the rotor and the alternator. In this paper, 2-D FEM simulation is performed for a single axis double coil to find out the required flux, force etc. using ANSYS Maxwell (version 17.1).

FINITE ELEMENT METHOD AND ANSYS ANALYSIS

Utilizing a numerical method called a Finite Element Method (FEM), solutions can be achieved for a number of problems and questions in engineering. Linear or non-linear problems, steady, transient system, fluid flow, heat transfer and electromagnetism problem can be analyzed with finite element method [5,6]. Compare to other approximate method FEM is more comfortable and easy to use, a complex problem can be easily handled and the graphics facilities are superior, FEM procedure is implemented in a computer and a number of code and software is implemented. FEM can be divided into three groups- pre-processing, processing and postprocessing [6,7]. During pre-processing stage, the given structure is dividing into a number of elements and after this, the data related to the elements and nodes are prepared and the materials properties are assigned. During the processing stage, the generated data are used to compute the element matrix and solve the equations. Post-processing part reviews the results of FEM, it involves checking the solution, prepare the chart in a table and graphical form. One of the advance working environment of FEM is ANSYS software.

In this work ANSYS Maxwell (version 17.1) is used for analyzing a single axis double winding AMB. For electromagnetic analysis, ANSYS Maxwell provide a perfect environment, modeling of a system can be done in 2-D as well as in the 3-D model. ANSYS Maxwell has many finite element analysis capabilities range from complex to dynamic, linear and transient etc. The flowchart of calculation of flux pattern, field and force using ANSYS Maxwell is shown in figure 3. The calculation of flux, force and filed of AMB is based on Maxwell's equation of electromagnetism, the differential form of Maxwell's equation can be written as [8,9].

$\nabla X \quad = J + \frac{\partial}{\partial}$

$\nabla X \quad = -\frac{\partial}{\partial}$ (4)

$\nabla . B = 0$ (5)

$\nabla . D = \rho$ (6)

For static magnetic field $\frac{\partial}{\partial} = 0$. So, $\nabla X \quad = J$ (7)

$B = \mu H = H\mu_0\mu_r$ (8)

$D = \varepsilon. \quad = \varepsilon_0\varepsilon_r E$ (9)

$J = \sigma$ (10)

$J = \rho$ (11)

$\nabla . J = -\frac{\partial}{\partial}$ (12)

$F = Q(E + \nabla XB)$ (13)

Where, H is magnetic field intensity, J is current density, B is magnetic flux density, ρ is volume charge density, D is electric charge density, σ is the electrical conductivity, ε is permittivity and μ is permeability respectively. Ampere's circuital law in differential form is shown in equation 3 and the differential form of Faraday's law is given in equation 4. Equation 10 and 11 are the current density for conduction current and for convection current. The parameters used in this present analysis for a single axis double winding are shown in figure 1. Radius of a rotor (r)=2cm, height of coil(wh)=3cm, width of a coil(wl)=4.7cm, width of a back iron(ws)=1.7cm, length of back iron (lw)=9cm, height of back iron(lh)=5cm.

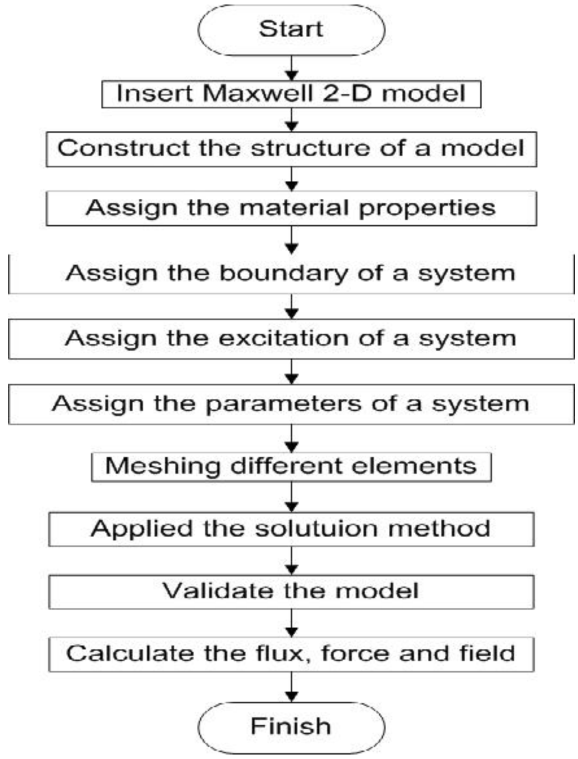

Figure 3: Flow chart for calculation of parameters using ANSYS Maxwell

SIMULATION RESULT AND DISCUSSION

FEM simulation has been carried out for solving different problems using ANSYS Maxwell (version 17.1). In this analysis, 2-Dimension workspace is used. The material used in the rotor and stator are iron material and the winding material is copper. The analysis is carried for different air gap, range from 2mm to 20mm that is, ten different air gaps. Coil current used in this analysis is 3Aand the number of coil turns is 500 turns. The flux pattern, flux density, magnetic field and force for 4mm is shown in figure 4 to figure 7. The vector plot of flux pattern for different air fap (2mm to 20mm) with current 3A and the number of winding turns(N)=500 is shown in figure 8. It is observed that with the increased in air-gap leakage flux between the electromagnet and the rotor increased which results in the reduction of flux and it is observed that the generated flux is almost constant with a large airgap (air gap for more than 18mm). The plot between the change in air-gap with flux density, field, and force is shown in figure 9, 10 and 11. From figure 9 it is observed that the flux density decreases with the increased in the airgap. Reduction in a magnetic field is observed when the space between the ferromagnetic (rotor) and electromagnet (stator part) is increasing as given in figure 10. The graph between the force with airgap is shown in figure 11, here in this analysis the force between the stator and rotor is reduced with increased in the distance between the rotor and stator of AMB.

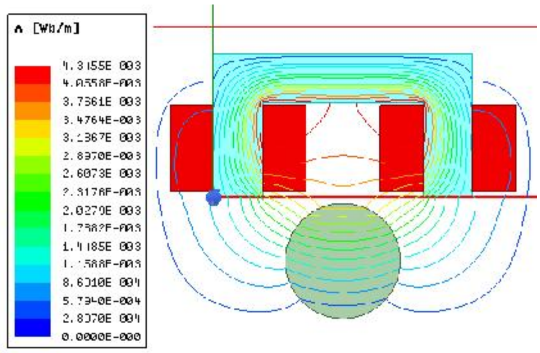

Figure 4: Flux Pattern for I=3A, N=500, airgap=4mm

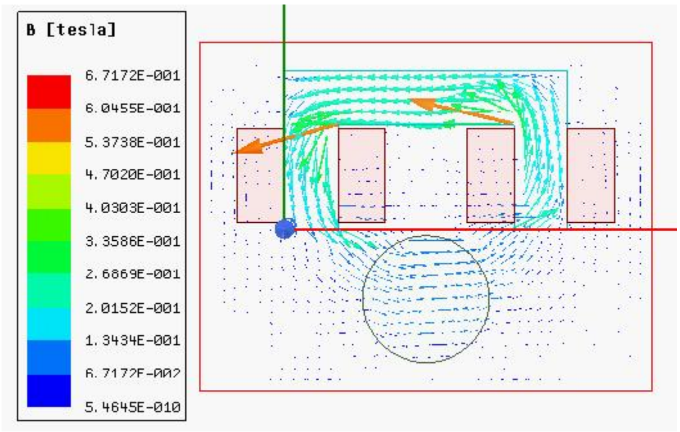

Figure 5: Flux density for I=3A, N=500, airgap=4mm

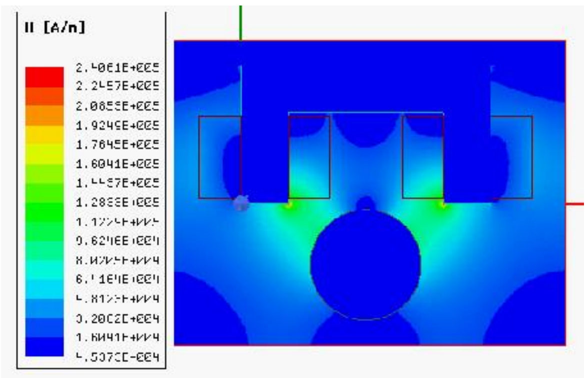

Figure 6: Field intensity for I=3A, N=500, airgap=4mm

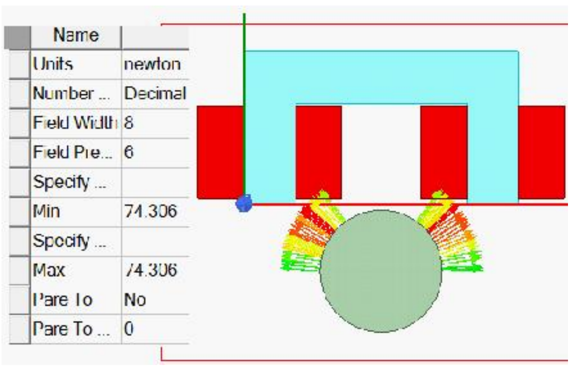

Figure 7: Force for I=3A, N=500, airgap=4mm

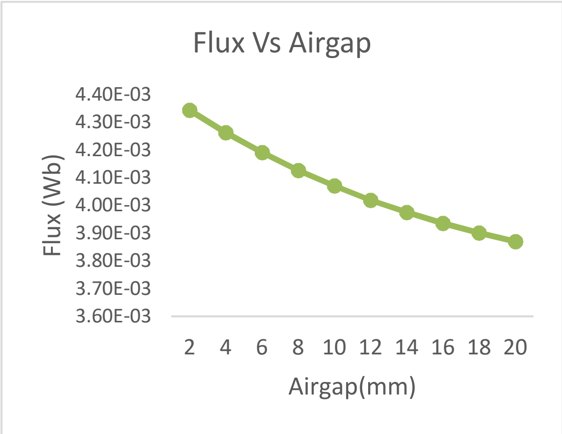

Figure 8: Magnetic flux Vs airgap for different air-gap with current I=3A

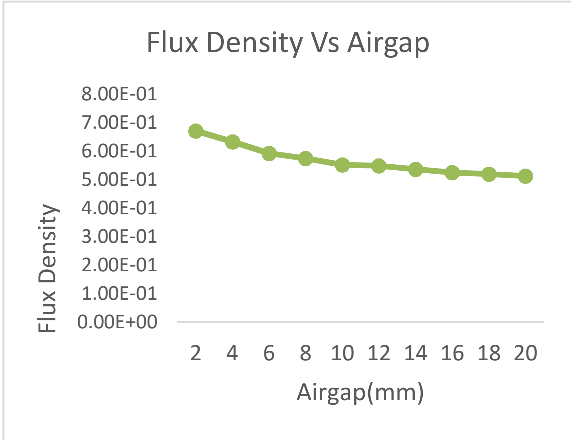

Figure 9: Magnetic flux Density Vs airgap for different air-gap with current I=3A

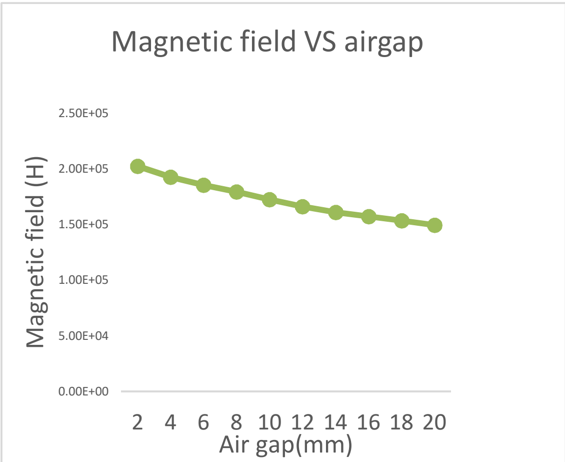

Figure 10: Magnetic field Vs airgap for different air-gap with current I=3A

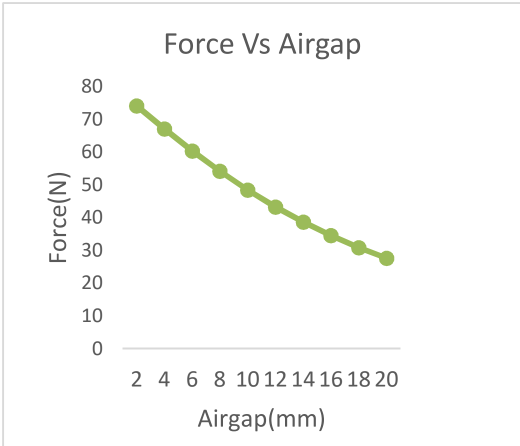

Figure 11: Magnetic force Vs airgap for different air-gap with current I=3A

CONCLUSION

Simulation of single axis Active Magnetic Bearing with double winding has been given in this paper. Using ANSYS Maxwell environment, 2-Dimension FEM analysis has been performed. Since the magnetic field is stronger in double winding as compare to single winding. Therefore, double winding is used in this analysis. The effect of flux, flux density, magnetic field and magnetic force with the change in air-gaps and constant current 3A has been studied. In this ANSYS simulation, it is observed that with the increase in air-gap between the stator and rotor, leakage flux is increasing which results in the reduction of flux. Here in this study it is also observed that the flux, force, and field decrease with the increase in the space between the stator and the rotor. From the simulation result, the force and magnetic field for a given AMB system are observed for a different air gap. For real-time implementation levitating of a rotor depend upon the size and weight, accordingly the force required for the AMB can be calculated.

This work can be further extended to a Comparative study of a single axis AMB with the change in number of coil turns and change in coil current also with the increase the number of stator poles with coils.

ACKNOWLEDGMENT

For this work, the authors of this paper are grateful to the Science and Engineering Research Board (SERB), Department of Science and Technology, Govt. of India for sponsoring the Project.

REFERENCES

[1] Gayathri. S, Subakaran. K, Somshekar. B, "State and Art of the Active Magnetic Bearing Design and Analysis by Using MATLAB". International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 3, Issue 11, November 2014, pp 13168- 13175.

[2] P.C. Krause and C.H. Thomas, "simulation of symmetrical induction machinery", IEEE transaction on power apparatus and system, vol. 84, Nov-1965, pp. 1038-1053.

[3] Andrea et al, "Rotor on Active Magnetic Bearing: Modelling and control techniques. Advances in Vibration Engineering and Structural Dynamics". book edited by Francisco Beltran-Carbajal, ISBN 978-953-51-0845-0, Published: October 2, 2012 under CC BY 3.0 license. © The Author(s).

[4] Baljinder Singh; Vijay Kumar, "A real time application of model reference adaptive PID controller for magnetic levitation system". 2015 IEEE Power, Communication and Information Technology Conference (PCITC), Year: 2015Pages: 583 - 588, DOI: 10.1109/PCITC.2015.7438065

[5] Hammond P., Sykulski J.K., ―Engineering Electromagnetism – Physical Processes and Computation‖, Oxford University Press, New York 1994.

[6] Saeed Moaveni, "Finite Element Analysis-Theory and Application with ANSYS" 3rd edition, Pearson.

[7] R. dhanaraj, K.P. Prabhakaran Nair, "Finite Element Method". Oxford University Press 2015.

[8] Rothwell, E.J and Cloud,M.J, "Electromagnetic". CRC Press 2001.

[9] S.C Mahapatra, S Mahapatra.Principle of Electromagnetic. 2nd edition, Mc Graw Hill.

[10] P.K.Biswas, S.Banerjee, "ANSYS Simulation Based Comparative Study between Different Actuators and Guide-ways used in DC Electromagnetic Suspension Systems", International Journal on Electrical Engineering and Informatics, ISSN NO- 2087-5886,Volume 4, Number 2, July 2012,pp-217-230

[11] P.K.Biswas and S.Banerjee, "Design and ANSYS software based simulation of C-I type actuator and rail used in electromagnetic levitation system", International Journal of Applied Sci. and Engg., ISSN NO- 1727-2394, Vol.12 No.3., Sep, 2014, pp-225-239

[12] ANSYS Inc., Licensing Guide, Release 12.1 (002829), November 2009.

[13] Introduction to Scripting in Maxwell, ANSYS 2017.1

[14] Low -frequency Electromagnetic Analysis Guide, ANSYS, Inc., Release 12.1, 2009