# AN EXPERIMENTAL COMPARISON OF PERMANENT MAGNETIC BEARING AND DEEP GROOVE BALL BEARING-A REVIEW

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**ABSTRACT**

*In today's era, high-speed and high-precision are the main requirement of any rotating machinery. Ball bearings are the main element used to support this rotating machinery. There are some limitations of ball bearing like, more friction, it requires lubrication, heat generation during operation and not efficient in space applications. Permanent magnetic bearing (PMB) is capable to operate without lubrication, non-contact operation and with low magnetic resistance. So, it is necessary to compare both bearings so that we can take advantage of magnetic bearing in related applications. Therefore there is a need of experimental investigation to explore performance of PMB.*

*This paper presents the comparison of permanent magnetic bearing and deep groove ball bearing. Main objective of this study is to find out static magnetic resistance and magnetic resistance torque of permanent magnetic bearing and compare same with static friction co-efficient and frictional torque of deep groove ball bearing.*

**Keyword:-** *permanent magnetic bearing (PMB), static friction, magnetic resistance, frictional torque, magnetic resistance torque*

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## 1. INTRODUCTION :

Bearing is the main element used to support rotating elements.

A bearing is a supporting machine element that used to support rotating parts of machinery, and reduces friction between moving parts. Main purpose of bearing is to reduce friction between rotating parts for this purpose various research works are carried out on bearing for friction reduction and design improvement. Rotary bearings hold rotating components such as shafts or axles, and transfer loads to the structure supporting it. Lubrication is used to reduce friction and in the ball bearing and roller bearing, to prevent sliding friction, rolling elements such as rollers or balls are used.

In ancient time people were using wheel for the reducing friction and less work. After that day by day revolutions of many civilizations invented various methods for friction reduction. Leonardo da Vinci integrated drawings of ball bearings in his design for a helicopter and carried out various experiment for static friction of sliding parts. [11]

BALL BEARING

A ball bearing is a rolling-element bearing that uses balls to reduce friction and maintain the partition between the bearing races. The purpose of a ball bearing is to support load and reduce rotational friction. It can be achieved by races having the balls and transmit the loads through the balls. One race is stationary outer race and the other rotating inner race. Ball bearing having lower load capacity compare to roller bearings.

MAGNETIC BEARING

Modern technology in rotating machinery tends towards high-speed, high-accuracy and high-efficiency. Magnetic bearings are contactless suspension devices, which are mainly used for rotating applications. There is no contact between stator and rotor therefore less resistance between the rotating part and its supporting parts.

There are two types of magnetic bearing, [1]

- Active magnetic bearing
- Passive magnetic bearing

Their main applications of passive magnetic bearings (PMB) are high speed applications such as, in space technology (satellite), energy storage flywheel, High-speed machine tool spindles, Turbo-molecular pumps, Turbo-compressors, Ultra-centrifuges etc. [9] [1]

- Working principle of permanent magnet bearing:

Permanent magnetic bearings (PMB) the rotor is levitated by the repulsive forces generated between the magnets placed on both rotor and stator.

There is arrangement of magnets on periphery of stator such that the same pole of magnet faces each other and also same pole magnetic ring mounted on shaft as a rotor so due to repulsive retraction of magnetic force rotor will levitate in air.

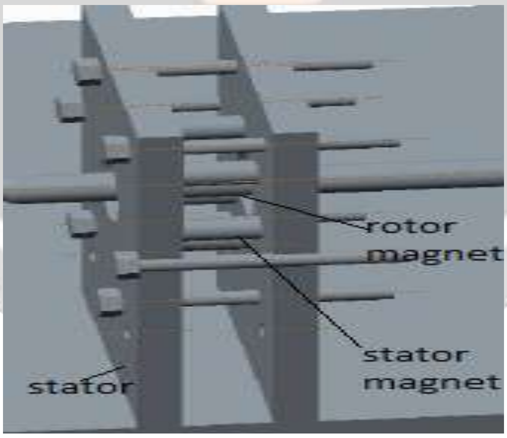


Fig. magnetic bearing drawing

Difference between active magnetic bearing and passive magnetic bearing is below,

| **Active magnet bearing** | **Passive magnet bearing** |
| --- | --- |
| AMB operated by electro magnets. | PMB operated by permanent magnets. |
| Actively controlled magnetic bearings operate in attractive mode.[1] | Passively controlled magnetic bearings operate in repulsive mode.[1] |

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| AMB have the ability to support large Loads compare to PMB. [1] | PMB have the ability to support small Loads[1] |
| AMB are expensive and require complicated control hardware, such as digital signal processors, amplifiers, digital-to-analog converters, analog-to-digital converters, and software.[12] | Passive magnetic bearings do not require this hardware and software. PMB can be made smaller, more efficient and reliable.[12] |
| AMB have the ability to support large loads, they have characteristics such as damping and stiffness, and dynamic control.[12] | The disadvantages of passive magnetic bearing are that they typically have smaller stiffness and smaller damping than similar size active magnetic bearings, and vibration problem during operation.[1] |

Motive of this paper is to review for permanent magnet bearing which is able to work with less magnetic resistance, without lubrication and non-contact operation.

In case of ball bearing, it requires lubrication, more friction, heat generation during operation and not efficient in space applications.

Magnetic bearing is capable to operate without lubrication, non-contact operation and with very low friction. So, it is necessary to compare both bearings so that we can take advantage of magnetic bearing in related applications.

Therefore there is a need of experimental investigation to explore performance of PMB.

## 2. LITERATURE REVIEW :

Literature review is carried out for permanent magnetic bearing and it's comparison with deep groove ball bearing. During this review we also find that Magnetic bearing is capable to operate without lubrication, with less magnetic resistance and non-contact operation.

### Paper 1 : Permanent Magnetic Bearing For Spacecraft Applications

Wilfredo Morales and Robert Fusaro[1] they have done design construct and operate a totally passive, permanent magnetic bearing ring for spacecraft applications. The design integrated permanent magnetic bearings (PMB), operated in the repulsive mode for radial support as a bearing, and jewel bearings for axial support. They carried out his work on Permanent magnetic bearing for spacecraft applications (satellite).They have proposed passive magnetic bearing (PMB) design, construction, and testing for satellite application. PMB was run for a speed of 5500 rpm by an air impeller. They have measured stiffness with the help of dial indicators and the rotor was deflected by adding weights to the shaft near the free end. They Measured Radial stiffness experimentally 1.78×10^5 N/m and in finite element method it was 1.87×10^5 N/m. They have Measured damping coefficient $\xi$=0.0649 and suggested that experimental and finite element method results are similar can used to select size and number of magnet in magnetic bearing.

### Paper 2 : Failure Mode And Effect Analysis Of Passive Magnetic Bearing

K.P. Lijesh , S.M. Muzakkir , Harish Hirani[2] carried out his work on Failure mode and effect analysis of passive magnetic bearing. The main objective of an FMEA Process is to find out all the potential modes of failure of a product. They applied Failure mode and effect analysis for a passive magnetic Bearing (PMB). They found out thirteen possible modes of failure of passive magnetic bearing system. They have given Risk Priority Number (RPN) according to failure priority more large number means more risk to failure. They found the failure modes and most critical are reduction in magnetic Strength due to repulsion mode, non-uniform magnetic field, new pole formation and fracture of magnets. For the understanding of the effect of different crack-depth on the magnetic field, a three dimensional 3D magneto-static analysis was performed and the magnetic field was studied at a mid-plane, and concluded that failure due to crack will be severe if the rotor is operated near to the surface of the stator. They have designed rotor with square magnet to avoid crack formation. The dis-advantage of the rotor with square magnets is its non-circular configuration that induces intrinsic unbalance and result in instability of rotor during rotation motion. They proposed possible solution to prevent the cracking of the magnets is to introduce rubber as isolators. To prevent hitting of rotor and stator, the isolation of the magnets is carried by using rubber that absorbs the vibration energy. The rubber acts as an isolator between the structure and rotor magnet and reduces the transmission of impact by absorbing the energy. They suggested that all these failure modes drastically reduce the load carrying capacity of the passive magnetic bearing.

**Paper 3 : Optimization Of Halbach Magnetized Permanent Magnet Axial Bearing**

S. I. Bekinal, T. R. Anil, S. Jana, M. I. Peerzade[3] They have carried out a parametric study of permanent magnet axial bearing Halbach magnetized having two concentric rings using two dimensional (2D) analytical equations for force and stiffness in MATLAB. They carried out validation of parametric study with the results of Finite Element Analysis using ANSYS. They have optimized geometrical parameters of the selected bearing configuration for higher magnitude of force and stiffness. They have concluded that axial force and axial stiffness will increase when the magnet volume increases and air gap dimension should be as small as possible to have a large axial force. They found the maximum axial force exerted by the outer ring on the inner one is 94.77 N at zero axial offset and the maximum axial stiffness ($3.68\times10^4$ N/m) was found out. They have suggested that this study using either 2D equations or ANSYS can be used for the selection of permanent magnet bearing made of two concentric rings a variety of applications having a constraint of volume and need of higher axial stiffness and force.

**Paper 4 : Frictional Torque On A Rotating Disc**

Carl E Mungan[4] carried out his work on Frictional torque on a rotating disc. They have performed measurement on an aluminum disc mounted on bearings that is gives an initial twist and allowed to spin until it comes to a stop. They used standard kinematic equations for constant angular acceleration. Frictional torque $\tau f = -I\, d\omega/dt$ by measuring the time $t$stop and number of revolutions $N$stop = $\theta$stop$/2\pi$ that it takes for the disc to come to a full stop, frictional torque can be determine.

**Paper 5 : Passive Magnetic Bearing**

A. Hamler, V. Gori&can, B. Stumberger, M. Jesenik, M. Trlep[5] carried out his work on Passive magnetic bearing. They have developed PMB such that Ability to take both radial and axial loads in both directions by using axially magnetized permanent magnets. They have used 3D finite element method (3D FEM) for analysis of magnetic conditions in the bearing and the performance of passive magnetic bearing was determined by the Maxwell Stress Method. They concluded that the magnitude of magnetic force is dependent on the magnitude of shift. Passive magnetic bearings are suitable for high-speed rotary elements. The magnitude of magnetic force is dependent on the magnitude of shift. Higher outside forces will also cause higher shift.

**Paper 6 : Rotor Dynamics Of A Passive Magnet Bearing System**

H. Ming Chen, Thomas Walter, Scott Wheeler, Nga Lee[6] carried out his work on Rotor dynamics of a Passive Magnet Bearing System. They have developed passive magnetic bearing system for flywheels used in space energy storage systems. The system having two radial passive magnet bearings and an active radial damper. The remnant flux density of the PM was 1.0 Tesla, and they have measured the bearing radial stiffness of 263 N/mm and load capacity 65 N. They performed Spin tests for the PM bearings were operated to 66,000 rpm. They have used an active radial damper in the system instead of an active radial bearing to replace one of the passive bearings, because the active damper does not take radial load and can be made small. It took 50 min for the rotor to coast down from 5000 rpm in air. The damper and bearings have very low power loss. Without using the damper the rotor would not be stable. They have concluded that the radial part of the bearing system is simple in control and efficient in power consumption. PM radial bearings are well suited for high-speed rotors, such as flywheels, provided a small active radial damper is used to supplement system damping for traversing critical speeds and PM radial bearings are well suited for high-speed rotors, such as flywheels.

**Paper 7 : Investigation Of Passive Magnetic Bearing With Halbach-Array**

Arkadiusz Mystkowski, Leszek Ambroziak[7] carried out his work on Investigation of passive magnetic bearing with halbach-array. They have used the Halbach-array configuration to increase the radial passive magnetic bearing stiffness. In the construction of the passive radial magnetic bearing 180° Halbach-array was used. The main purpose of the work was developing the nonlinear model of the PMB. Therefore, the magnetic flux circuit of the PMB was analytically calculated by using the Ohm and Kirchhoff methods. The nonlinear effect of the discrete 3D model of the PMB was analyzed using Finite Element Method (FEM). To analyze the magnetic bearings and to estimate their radial force distribution, 3D models of the passive magnetic bearing was built. Simulation calculations were made by using the FEM via Comsol Multiphysics ver. 3.5a software. Three-dimensional model of magnetic bearings was used to compute the magnetic potential, magnetic flux density and magnetic energy in the air gap. The radial displacement of the rotor was measured in two directions x-y by using inductive sensors. Designed model was 1282681 elements and 1.28×10^5 N/m Radial stiffness. They have concluded that the finite element method, with a careful analysis and accurate modeling, may be used with quite good results in the design of passive magnetic bearings. HALBACH-ARRY can be used for the implementation of the high performance of passive magnetic bearings.

**Paper 8 : Reduced-Friction Passive Magnetic Bearing: Innovative Design And Novel Characterization Technique**

Guillaume Filion, Jean Ruel and Maxime R. Dubois[8] carried out his work on Reduced-Friction Passive Magnetic Bearing: Innovative Design and Novel Characterization Technique. They have designed and developed PMB for flywheel energy storage systems (FESS).The main objective of this study was innovative design of PMB that minimizes energy losses produced by the axial thrust bearing, and development of methodology used for the measurement of its stiffness and damping. The stiffness of the bearing was obtained by measuring the forces generated by the relative positioning of the concentric magnets. The characterization of the damping was measured with an accelerometer. They have designed such that the axial force does not vary when the rotor moves radially. They have concluded that the number of magnets used in the bearing has a limited influence on the damping ratio, while it increases the stiffness.

**Paper 9 : Solution Of Contact Free Passive Magnetic Bearing**

Daniel Mayer, Vit Vesely[9] carried out his work on Solution of contact free Passive magnetic bearing. They used professional programs (SW products) for magnetic field analysis and suggested that it is possible to solve magnetic bearings effectively. They found two ways in which it is possible to improve the qualities of magnetic bearing. The first was asymmetrical arrangement of the stationary part of the magnetic bearing and the second one was the magnetic shielding of the bearing. It is possible to improve the qualities of the magnetic bearing by asymmetrical arrangement of the fixed part. By lowering the Reluctance of the paths of the magnetic flux outside the bearing we can cause an increase of magnetic flux density in the air gap and so an increase of loading capacity of the bearing. They have concluded that the loading capacity of the bearing increased considerably for both ways. For asymmetric bearing it by 283% and for shielded bearing by 383%.

**Paper 10 : Magnetic Bearing : An Integrated Platform For Teaching And Learning**

S.C.Mukhopadhyay, C. Gooneratne and G. Sen Gupta[10] carried out his work on Magnetic Bearing: An Integrated Platform for Teaching and Learning. This paper has described different aspects of a repulsive type magnetic bearing system which is used as an integrated platform for teaching and learning. They have carried out his work on the different components of a hybrid magnetic bearing model. They have measured the repulsive force using the JJ Instruments. They have carried out design of control system is based both on analog electronics design and microcontroller design. The flux distribution due to the worst situation of the permanent magnet was analyzed using finite element method. They concluded that the few subjects such as electromagnetics, sensing technology, electronics, control system, microcontroller etc. can be effectively taught with this model.

## 3. CONCLUSION:

After studying all these research papers it is conclude that permanent magnetic bearing is applicable for high speed, with less magnetic resistance, lubrication free and can work in vacuum. Magnetic bearing is capable to operate without lubrication, non-contact operation and with very less magnetic resistance. So, it is necessary to compare both bearings so that we can take advantage of magnetic bearing in related applications. Therefore there is a need of experimental investigation to explore performance of PMB.

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