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MAGNETIC BEARING INDUCTION MOTOR

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Abstract — *Active magnetic bearings (AMB) provide a means of supporting a body completely without any contact. The advantages of such bearings compared with traditional solutions are: absence of mechanical wear and friction, lubricant free operation and therefore suitability for severe environments, active vibration control, unbalanced compensation etc. They can be used in number of industrial applications such as turbo machinery, vacuum technology, machining and transportation. This paper demonstrates designing a prototype of magnetic bearing.*

Keywords*-Magnetic Bearing, Rheostatic control, Electromagnetic force, Induction motor*

I. INTRODUCTION

Bearings are essential components of all rotating machinery. By definition, the bearing is the static part of the machine (often called the stator) that supports the moving part (often called the rotor). While air and fluid bearings, ball bearings, which allow for pure rotation are by far the most popular. They are widely available, cheap and can handle very large static loads. However, the most common failures in rotating machinery are ball- bearing failures. For example, such a failure may be due to over-stress from imbalance loads, lubrication thermal breakdown, or lubrication contamination.

Magnetic bearings are an alternative to ball, air or fluid bearings. Magnetic bearings are constructed from permanent magnets (PM), electromagnets (EM), or combinations of both. A magnetic bearing is a bearing that supports a load using magnetic levitation. Magnetic bearings support moving parts without physical contact. For instance, they are able to levitate a rotating shaft and permit relative motion with very low friction and no mechanical wear. Magnetic bearings support the highest speeds of all kinds of bearing and have minimum relative speed.

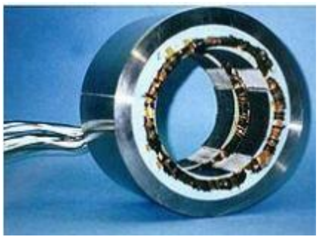

Fig. 1: The Magnetic Bearing

There are two types of magnetic bearings namely passive magnetic bearing (PMB) and active magnetic bearing (AMB). Passive magnetic bearings use permanent magnets and, therefore, do not require any input power but are difficult to design due to the limitations described by Earnshaw's theorem. In 1842, Earnshaw proved that a stable magnetic suspension system couldn't be achieved using only passive permanent magnets. According to Earnshaw's theorem, to ensure stability, at least one axis must be actively controlled. Techniques using diamagnetic materials are relatively undeveloped and strongly depend on material characteristics.

II. WORKING PRINCIPLE.

Magnetic Bearings are devices used to support (levitate) objects using magnetic forces. Some magnetic bearings provide a full non-contact support of an object, whereas others provide only a partial support working together with more conventional mechanical bearings. While a wide variety of magnetic bearings have been developed, only one type has been widely accepted in the industry so far - Active Magnetic Bearings (AMBs). This is because AMBs can exert higher-density forces on surfaces of supported objects than any other type of magnetic bearings.

They can also operate in a wide range of environments and their properties can be made highly configurable through software parameters. The basic operating principle of AMBs is very simple. A ferrous object is known to be attracted to a permanent magnet or an electromagnet (an electrical coil wound around a ferrous core).

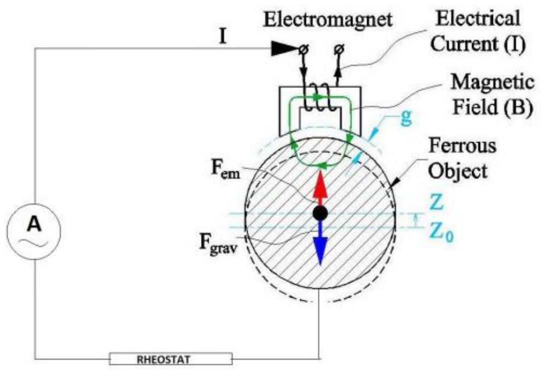

Fig. 2: Function principle of the active magnetic bearing.

The portion of an AMB that is responsible for generating electromagnetic forces is called the Electromagnetic actuator. Thus, the electromagnet shown in Fig.2 is a simple form of an electromagnetic actuator. In addition to an electromagnetic actuator, any magnetic bearing includes two other components shown in Fig.2: Rheostat and Digital Ammeter. There is one more component present in all AMBs, which is not shown in Fig.2.3 - backup bearing (also often referred to as 'catcher bearing', 'touchdown bearing' or 'auxiliary bearing').

III. CALCULATIONS

The force required for lifting the shaft should be equal and opposite to gravitational force because force acting on the shaft should overcome gravity. Weight of the shaft including rotor and lamination stacking is 0.8 kg
Hence force required equal to F=mass*gravity = 7.8 N
The cross sectional area of a pole is 400*10-6 mm2
Permeability of vacuum = μ0= 4*π*10-7 H/m
The force is given by formula,

$F = \mu_0 H^2 A_a / 2 = B_a^2 A_a / \mu_0$....... From equation (3.8)

$7.8 = B_a^2 * 400*10^{-6} / \mu_0$

$B_a^2 = 7.8*4\pi*10^{-7} / (400*10^{-6})$

$B_a^2 = 0.0256$

$B_a = 0.16$ wb/m^2

But,

$B = \mu_0 Ni / 2S_g$

Where,S_g= Air gap between stator and rotor

Therefore Ni can be calculated as

$Ni = B_a *2S_g / \mu_0$

$= 0.16 *2 *0.5*10^{-3} / 4\pi* 10^{-7}$

= 129.87 AT

i.e. 130 AT

Now, for current passing through coil(i) = 372 mA

Hence , No. of turns (N) = $130/ (372 *10^{-3}) = 349.46$

Therefore, approx.. 350 turns are wound on each pole of the bearing.

The flux passing through core is,

$\phi = B_a * A_a$

$= 0.16*400*10^{-6}$

$= 64*10^{-6}$ Wb

The inductance in the winding is,

$L = N \phi / i$

$= 350*64*10^{-6}/(372*10^{-3})$

$= 60.21$ mH

III. HARDWARE DESIGN

The ratings and specifications of 1ϕ capacitor start squirrel cage induction motor used are:

1. Output power = 40W
2. Rotational speed = 1440rpm
3. Rated current = 0.17 A
4. No. of slots on stator = 16
5. Rotor Diameter = 40 mm
6. Shaft diameter = 8 mm
7. Air gap = 0.5 mm

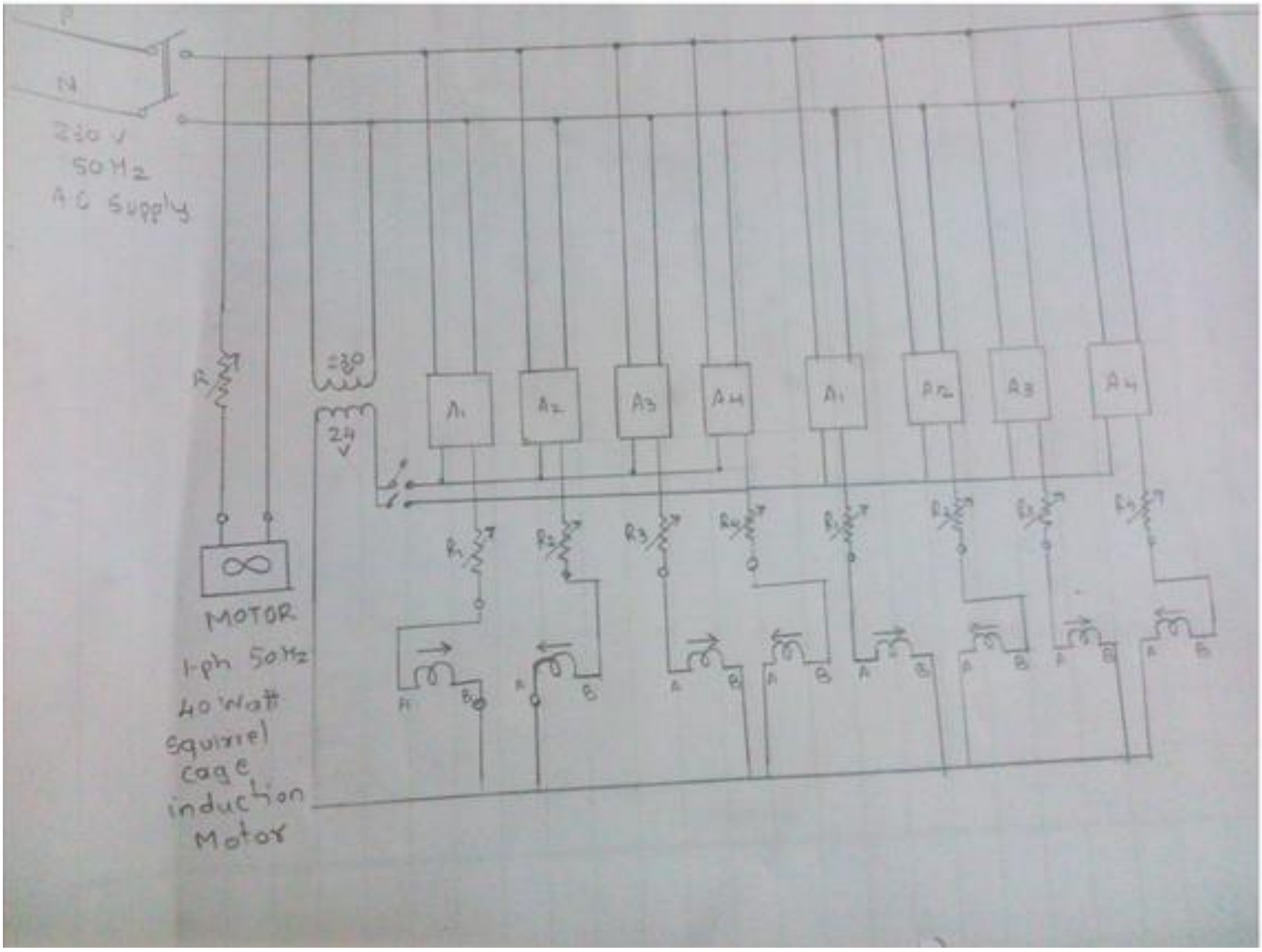

Fig. 2: Circuit Diagram

IV. TEST RESULTS

The magnetic bearings are tested for different values of coil currents.

Sr. No	Current in RH coil	Current in LH coil	Comment
1	60mA	60mA	Magnetic-field established but rotor does not levitate
2	150mA	150mA	Rotor levitates
3	250mA	250mA	Vibrations in rotor
4	372mA	372mA	Threshold current value for rotor levitation without saturation
5	390mA	390mA	Saturation will occur

V. CONCLUSION

As stated in chapter 1 (1.4) the objective of this project is to design magnetic bearings for an induction motor to eliminate friction losses and for high speed operation. To achieve this, the components employed in this project are:

- Rotor laminations
- Digital ammeters
- Rheostats
- Step down transformer

By using above components and designing magnetic bearing by studying the behavior of Ferro-magnetic material under controlled magnetic field the magnetic bearings are designed. The magnetic field is adjusted such that the rotor can completely levitate in the magnetic field without any physical contact with bearing.

The dimensions of shaft, laminations, cross section area of copper wires used for windings is decided by iterative process after several tests of the magnetic bearing. These dimensions are finalized after satisfactory working of the bearing.

The results of this project are satisfactory. The entire flow of the project can be stated as below:

- The inner diameter of the stator of magnetic bearing is decided and laminations are put on the rotor shaft so that the air gap of 0.7 mm is maintained between stator and rotor.
- A four pole stator is designed a copper windings are wound on the poles of the stator. The ends of each winding are taken out to give supply.
- Digital ammeters are employed for measurement of current and rheostats are employed for controlling the current through each coil.
- The current through each coil is adjusted such that the shaft should completely levitate in the field produced by stator.
- After suspension of the shaft the motor is started to run at high speed eliminating frictional losses.

IV. FUTURE SCOPE

The self-sensing (sensor-less) magnetic bearing is a special kind of magnetic bearing, which needs no external position sensors. The position information is deduced from the air gap dependent properties of the electromagnets. The main advantage is the reduction of the manufacturing costs. Furthermore, self-sensing bearings have a number of features that make them interesting for solving technical problems. The absence of the position sensor simplifies the construction, the assembly, and the maintenance of the magnetic bearing system. Additionally, it allows a more compact design of the rotor, which increases its natural frequencies.

Advanced applications are a challenge for actual AMB research, promising novel and attractive solutions. Examples a nuclear power plant, and for the use of high temperature superconductors. AMB's in aero-engines would lead to the futuristic all-electric, or rather oil-free, airplane. For the deep-sea exploration of natural gas, compressors will be needed that work autonomously and with minimal maintenance, and AMB equipped machinery is offering such performance.

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