Microcontroller Based Design and Analysis of Active Magnetic Bearing

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***Abstract-* Active magnetic bearing (AMB) systems can support a rotor without physical contact and enable users to precisely control rotor position and vibration as function of time. The frictionless and programmable features have made AMB suitable to meeting the demand for higher speed and high reliability of rotating machineries in many industrial application such as including power generation and energy conservation, transportation, oil and gas production to provide clean manufacturing. Active magnetic bearing system levitates the rotating shaft and maintains it in position by applying controlled electromagnetic forces on the rotor in radial and axial directions. The active magnetic bearing is the principle which is actually used most often among the magnetic suspensions. A sensor measures the displacement of the rotor from its reference position, a microcontroller as a controller derives a control signal from the measures and gives signal to a power amplifier into a control current, and the control current generates the magnetic forces within the actuating magnet in such a way that the rotor remains in its hovering position.**

***Keywords*: Active Magnetic Bearing, Position Sensor, Rotor, stator, Microcontroller, Power Amplifier.**

1. INTRODUCTION

Initially, three decades ago, active magnetic bearing (AMB) have been designed to overcome the deficiencies of conventional journal or ball bearings [1]. Mostly in research labs, they showed their ability to work in vacuum with no lubrication and free of contamination and to run at high speed, and to make novel rotor dynamics. in modern era, magnetic bearings have been introduced into the industrial world as a very valuable machine element with quite a number of novel features, and with a more range of applications. Now, exits a question about the potential of these bearings what experiences have been made as to the performance, the state of the art, what are the physical limits. In particular, there are features such as size, load, speed, losses and dynamics, temperature, stiffness,. Even such complex issues as reliability and smartness of the bearing can be seen as features, with increase in importance and growing maturity [2]. The paper will discuss key problems and give importance of AMB, pros and application examples. It will help to make design decisions, point to alternatives to classical approaches, and in the end, it might stimulate further research into promising areas.

2. PRINCIPLE AND OPERATION OF AMB

Active magnetic bearing (AMB) works on the electromagnetic suspension principles. Electromagnetic suspension is the magnetic levitation of an object achieved by constantly altering the strength of a magnetic field produced by electromagnets using a feedback loop. A charged body cannot rest in stable equilibrium when placed in a pure electrostatic field or magneto static field [4-5]. In these kinds of fields an unstable equilibrium condition may exists, also static fields may provide to fail the stability, electromagnet suspension works by continually altering the current sent to electromagnets to change the strength of the magnetic field and allows a suitable levitation to occur. In EMS a feedback loop which continuously adjusts one or more electromagnets to correct the objects motion is used to cancel the instability. A set of power amplifiers which supply current to the electromagnets, a controller and gap sensors with associated electronics to provide the feedback required to control the position of the rotor within the gap [3]. The power amplifier supplies equal bias current to two pairs of electromagnets on opposite sides of the rotor. Then constant tug-of-war is mediated by the controller which offsets the bias current by equal and opposite perturbations of current as the rotor deviates from its center position. The gap is monitored by a current sensors and sense in a differential mode. The power amplifiers operation can be achieved by pulse width modulation (PWM) technique. The controller is usually a PID controller.

3. ANALYSIS & DESIGN OF AMB PARTS

The basic AMB components are shown in the figure Electromagnets are composed of a soft magnetic core and electrical coils. They look somewhat like the stator of an electrical motor is shown in the below Fig.1.

Fig.1. the physical arrangement of Stator & Rotor of AMB.

3.1 STATOR

The stator conducts the magnetic field to the air gap. It should have high permeability as well as its magnetic saturation. The stator core consists of insulated lamination sheets in order to reduce eddy current losses.

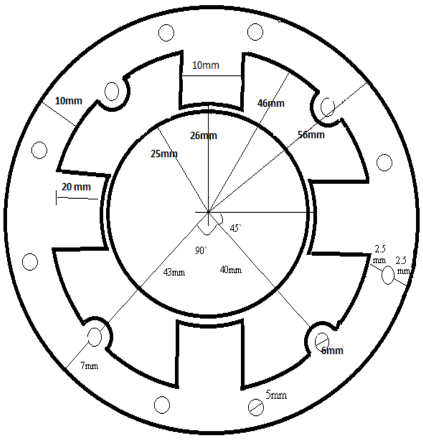

Fig.2. Design Specification of Stator of Active Magnetic bearing.

For better permeability and saturation levels the best choice for stator material will be steel sheets. Steel sheets laminations are 0.4mm-0.5mm thick the laminations have rivet holes for the assembly of poles. The above fig.2 shows the inside view of stator. The laminations are assembled on steel rods and this assembly is then passed between thick steel end plates. The rods are riveted and the rivet heads are spot welded.

3.1.1 STATOR DESIGN

Pole length = 20mm
If lamination thickness = 0.5mm, then use 40 laminations.
Material - sheet steel.
Poles = 4poles.

3.2 ROTOR

Rotor is basically constructed with a lamination packet shrinked on a nonmagnetic shaft. In order to avoid unbalances tight manufacturing tolerance are needed. In order to overcome the centrifugal stress due to high speed rotation the mechanical properties of rotor have to be good. The below fig.3 shows the design specification proposed active magnetic bearing. The rotor must possess good magnetic properties so cast iron is selected because of its high permeability, high mechanical strength and low cost. Rotor will be magnetized and pulled towards the respective poles when is displaced from its equilibrium position. Rotor size depends on the weight of the shaft.

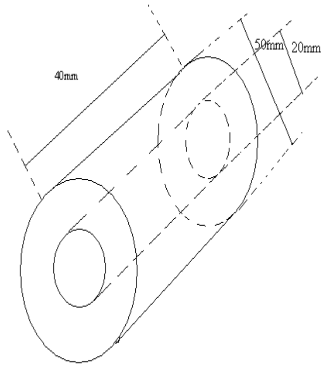

Fig.3. Design Specification of Rotor of Active Magnetic bearing.

3.2.1 DESIGN

Rotor material - Cast iron
Rotor length – Depends on the load

3.3 WINDINGS

Windings are the important part as the current through the windings is the source of magnetic field. The winding comprises of an insulated conductor wound on the soft magnetic core. The conductor has a low electrical resistance and must be wound with a high fill-factor so as to improve the efficiency of the AMB.

3.4 OUTER YOKE OF THE AMB

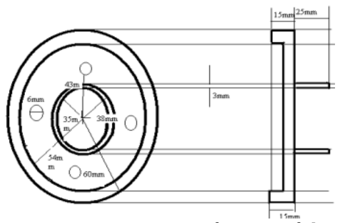

Fig.4. Outermost part specification of the AMB

The above fig.4 shows the outer most of the active magnetic bearing is called yoke and there specifications, which the yoke will provide the mechanical support to the field winding and protests against the environmental hazards; here yoke is made by cast iron which will be having low reluctance path, yoke dimensions expressed in the above clearly.

3.4 POSITION SENSORS

The fundamental principle underlying all eddy current sensing applications is electromagnetic induction. Fluctuating electromagnetic fields are created in a sample by passing an alternating current through a primary coil located near the electrically conducting test sample. The fluctuating electromagnetic fields created by the coils induce eddy currents in the test object which perturb the applied field and change the exciting coils inductance. The resulting change in the impedance of a test circuit containing the coil can then be related to the design of the coil, (i.e its size, shape and number of turns), the test frequency, and to the position, shape, magnetic permeability and electrical conductivity of the nearby test object. The impedance of the coil is only affected by local variations in permeability, conductivity and geometry, provided these occur in regions where the applied field penetrates.

In Various Applications AMBs have Position Sensors since AMBs are Actively Controlled regarding to the sensor signal, the control performance strongly depends on the sensor performance [7]. The several sensors employed in AMBs are: Inductive, Eddy Current, Capacity and Optical Displacement Sensor. Position Sensors Monitors the Radial and Axial Displacement of Rotor. The Sensor consists of sensitive elements located on the Stator and an acting element located on the Rotor in front of the sensitive element.

Fig.4. Sensor arrangement in AMB to control the position of the rotor

The above fig.4shows the sensor arrangement for controlling the position of the rotor. The various types of displacement sensors available are: Capacitive transducer, capacitive displacement sensor, Eddy-current sensor, Ultrasonic sensor, Inductive non-contact position sensor, Photodiode array, axial sensor. Eddy-current sensors are employed for greater accuracy and faster response.

3.5 CONTROLLER

A system can be operation achieved by with the help of microcontroller. The below fig.4 shows the microcontroller based circuitry assembly to control the operation of AMB. If suddenly load varies means that time there a chance of causing a more stress on particular field winding of stator that time microcontroller will get the signal from the sensor which will be placed to sense the rotor position is shown in fig.4 mean time microcontroller will gives the signals to the amplifier to increase the signal of the particular field winding and it will results in strengthen the field winding excitation and it will maintains the speed in the provided designed air gap and there will no matter of occurring the friction and all. The controlling action is achieved by either attenuating or amplifying the input signal to the plant so that the output is returned to the same point controllers provides high flexibility and high computation speed. AMBs are controlled in closed –loop. Different methods such as PD PID, optimal output feedback or observer based state

Fig.5. Microcontroller based Controlling arrangement of AMB

3.6 POWER AMPLIFIERS

The power amplifiers are employed for conversion of control signals into control currents. In the AMBs the amplifier is often the limiting component. Generally power amplifier is a kind of control constant-current

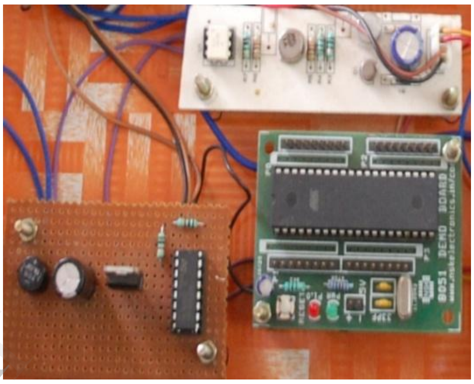

Fig.6.Power amplifier of Active magnetic Bearing.

source to the inductive reactance. Considering the losses and efficiency switch amplifier is the best. The above fig.6 shows the arrangement of power amplifier to control the field excitation. To reduce the drawbacks of switch amplifier special methods like Three-state voltage level, two H-bridge connected in series, high switch frequency of 60K Hz. The phase lag is less than three degree at 200Hz to achieve good dynamic characteristics.

The power amplifiers convert the control signals into control currents. Switching amplifiers are usually used because of their low losses. The amplifier is often the limitating component in an AMB system.

The power amplifier receives the control signal in analog voltage from the controller and keeps the current in the magnet winding according to signal of the voltage. commonly says, power amplifier is a kind of constant-current controlled source to the inductive reactance. As the power of single amplifier unit is amplifier switch is the best type considering the efficiency and losses. To reduce the drawback of switch amplifier of sharp oscillation impulsion at stable operation state, a different method is selected to realize the relative current.

4. ASSEMBLY OF MICROCONTROLLER BASED ACTIVE MAGNETIC BEARING.

In the above section we have seen that different parts of active magnetic bearing like stator, rotor and yoke design specification and also we have seen the controlling technique is achieved by using the microcontroller, position sensor, power amplifiers to activate the stator winding according sensor action, Now by using all these assembly has been done which will illustrated in the below fig.7

Fig.7 microcontroller based active magnetic bearing

5. PROS OF AMB

The factors like mechanical friction, wear and tear are completed eliminated. Alongside it does not require any lubrication. AMB supports any speed and has longer life, provides a noise-free operation. AMB is contact free hence highly efficient and the maintenance required is Very low (or) Zero.

6. APPLICATION

Microcontroller based active magnetic bearing have advantageous as it has very low and predictable friction, do not require lubrication and can operate in vacuum. It is employed in industrial machines like compressor, generator, turbine, pumps and motors. Magnetic bearing are also used in high-precision instruments and to support equipment vacuum for example in flywheel energy storage systems. Magnetic bearing are also used to support MAGLEV train in order to get low noise and smooth ride by removing the physical contact of the surfaces.

CONCLUSIONS

The state of the actual technology in design and material, and from basic physical relations. The various aspects can be summarized as the maximum load depends on design. The specific load depends on the available ferromagnetic material and its saturation properties and limited to 30 to 60N/cm^2. The unbalanced forced can be adequately controlled and it depends on the design of the power amplifier. A high speed of about 300 KHz in physical experiments. For industrial applications values of about 6 KHz have been analyzed. Supercritical speed means that one or more critical speed can be passed by the elastic rotor. It appears to be difficult to pass more than two or three. Circumferential speed, causing centrifugal load, are limited by the strength of material values of about 250 to 300m/s have been realized with actual design. The size of bearing depends on design and manufacturability. There are large bearing with dimensions and load in meters and tons. High temperature bearings have been realized, running in experiments at an operating temperature of 600 degree Celsius. For ferromagnetic material the Curie temperature would be a physical limit. These magnetic bearings at ow loss at operating speed are much smaller than the normal bearings. A high precision of the rotor position sensor are which requires very high resolution sensors and adequate signal processing to separate disturbance signal from desired ones. A very high precision ,aimed at for non rotating suspension and position serving, requires iron free magnetic path to avoid hysteresis effect and adequate sensing . The information processing within the AMB system can be used to make the rotating machinery smart. The advanced information processing within the bearing system, extending the smartness to the rotating machinery will be a promising research area.

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