CFD Simulation of Air Bearing Material

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Abstract— Geometric model and CFD simulation of Air Bearing is presented, which allows to study the nature of deformation in the bearing material. In this paper CREO 2.0 software code for geometric modeling of the air bearing. Generated geometric model was imported in the finite element software ANSYS and the CFD simulation was done to simulate the deformation under radial fluid pressure in the bearing material. Air has been used as the fluid film material and three different materials has been used for bearing material (casing). The proposed modeling and CFD simulation has given to analyze stress in the different bearing material and pressure variation in fluid film. The study will help us to analyze more complicated problem and selection of bearing material.

Key words: Air Bearing, Geometric Modeling, CFD Simulation, Orifices, Casing

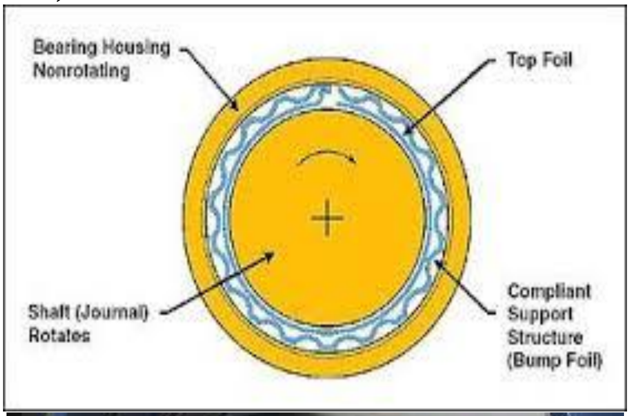
I. INTRODUCTION

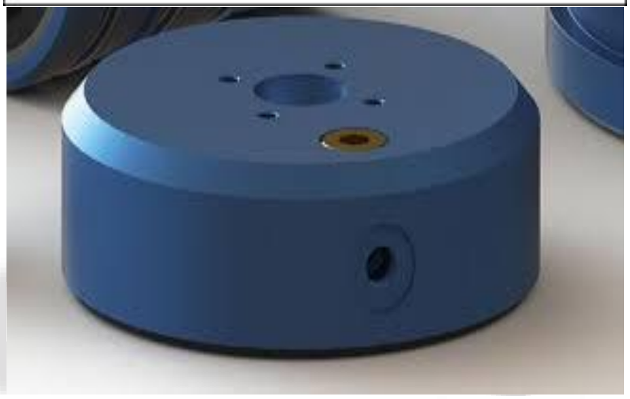
The Air float compliant air bearing supports loads on a cushion of air. It is a unique air support device, but may be compared with two other forms of air supported devices: the classical air bearing, and air cushion or “Hovercraft”.

The rigid air bearing can support large loads with small unit pressures when a film of air is forced between the support surface and the ground, but because this film is only a few thousands of an inch thick, a very smooth and very flat surface is required.

Unlike contact roller bearings, air bearings utilize a thin film of pressurized air to provide a ‘zero friction’ load bearing interface between surfaces that would otherwise be in contact with each other. Being non-contact, air bearings avoid the traditional bearing-related problems of friction, wear, and lubricant handling, and offer distinct advantages in precision positioning and high speed applications.

The fluid film of the bearing is achieved by supplying a flow of air through the bearing face and into the bearing gap. This is typically accomplished through an orifice or a porous media that restricts or meters the flow of air into the gap. The restriction is designed such that, although the air is constantly escaping from the bearing gap, the flow of pressurized air through the restriction is sufficient to match the flow through the gap. It is the restriction through the gap that maintains the pressure under the bearing and supports the working load. If air pressure were introduced to the gap without restriction, the flying height would be higher, the air consumption higher, and the stiffness would be lower than could be achieved with proper restriction. This restriction is referred to as air bearing compensation. It is used to optimize the bearing with respect to lift, load, and stiffness for particular applications and will be discussed later in more detail.





There are two main kinds of air bearing:

A. Aerostatic:

- Externally pressurized: A separate external supply of air is fed under pressure between the two surfaces being kept apart. It is a continuous flow system where pressurized gas from the source flows through restrictors into the clearance between the bearing surfaces escaping to the atmosphere at the outside edges of the bearing.
- Types: Simple orifice fed, Pocketed orifice, Slot fed and Porous.

B. Aerodynamic:

- Self-generating: The supporting film is generated by the relative motion of the two surfaces being kept apart.
- An aerodynamic bearing can be of several types. The design characteristics differ greatly between journal and axial bearings and they can suffer problems of instability.
- Types: Simple cylinders, Tri-lobe, Grooved (axial/ herringbone/ spiral) and Stepped.

C. Advantages

- Wear less operation, durability
- Guiding, repeatability, and position accuracy
- Cost advantage and repeatability
- High-purity, oil-less operation

– Environmental advantages

Air bearings are composed of a cylindrical shaft of radius R, called a journal, rotating with an angular velocity, ω, about its axis in a cylindrical bushing of radius R+c and length L. The center of the bearing is labelled as O_b and the center of journal as O_j as shown in figure 1.1. Under steady state conditions the journal center remains at a constant eccentricity e and attitude angle Φ for a given load W acting on the shaft (Allaire et al. (1975), Allaire et al. (1980)). The air journal bearing is the simplest and most common radial bearing, where a plain cylindrical shell encircles the shaft. Plain sleeve bearings have the highest cross coupling of all bearings and are suitable for highly loaded or low-speed shafts. Advantages are low cost and ease of manufacture. Examples include automotive crankshaft bearings and low-speed or highly loaded turbo machinery applications.

Air bearings may be further classified as central or eccentrically loaded depending upon whether the load line bisects the bearing pad arc or divides it eccentrically. Typically the radius of the bearing is greater than the radius of the journal by an amount equal to the radial clearance. When the load applied is primarily unidirectional, there is no need of full journal bearings and instead a single partial arc bearing may be used (Allaire, 1987). Partial arc bearings are used in relatively low speed applications. The air may also be designed with a hydrostatic recess thus enabling fluid film lubrication due to both hydrostatic and hydrodynamic effects. air bearings are important because they form the building blocks for axial groove, multi-lobe and tilting pad bearings.

II. Problem Formulation

In comparison with the theoretical analyses of air bearing material in this paper geometrical modal is prepared and is CFD simulation is done and earlier it has been seen that theoretical approach was not so accurate as well as it's laborious so in this experiment geometrical model is prepared in cre-o 2.0 and it's simulation and analysis is done in ANSYS 14.5 and it's solution is obtained and there results are compared and pressure variation in final film is investigated.

III. Geometric Modeling

In this section CREO 2.0 software code for geometric modelling of the air bearing is used. The generation of a computer geometric model for air film and bearing casing is created.

We have created individual geometric models for air film, bearing casing and shaft. The geometric model of air film as illustrated in (Fig. 3.1) having effective thickness 0.25 mm. Diameter of air film is 139.5 mm and height of air film is 35 mm.

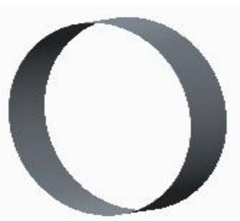


Fig. 3.1 Single Helix Wire

Diameter of bearing casing is 140 mm. The geometric model of bearing casing is illustrated in (Fig. 3.2) having thickness of 10 mm and height of bearing casing is 35 mm.

Fig. 3.2 Helix Wire with Straight Core

Diameter of shaft is 139.5 mm. The geometric model of shaft is illustrated in (Fig. 3.3).

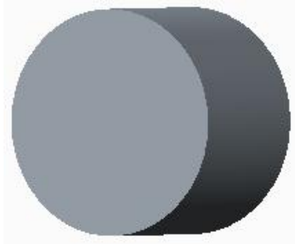


Fig. 3.3 Top view of single strand wire rope

Overall assembly is illustrated in (Fig. 3.4).

Fig. 3.4 Geometrical model of single strand wire rope

IV. Finite Element Analysis

The geometric model of the air bearing created in CREO 2.0 was further imported in the finite element software ANSYS 14.5, which was used for its finite element numerical analysis. Finite element analysis is applied to simulate the stress and deformation in the bearing material and to find out the pressure variation in the air film. CFD solver was used for this process.

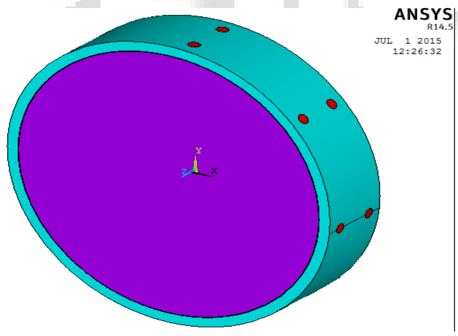


Fig. 4.1 Geometrical model for air bearing imported in ANSYS

V. Material Properties

The three different bearing material i.e. Cast iron, brass & aluminium in which steel material is used as jounral. Mechanical Property of the Cast iron, model having modulus of elasticity E = 110 Gpa, the density is ρ = 7200 kg/m^3 and the Poisson's ratio is υ = 0.28. Mechanical Property of the Aluminium, model having modulus of elasticity E = 71 Gpa, the density is ρ = 2770 kg/m^3 and the Poisson's ratio is υ = 0.33. Mechanical Property of the Brass, model having modulus of elasticity E = 97 Gpa, the density is ρ = 8490 kg/m^3 and the Poisson's ratio is υ = 0.31. The jouranal is made up of steel for which mechanical properties are, modulus of elasticity E = 205 Gpa, the density is ρ = 7850 kg/m^3 and the Poisson's ratio is υ = .30.

VI. MESH CONTROL

Meshing in ANSYS Workbench is to provide robust, easy to use meshing tools that will simplify the mesh generation process. The meshed model has total number of nodes 24338, solid elements 120362 and element size 2.e-003 m for model. The meshed model is shown in Fig. 5.1

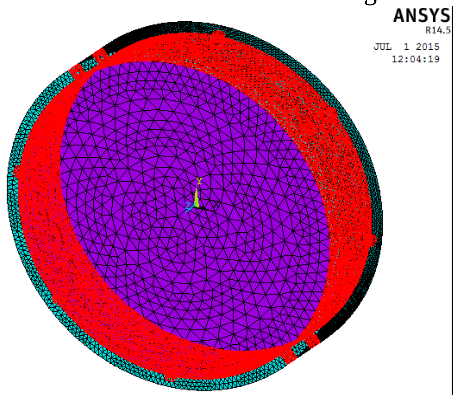


Fig 5.1: Meshing done for the model

VII. BOUNDARY CONDITIONS

In this analysis, we have 8 orfices in bearing through which air is inlet at .7 Mpa and form a thin layer between shat and bearing casing and this pressurized air form a thin layer and which will avoid the contact between the bearing and shaft and shaft will continuously rotate at 30000 rpm and the weight of the shaft will act.

VIII. RESULT AND DISCUSSION

Resultant deformations, stresses in the bearing materials for the model are obtained when the shaft is rotating at the constant speed of 30000 rpm are shown in Figs.

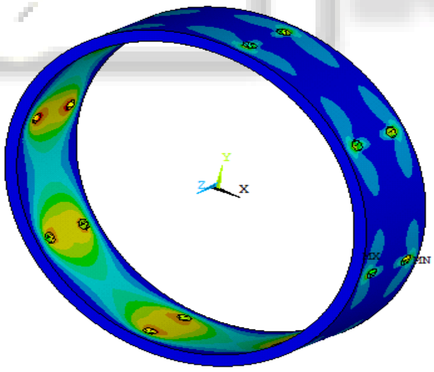


Fig. 5.2 Deformation obtained in aluminium model.

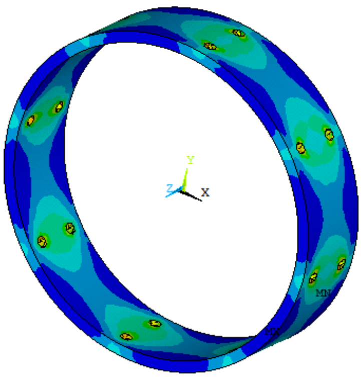


Fig. 5.3 Stress obtained in aluminium model.

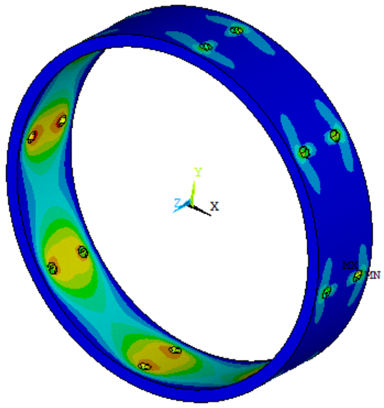


Fig. 5.4 Deformation obtained in cast iron model.

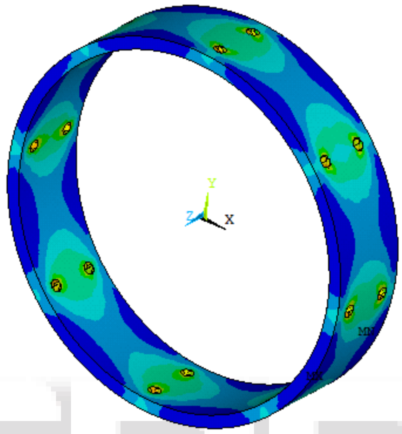


Fig. 5.5 Stress obtained in cast iron model.

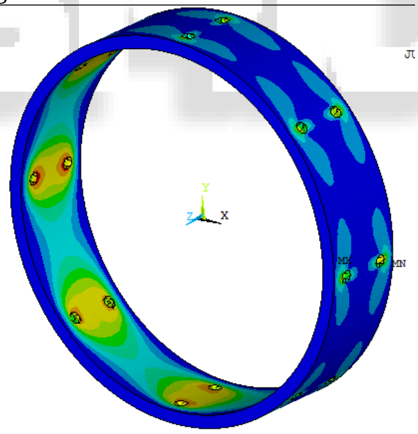


Fig. 5.6 Deformation obtained in Brass model.

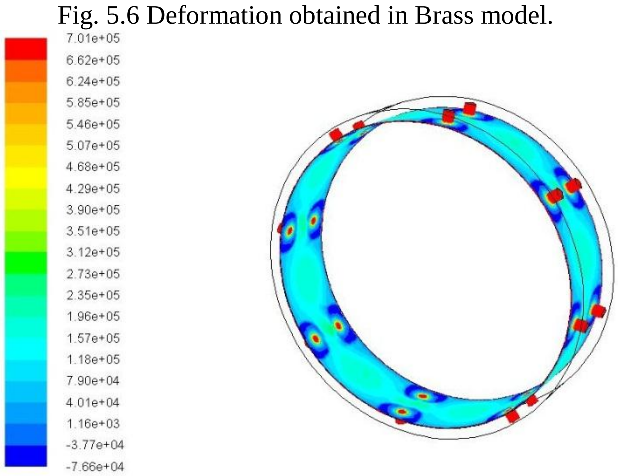


Fig. 5.7 Pressure distribution in air bearing

Resultant deformations and stress for the various materials of the bearing modal at the shaft rpm with the corresponding air inlet pressure are shown in Table-1.

Bearing Material	Shaft rpm	Air inlet pressure (Mpa)	Total deformat i-on (mm)	Von-mises stress (Mpa)	weight (kg)
Aluminum	30000	0.7	2.81E-05	0.5831	0.216
cast iron	30000	0.7	2.03E-05	0.65447	0.562
Brass	30000	0.7	1.77E-05	0.567557	0.672

Table 1: Air Inlet Pressure

IX. CONCLUSION

In this paper geometric model of the Air bearing is presented. A finite element analysis with CFD solver is used in the model for finding stress in different bearing material i.e. cast iron; aluminum & brass and condition is when spindle is rotating at 30000 rpm and air is inlet with through orifices. It is observed that the deformation obtained at various point in the bearing is directly proportional to stress generated and bearing material properties. It also depends upon the rotation of the spindle and various loading condition as well as geometrical parameters of the bearing material.

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