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Introduction and Parametric Analysis of Air Bearings

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Abstract: Bearing technology represents one of the age old challenges for mechanical engineers. Plain bearings and rolling bearings have been pushed to their limits in applications like electric motors and high resolution scanning respectively. Hence air bearings represent the next logical step in bearing design. Unlike contact bearings, air bearings utilize a thin film of pressurized air to provide 'zero friction' load bearing interface between surfaces. Air bearings have many technical advantages like high precision, high stiffness, no lubrication and negligible wear and tear. This seminar focuses on parametric analysis of these air bearings, their types, properties, performance parameters. From the previously obtained results and trends it is observed that load carrying capacity increases with increase in orifice diameter i.e. higher mass flow rate and also it increases with increase in supply pressure. This paper deals with giving an introduction of the air bearings to the world, telling their advantages and encouraging their use.

Keywords: Introduction, Types, Aerostatic Bearings, Material, Parametric Analysis, Applications.

I. INTRODUCTION

Bearing design is always a challenge for mechanical engineers. A revolutionary improvement over the plain bearings were the rolling contact bearings, where the former had been pushed to their limits in applications like electric motors and automobile wheels. Similarly, the rolling element bearings are being pushed to their technical limits by the demands of applications like semiconductor manufacturing, high resolution scanning, and high-speed machinery in today's world. Hence Air bearings represent the next logical step in bearing designs. For the past 20 years air bearings have a proven track record in co-ordinate measuring devices. The many technical advantages of air bearings such as negligible friction and wear, high speed and high precision capabilities, and no oil lubrication requirements are powerful advantages for today's machine designers. However, these advantages have not been more fully exploited to date because air bearings are tough to manufacture and they have not been commercially presented until recently. A frictionless interface between two surfaces is provided by a thin film of pressurized air in these bearings.

Some Applications of air bearings are semiconductor wafer-processing machines, precision machine tools, and other clean-room, high-speed, and precision positioning environments. Clear advantage is provide by the non-contact principle of the air bearings over traditional bearings since problems such as wear are eliminated, as the two surfaces are separated by thin film of air. The two types of air bearing systems are: aerostatic and aerodynamic systems. Air bearing technology bids actual benefits to applications where the demand for correctness, speed and consistency is critical. The performance of air bearing technology repeatedly exceeds the parameters offered by conventional bearing systems, with speeds ranging from 0 to 300,000 rpm, powers range from 10w to 30kw, load capacities of up to 150 kg radial and 500 kg axial, and bearing stiffnesses of up to 12kg/μm radial and 50 kg/μm axial.

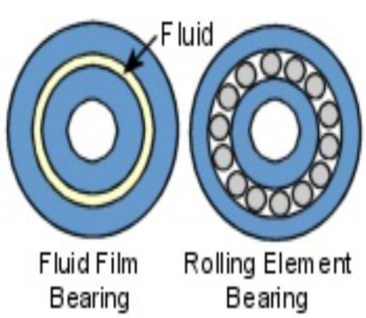

Fig 1: Contact surfaces

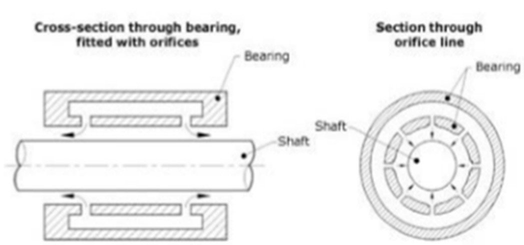

Fig 2: Air-bearing

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II. AIR BEARING

Air bearings use a thin film of pressurized air to provide almost negligibly low friction load-bearing interface between surfaces. The two surfaces don't touch. Being contact-free, air bearings avoid the customary problem of friction, wear, particulates, and lubricant handling, and provide distinctive advantages in precision positioning, such as lacking backlash and static friction, as well as in high speed applications. The fluid film of the bearing is the air that flows through the bearing itself to the bearing surface. The design of the air bearing is such that, although the air constantly escapes from the bearing gap, the pressure between the faces of the bearing is enough to support the working loads. Thus, there is a differentiation that has to be made between Aerodynamic bearings, which establish the air cushion through their movement, and Aerostatic bearings, in which the pressure is being externally supplied.

III. TYPES OF AIR-BEARINGS

There are basically two types of air bearings based on their working methods. They are-

A. Aerostatic Bearings

An externally pressurized air source is required by the aerostatic bearings. This pressurized air is introduced between the bearing surfaces by precision holes, grooves, steps or porous compensation techniques. In aerostatic bearings pressurized air is fed externally, hence they are able to maintain the air gap even if relative motion between the bearing surfaces is absent. Where high-performance and high accuracy is necessary the usage of air bearings is the best solution.

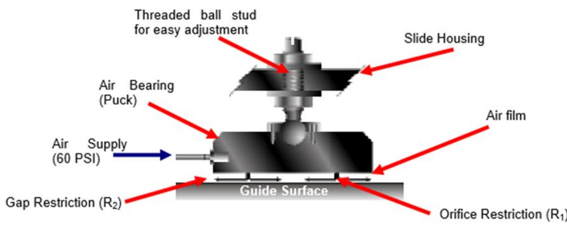

Fig 3: Aerostatic bearing

B. Aerodynamic Bearings

The operation of Aerodynamic bearings depend on relative motion between the bearing surfaces and usually some type of spiral grooves or geometrical construction to draw the air in between the bearing lands. When there is no motion or when the motion is not fast enough to generate the air film the bearing surfaces will come into contact. Hence these bearing support zero load at stationary position. Aerodynamic bearings are often stated to as foil bearings or self-acting bearings.

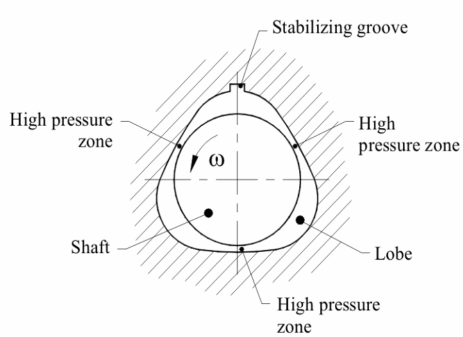

Fig 4: Aerodynamic Bearing

IV. MATERIAL SELECTION

The bearing materials should have the following properties.

A. Corrosion resistance
B. Machinability
C. Material stability
D. Thermal conductivity

E. Thermal expansion

Lead bronze is best suited as the bushing material for the bearing. It is corrosion resistant, can be easily machined and soldered or brazed so that the pressure tight fixing of several feed jets is a relatively a simpler procedure. They can be readily used in combination with austenitic stainless steel body material. In order to manufacture air bearing surface geometries to sub-micron accuracy, rigid metals, ceramics or other similar materials often comprise the housing and/or static components. Additionally, long-term stability of the material is an unconditional requirement if the target is to achieve high repeatability.

V. PARAMETRIC ANALYSIS OF AEROSTATIC BEARINGS

So for the analysis purpose we consider an aerostatic air bearing. The basic properties of aerostatic bearings on which its performance depends are:

A. Load Carrying Capacity
B. Mass Flow Rate
C. Pressure Distribution
D. Stiffness

For any application it is necessary to know how these properties depend upon bearing parameters like:

A. Bearing Dimensions
B. No of Orifices and orifice Diameter
C. Permeability Coefficient of Porous Materials
D. Supply pressure

And hence it is crucial to plot the trends of these properties with reference to bearing parameters.

VI. TRENDS OBSERVED

In this section, effect of change in supply pressure, orifice diameter and number of orifices on the dynamic properties of an aerostatic air bearing like load carrying capacity, mass flow rate and pressure distribution are observed. These trends play a decisive role in selection of air bearings.

A. Load Carrying Capacity

Load carrying capacity is given by the ability to withstand the forces applied to the shaft produced by pressure distribution between the bearings and the shaft. Load carrying capacity can be increased by using high value of orifice diameter or more no. of orifices. Load carrying capacity can also be increased with higher mass flow rate. Load capacity and stiffness can be improved with high supply pressure, high L/D ratio .Higher the value of clearance, lower is the load bearing capacity.

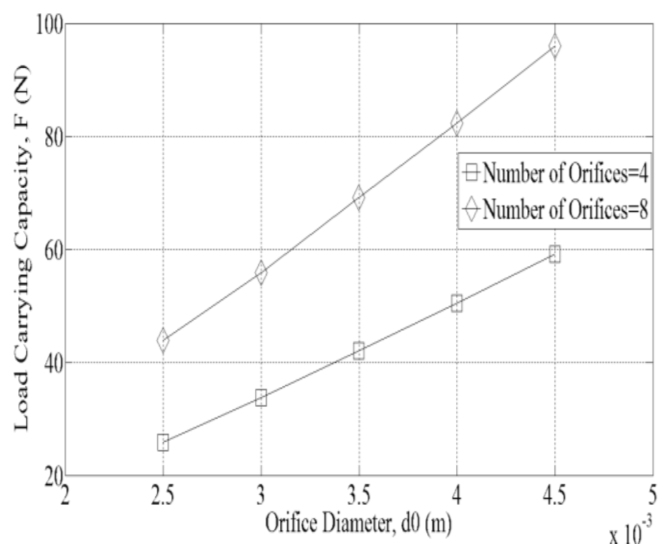

Fig 4: Load carrying capacity vs. orifice diameter for different number of orifice (Ps=2 atm and c=125 μm)

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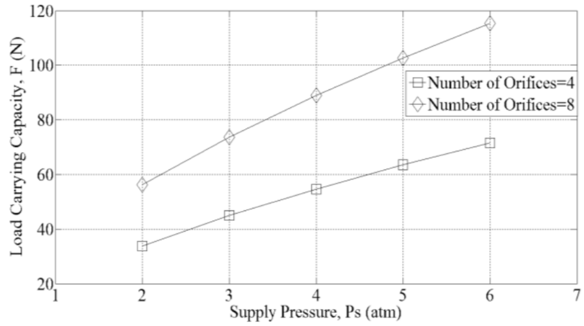

Fig 6: Load carrying capacity vs. supply pressure for different number of orifices (d0=0.003 m and c=125 µm)

B. Mass Flow Rate

Mass flow rate is a function of orifice diameter and clearance. Mass flow rate increases with increasing orifice diameter and this also affects the pressure distribution. Mass flow rate increases with increasing supply pressure.

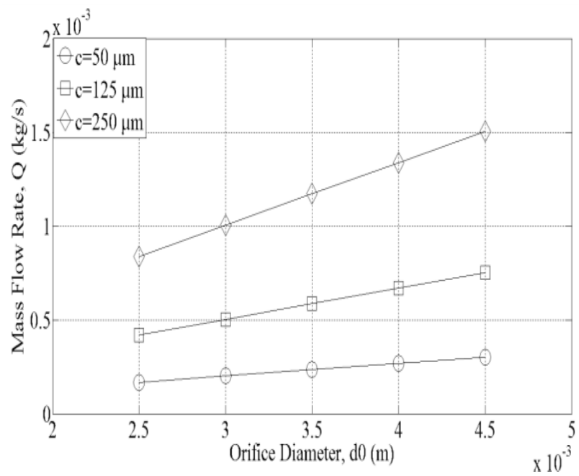

Fig 7: Mass flow rate vs. orifice diameter for different radial clearance respectively 50 µm, 125 µm and 250 µm, (Ps=2 atm)

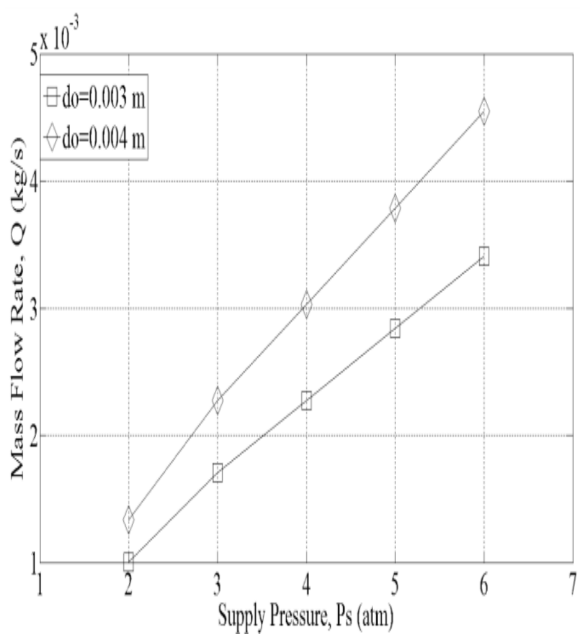

Fig 8: Mass flow rate vs. supply pressure for different orifice diameter (Ps=2 atm and c=125 µm)

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C. Pressure Distribution

Pressure value decreases as radial clearance is increased, because the gap volume increases for the same mass flow rate.

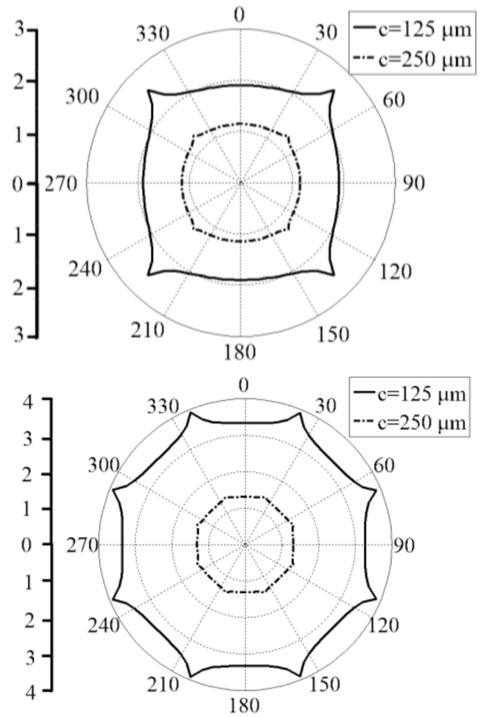

Fig 9: Pressure distribution at 2 atm, ε= 0 and do=0.003 m a. 4 orifice b. 8 orifice

VII. ADVANTAGES OF AIR-BEARINGS

The air bearings have the following advantages

A. Greater precision
B. High speed (0-350,000rpm
C. Self-centerin
D. Improved surface finis
E. Long bearing life
F. Lower thermal growth
G. Lack of maintenance
H. Large load carrying capacity
I. Reduced vibratio
J. Cleanliness

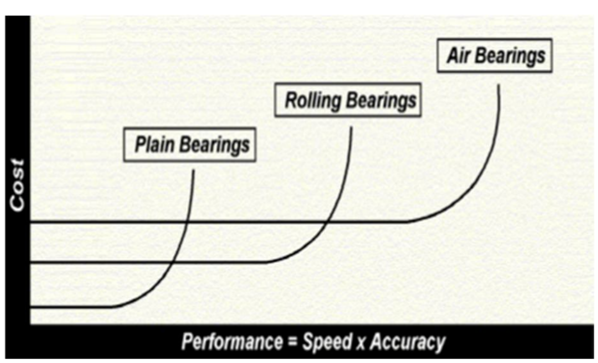

Fig 10: Cost Vs. Performance graph

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VIII. LIMITATIONS OF AIR-BEARINGS

Along with the various advantages of the air-bearings, they do have some disadvantages. They are as follows-

A. High manufacturing cost
B. Highly precise construction
C. Added operating costs
D. Lower stiffness than rolling element bearings.
E. Phenomenon of pneumatic hammer (Aerostatic bearings)

IX. APPLICATIONS OF AIR-BEARINGS

Air Bearings are used in a variety of applications including: Coordinate Measuring Machines, Precision Machine Tools, Semiconductor Wafer Processing, Medical Machines, Optical Lens Production Equipment, Digital Printers, Lithography Precision Gauging, Diamond Turning Machines, Materials Testing Machines, Crystal Pulling, Rotary Tables, Spindles, and Friction Testing. Also Hyperloop, the fifth mode of transport, uses air bearing suspension system. Machine spindles also use air bearings for high speed rotation and accuracy. Air bearings also find their application in HDD drives to absorb operational shocks.

Fig 51: Applications

X. CONCLUSION

It is observed that the Load Carrying capacity increases with supply pressure, number of orifices and orifice diameter

Thus from this we can conclude that Load carrying capacity is a direct measure of the Bearing Stiffness and hence selection of bearing dimensions and working parameters directly affect dynamic properties of the Air Bearing.

Studying the various advantages and applications of the air bearings we conclude that the future of bearing technology is air bearings. Air bearings have found their use primarily where it is mandatory to negate friction and provide zero contamination. Various companies and research labs have started their work to implement air bearings in their processes.

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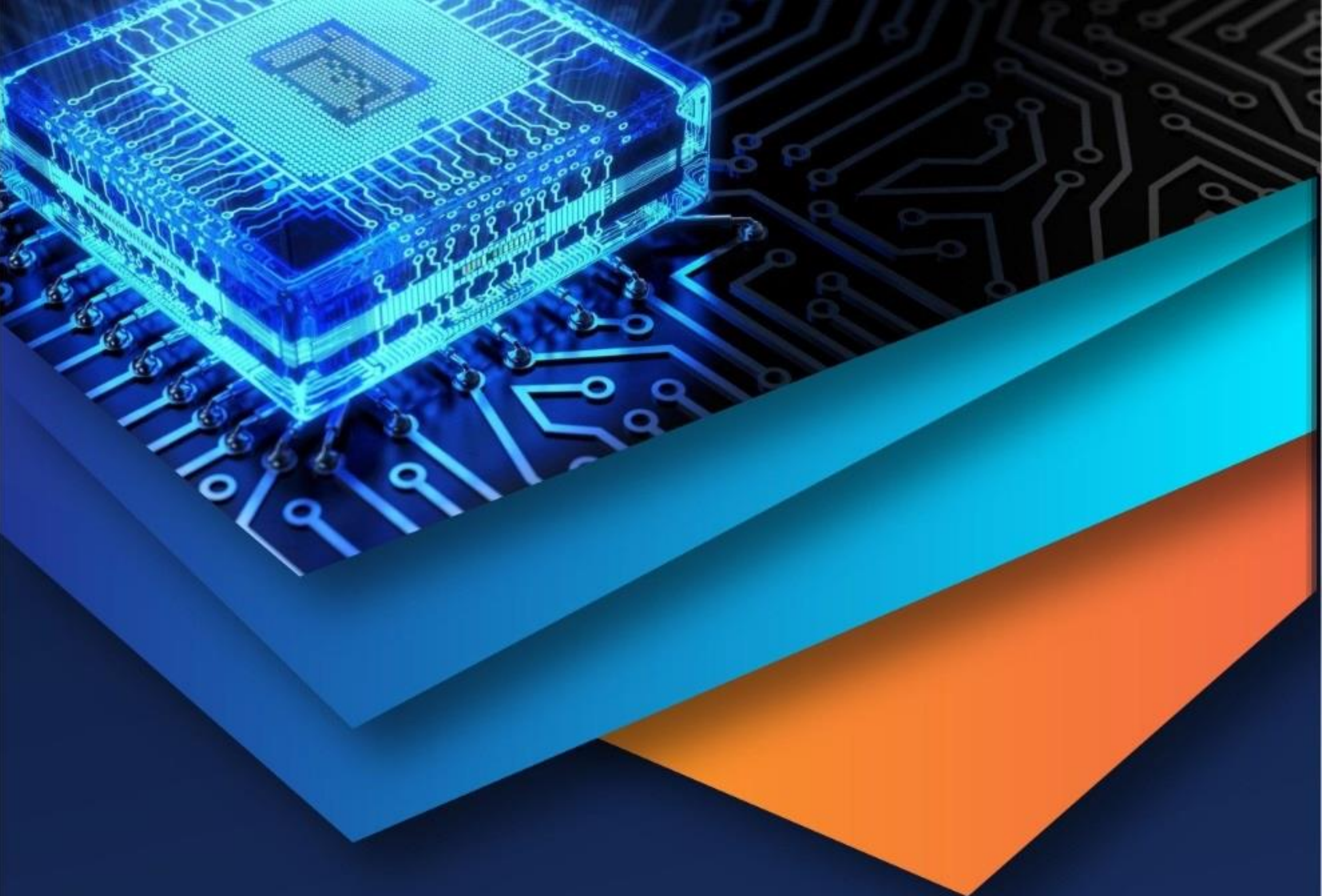

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