Foil Bearing Technology

Aditya P. Choure

NBN Sinhgad School of Engineering, Department of Mechanical engineering, Ambegaon bk, Pune, India

Abstract— *This paper introduces air bearings. High-speed air bearings offer very specific advantages over other, more conventional bearing technologies. The reason use of air bearing air bearings as it avoid the traditional bearing-related problems of friction, wear, and lubricant handling, and offer distinct advantages in precision positioning and high speed applications. The use of air bearings means tool life can be greatly extended. Air bearings provide extreme radial and axial rotational precision. The factors affecting the performance of the air bearing like friction, wear, stiffness, load capacity. This paper also introduces with the types of air bearing. New air bearing products like flat bearing, air bushing, vacuum preloaded bearings, air bearing slides, radial bearing and its applications in various fields. It also discuss about the advantages and disadvantages of air bearings.*

Keywords— Air bearing, friction, load capacity, stiffness, wear.

I. INTRODUCTION

Rolling element bearings are today being pushed to their technical limits by the demands of applications like semiconductor manufacturing, high resolution scanning, and high-speed machinery. Air bearings represent the next logical step in bearing design. [1] Air bearings in general have a proven track record having been employed in coordinate measuring machines for 20 years. The many technical advantages of air bearings such as near zero friction and wear, high speed and high precision capabilities, and no oil lubrication requirements are powerful advantages for today's machine designers. However, these benefits have not been more fully utilized to date because air bearings are difficult to manufacture and they have not been commercially available until recently. Air bearings was founded ten years ago to pioneer the use of porous media technology and make air bearings that are robust, simple to use, inexpensive, and available off-the-shelf. [2]

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. [10]

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, referred to in Figure 2 as R1. 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, R2 that maintains the pressure under the bearing and supports the working load. [2] If air pressure were introduced to the gap without restriction (R1), 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. [4]

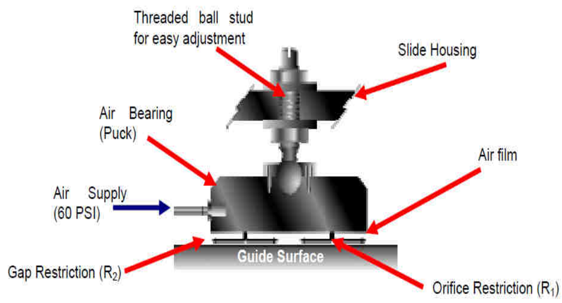

Fig.1: Flat Air bearing

II. TYPES OF AIR BEARING TECHNOLOGY

There are two basic types of precision air bearings: aerodynamic bearings and aerostatic bearings:

2.1 Aerodynamic Bearing

Aerodynamic bearings depend on relative motion between the bearing surfaces and usually some type of spiral grooves to draw the air between the bearing lands. This bearing action is very similar to hydroplaning in your automobile on a puddle of water at high speed. At a lower speed your tire would cut through the water to the road. In just this way, aerodynamic bearings require relative motion between the surfaces, 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. [2] Aerodynamic bearings are often referred to as foil bearings or self-acting bearings. Examples of this type of bearing include the read-write head flying over a spinning disk, crankshaft journals, camshaft journals, and thrust bearings for electrical generator turbines. [3]

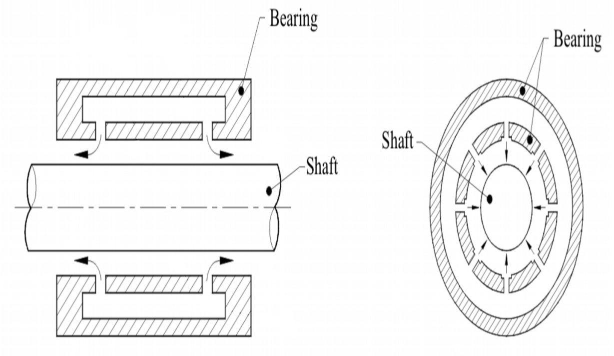

Fig.2: Sectional view of Aerodynamic bearing

2.2 Aerostatic Bearing

Aerostatic bearings require an external pressurized air source. This air pressure is introduced between the bearing surfaces by precision holes, grooves, steps or porous compensation techniques. Because aerostatic bearings have a pressurized air source they can maintain an air gap in the absence of relative motion between the bearing surfaces. [1][6]

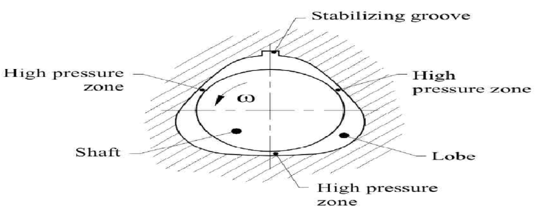

Fig. 3: Tri-lobed Aerostatic bearing

III. PROPERTIES OF AIR BEARING TECHNOLOGY

There are 4 major properties of air bearing technology:

3.1 Friction

In air bearings there is no difference between static and dynamic coefficients of friction so the stick-slip issue is completely eliminated. Friction in air bearings is a function of air shear from motion, so at zero velocity there would be zero friction making infinite motion resolution theoretically possible. [5]

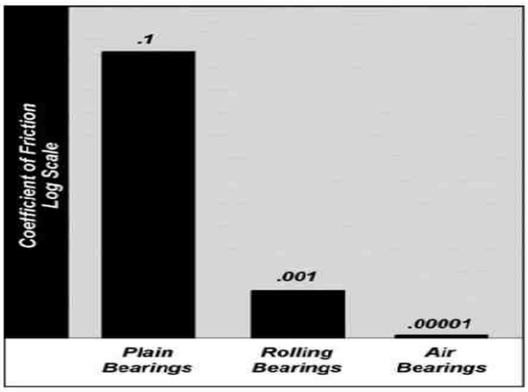

Fig: 4- Coefficients of friction

3.2 Wear

The problem of wear due to speed, acceleration, and loading are avoided due to non contact nature and these parameters have no influence on the life of the air bearing. [1]

The mode of wear in an air bearing is erosion, so the cleanliness of the air has the greatest effect. This is a big advantage when it comes to machine reliability. The lack of debris from wear and no need for oil lubrication due to the noncontact nature of air bearings also means that they are ideally suited for use in clean room, medical, pharmaceutical, and food processing environments. [3] Air bearings also excel in dry dusty environments such as salt or sugar factories, which can be highly corrosive. In these environments any oil lubrication quickly becomes lapping slurry. Air bearings have a self-purging effect with constant air exiting the bearing blowing away light dry dust.

3.3 Stiffness

Pressure and surface area both affect stiffness proportionately, but the most significant factor in air bearing stiffness is the idea and use of compensation. [1]

Compensation is a way of controlling the flow of air into the air gap and is the true key to air bearing stiffness. The object of compensation is to create a restriction of the airflow into the gap before the restriction of the gap itself. The air gap must be a restriction otherwise the pressure would not remain under the bearing and it would instead equalize with the ambient pressure. [7]

3.4 Load Capacity

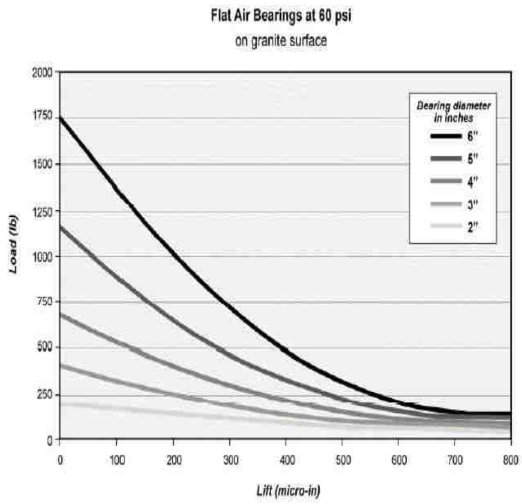

Fig. 5: Lifts and Loads

The load capacity of air bearings is limited compared to rolling element bearings; they carry the same load per unit area as traditional plain bearings for machine tools. This is usually more than sufficient for today's high-speed, lightweight machine applications. [4]

Surface area x input pressure = grounding force

Surface area x input pressure x efficiency = load capacity

IV. APPLICATIONS

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. [6][9]

V. ADVANTAGES

5.1 Greater precision
5.2 Increased tool life
5.3 Improved surface finish
5.4 Long bearing life
5.5 Low thermal growth
5.6 Lack of maintenance
5.7 Large load capacity
5.8 Reduced vibration
5.9 Cleanliness

VI. DISADVANTAGES

Air bearings only have a few disadvantages. The main challenging issues are the high geometrical accuracies which are required during manufacture. Another issue is the supplied pressurized air which has to be clean and dry. Fundamentally air bearings require some form of power consumption during operation to supply the high pressure air, unlike mechanical systems which may operate without any power input (except mechanical forces)[11].

VII. CONCLUSIONS

Foil bearings have been extremely successful for air cycle machines. They have increased the reliability of these machines up to tenfold. [7] Even though several machines have been built for other applications, the work has not been pursued by the same vigor and commitment for various reasons. Their low cost, oil free operation, resistance to abrasion and contact free operation etc have increased its potential to be used in various applications. [5][8]

VIII. FUTURE SCOPE

8.1 Future Vehicles can be designed using this technology.
8.2 It can be used for semiconductors manufacturing.
8.3 It can be used in aerospace application
8.4 It can be used in design of machine tools.
8.5 High speed machinery.
8.6 Escalators can be built using air bearing technology.
8.7 High resolution scanning

REFERENCES

[1] J. Peirs et al., Development of a gas turbine generator with a 20 mm rotor, Technical Digest PowerMEMS 2007 (Freiburg, Germany, 28–29 November 2007), 355-358.
[2] K. Liu, T. Waumans, J. Peirs, D. Reynaerts, High precision manufacturing of an ultra miniature ceramic gas turbine impeller, Technical Digest Power MEMS 2008 (Sendai, Japan, 9-12 november 2008).
[3] J. Peirs, T. Waumans, T. Verstraeten, K. Liu, D. Reynaerts, R. Van den Braembussche, Measurement of compressor and turbine maps for an ultra-miniature gas turbine, Technical Digest Power MEMS 2008.
[4] T. Waumans, P. Vleugels, J. Peirs, F. Al-Bender, and D. Reynaerts, Rotordynamic behaviour of a micro-turbine rotor on air bearings: modelling techniques and experimental verification, Proceedings of the International Conference on Noise and Vibration Engineering (September 18- 20, 2006, Leuven, Belgium), pp. 181-197.
[5] T. Waumans, F. Al-Bender, and D. Reynaerts, A semi-analytical method for the solution of entrance flow effects in inherently restricted aerostatic bearings, Proceedings of GT2008 ASME Turbo Expo 2008: Power for Land, Sea and Air (June 9-13, 2008, Berlin, Germany), GT2008-5049.
[6] Blok, H., and vanRossum, J. J., 1953, ‘‘The Foil Bearing-A New Departure in Hydrodynamic Lubrication,’’ ASLE J. Lubr. Eng., 9, pp. 316–330.
[7] Ma, J. T. S., 1965, ‘‘an Investigation of Self-Acting Foil Bearings,’’ASME J. Basic Eng., 87, pp. 837–846.
[8] Barnett, M. A., and Silver, A., 1970, ‘‘Application of Air Bearings to High Speed Turbo machinery,’’ SAE Paper 700720.
[9] Gross, W. A., 1962, Gas Film Lubrication, John Wiley and Sons, Inc. Heshmat, H., Shapiro, W., and Gray, S., 1982, ‘‘Development of Foil Journal Bearings for High Load Capacity and High Speed Whirl Stability,’’ ASME J. Lubr. Technology.
[10] DellaCorte, C., and Wood, J. C., 1994, ‘‘High Temperature Solid Lubricant Materials for Heavy Duty and Advanced Heat Engines,’’ NASA TM-106570.
[11] Wagner, R. C., and Sliney, H. E., 1986, ‘‘Effects of Silver and Group II Fluorides Addition to Plasma Sprayed Chromium Carbide High Temperature Solid Lubricant for Foil Gas Bearings to 650°C,’’ ASLE Lubr. Eng., 10, pp. 594–600.