AIR BEARINGS

Author: Anuj Sharma (Engine cadet)
AMET University, 135 East coast road, Kanathur, Chennai-603112, Tamilnadu
Email: anuj_sw@yahoo.co.in, Mob. - 9003062506

Abstract

This paper consists of a detailed description on the invention of air bearings. Air bearing can be defined as lifting the load using pressurized air instead of conventional method, lube oil. What leads to switch over from oil to air is mentioned in paper. The author through this paper throws light on the ***classification, working principle, application and merits of air bearings***. How the pressure is actually generated and pressurized air is fed in bearings using various feed devices is illustrated.

In this paper an attempt has been made on reducing ***frictional losses*** due to ***relative motion*** of components involved. The working of air bearings has been mentioned and how the load of the crankshaft in internal combustion engines and air compressors can be supported by ***thin film of pressurized air***. The paper illustrates how the crankshaft can be lifted using pressurized air and how the shortcomings can be overcome using ***air casters***. The paper consists of various illustrations on air bearings.

Keywords: Frictionless bearings, negligible viscosity, aerostatic bearings, feed devices, air casters, foil.

1. INTRODUCTION

Modern industrial approach is towards substantial growth and any hindrance to growth is unacceptable.

Science has reached so far that even if we try to trace back to know from where we started, we won't be able to find and where the end lies who knows. Every single day is the witness of development in science. One of the development of today's world is the invention of air bearings [7]. As mentioned earlier everything is trying to be more efficient by utilizing the resources in best possible way and without any loss in power. Air bearing is the recent development in bearings and can be stated as "frictionless bearings".

2. CLASSIFICATION

2.1. Bearings can be classified as mechanical bearings and fluid film bearings. Mechanical bearings can be classified as ball and roller bearings. Taking friction and load into consideration, ball bearings have point contact and roller bearings have line contact. Therefore roller bearings are capable to withstand more load than ball bearings but the friction provided is less in case of ball bearings.

2.2. In oil bearings, a film of oil with certain value of viscosity makes contact with bearing and shaft [2], whereas in air bearings a thin film of pressurized air (having negligible viscosity) supports load of shaft, with no solid to solid contact resulting in zero friction. But oil bearings have more load capacity.

3. WHY TO USE AIR??

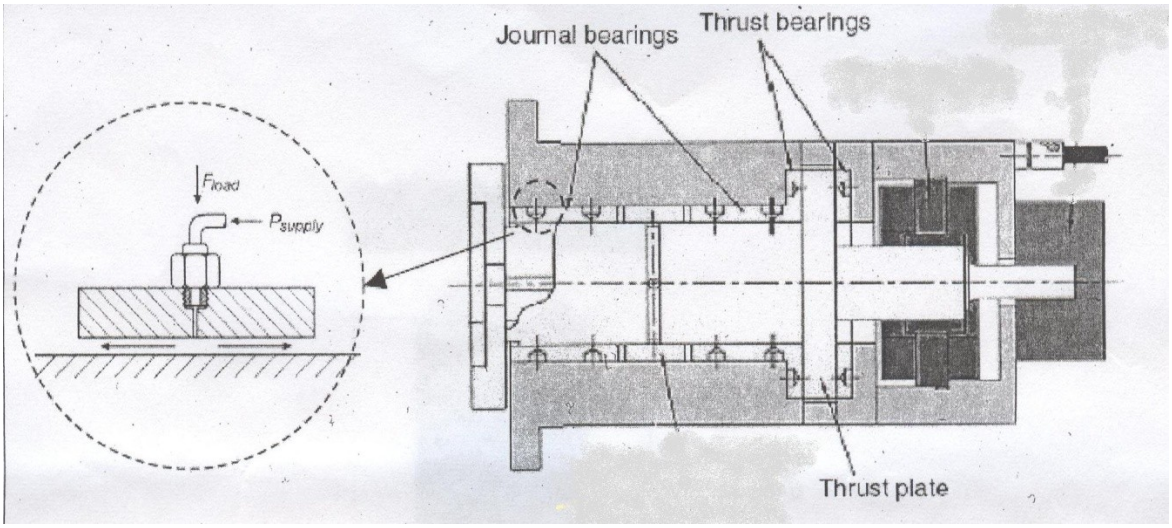
3.1. In fluid film bearings, difference between the two (oil and air) lies in their viscosity.Viscosity is defined as the property of fluid to provide resistance to the motion. As liquids have more viscosity than air, it bears the load and for the same working pressure liquid bearings have higher load carrying capacity than air bearings (usually it is 5 times more than air bearings).

3.2. But the foremost thing to be noted here is that due to low viscosity of air, it operates with essentially “zero static and running” friction, whereas liquid film bearings have higher friction and pumping losses within the bearings, which can generate heat. This is the main criteria to switch over from oil to air.

3.3. Also, oil deteriorates during its service causing carbon deposits on bearing surface resulting in adverse effects on working of bearing, which is not in case of air bearings. [6]

4, AIR BEARING CLASSIFICATION

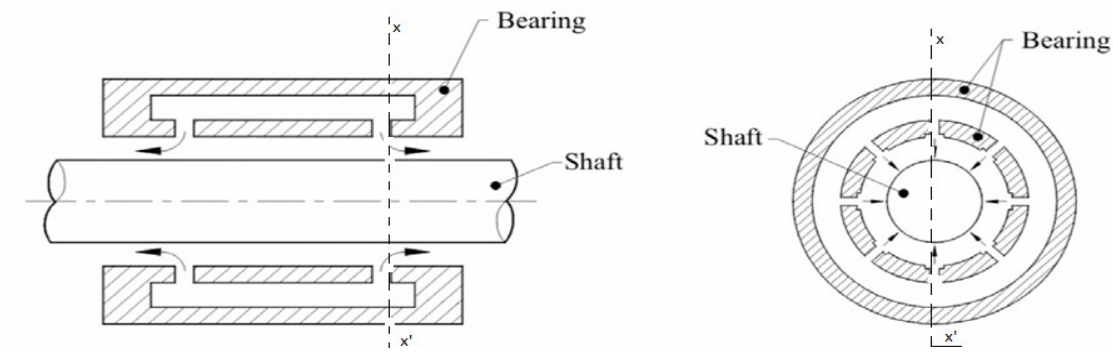
4.1. Air bearing are further divided into aerostatic and aerodynamic bearings. Aerodynamic bearings are same as hydrodynamic, in which pressure between the surfaces is generated as a result of the shape and motion of the surfaces themselves. Hence the load is carried by thin film of viscous fluid (oil) but in case of air (with negligible viscosity), this type of lubrication is impracticable and pressure generated is quite low [3]. Therefore aerostatic bearings are more pronounced as pressurized air is supplied externally. Aerostatic bearings are described in detail.



. Working sketch of "aerostatic bearings"

5. WORKING

5.1. An air bearing, as the name suggests suggests uses a thin film of pressurized air to support the load.This can be seen from air hockey table, pressure of air from the table lifts the puck, which floats in air.



. Basic working sketch

5.2. The same principle is applied in air bearings where thin film of air supports the load of shaft. A fine clearance is maintained between bearings and shafts. Pressurized air is pushed through bearing gap which moves axially in the bearing clearance and generates a pressure profile across bearing area [8].The force that can be supported is then,

Force=Avg. pressure * area

Great consideration in air bearings should be towards pressure profile, which depends upon bearing design. Therefore, air bearings require very fine bearing clearances for proper operation (10μm as compared to 100μm for liquid bearing), which solely depends upon extremely high accuracy requirements of the components.

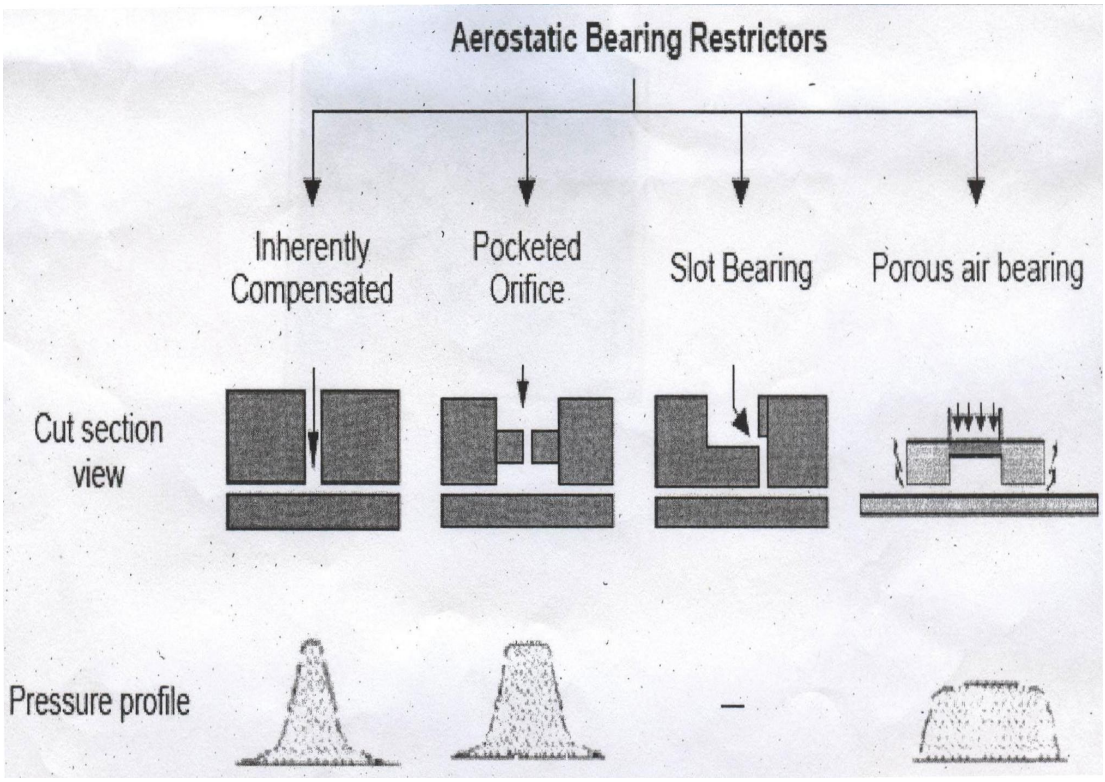
5.3. Air bearings though have lower load capacity, they have essentially zero friction at all speeds and because of very fine bearing clearances demands high accuracy of the components and this accounts for the flawless geometry of the components involved.

6. GENERATING PRESSURE

6.1. The question that arises is how to generate the pressurized supply of air for bearings. As in aerodynamic bearings, pressure of fluid film is generated(although less pressure generated) due to relative motion, but in aerostatic bearings, the film of pressurized air required to support the load and is carried out by supplying compressed air at a high pressure from external source. After supplying pressurized air next step is to feed the pressurized air to where it is needed.

6.2. Pressurized air for aerostatic bearings is accomplished through feeding device. Feeding device contributes a major role in maintaining the stiffness and load carrying capacity.Feed air is fed directly into the bearing gap.Two basic ways in which it is carried out are, orifice and porous media.

6.3. For orifice, air flows through a very small hole into bearing area. Porous media uses a porous material (carbon, bronze) through air penetrates into the bearing area. Figure shows different type of feeding device with pressure profile that they produce.



. Feed devices and respective pressure profiles

6.4. Selection of feeding restrictors becomes critical as air feed into the bearing should be uniform across all feed devices, eliminating the pneumatic hammer effect.The pneumatic hammer or the aerostatic instability is caused due to the pressure variations at the bearing point across various feed holes, affecting rotational accuracy.

7. BEARING FILM THICKNESS PRODUCED

7.1. Relation for bearing film thickness (h0), load carrying capacity (W) and stiffness (K):

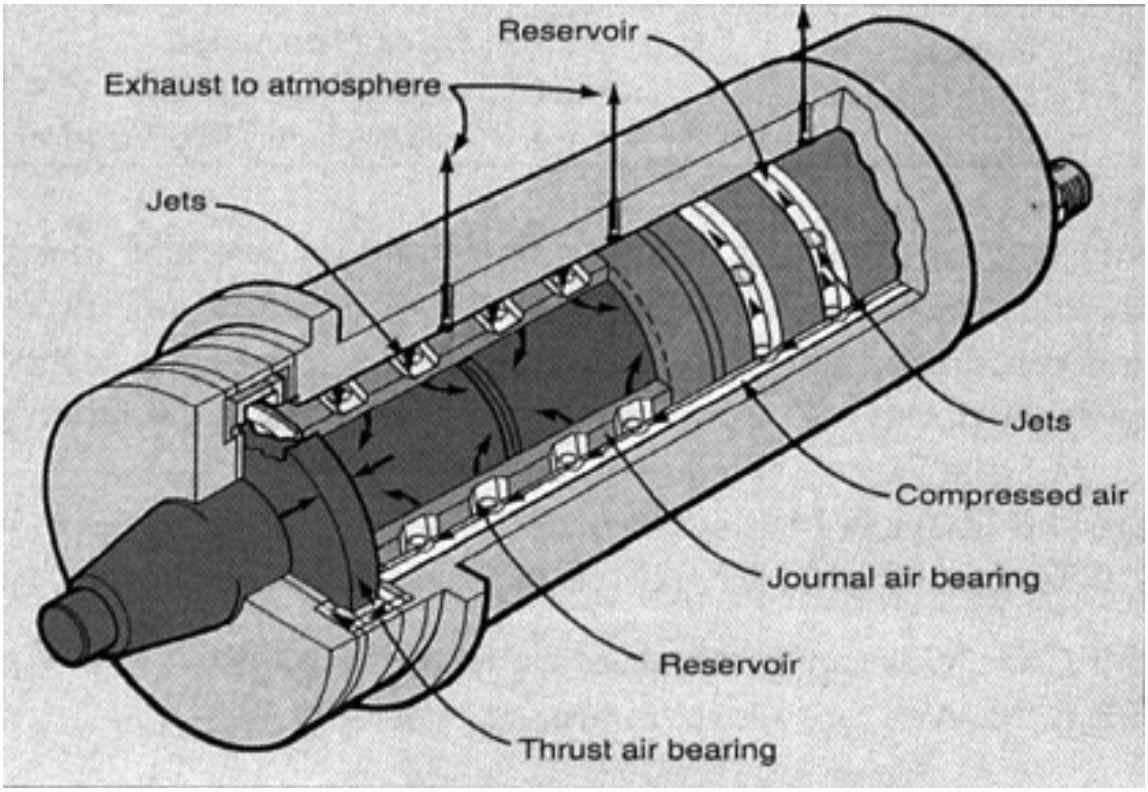
$$K=2W/ h0$$

This implies that for higher load carrying capacity, bearing clearance has to be increased for same stiffness.This leads to increase in air flow rate in bearing.

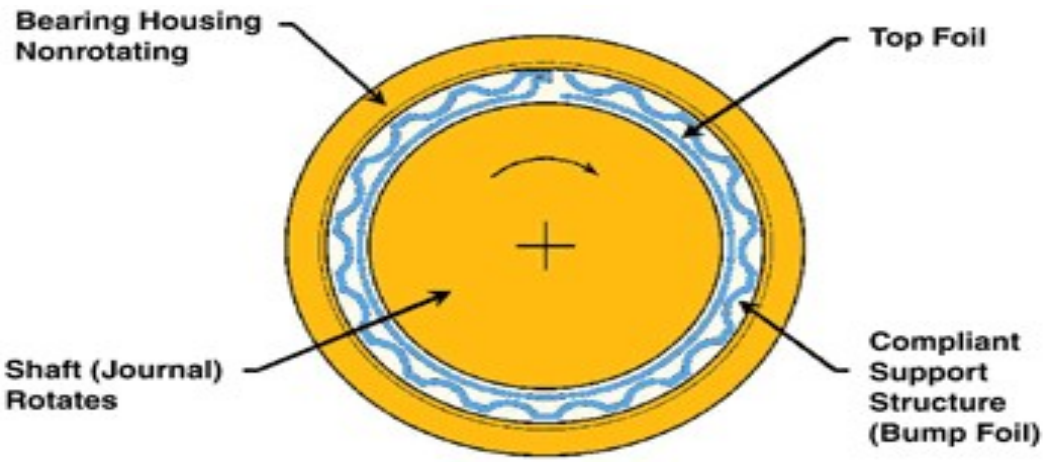
7.2. Bearing clearance should be kept minimum, as the pressurized air expands as it flows through bearing clearance towards ambient pressure outlet, the air temperature drops leading to localized cooling at various locations of shaft.This localized cooling causes dimensional changes in the bearing, leading to geometric error motion and thermal growth of the shaft.Therefore it is necessary to maintain bearing clearance to the minimum, in order to reduce volume of decompressing air.

8. APPLICATION

8.1. Aerostatic bearings can be used instead of oil bearings to support the weight of crankshaft, which is shown below:-

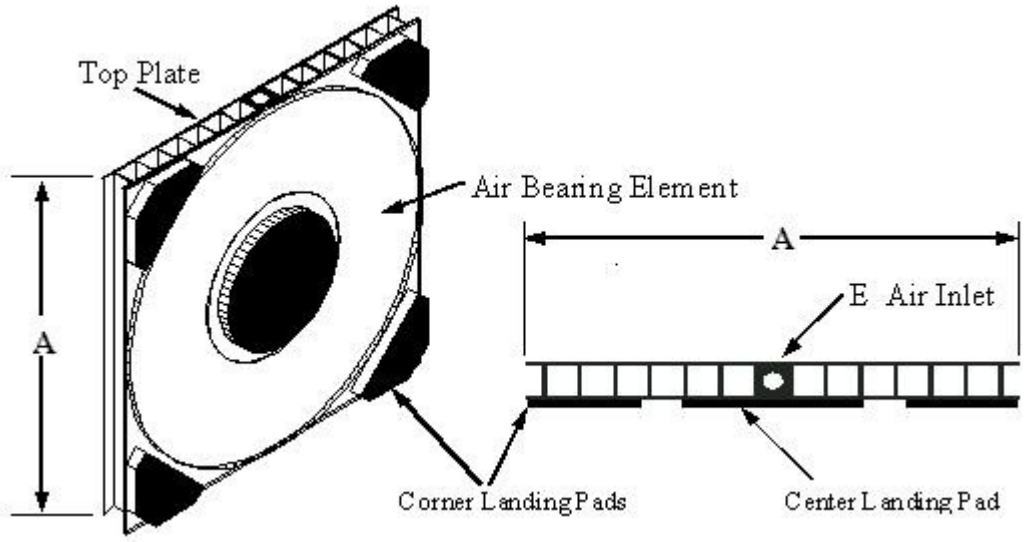


. Schematic sketch of "aerostatic bearings"



. Bearing Profile

8.2. As mentioned earlier that weight of crankshaft supported will depend largely on bearing clearance and uniform pressure profile created by feeding device. But when not in working condition, crankshaft will rest on bearing surface and all the weight will be on bearing surface. This causes adverse effects on holes for air inlet and gradually the passage required for pressurized air to flow reduces.This can be avoided by not allowing shaft to rest on bearing surface, this can be done by using air caster as shown in figure.

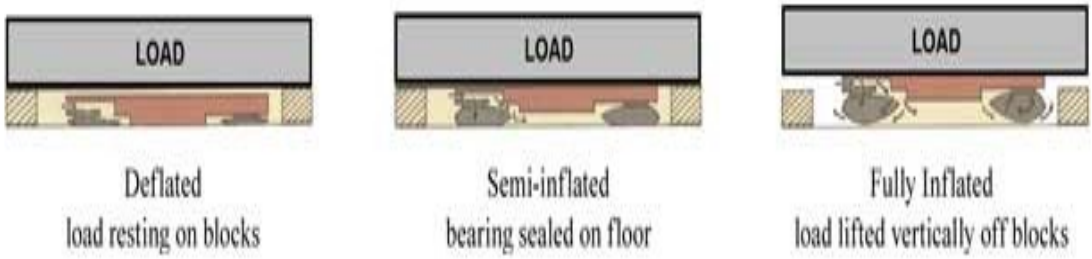


. Air Casters

8.3. Air caster has landing faces above its top plate on which shaft should rest. It has bellows below the top plate surrounding the bearing element which is inflated against rigid structure below it. [1]

When shaft stops rotating, it will try to rest on bearing material. As soon as it is quite close to make contact with bearing material, the air caster which is placed very slightly above the bearing surface supports the load of the shaft when the bellows are deflated.

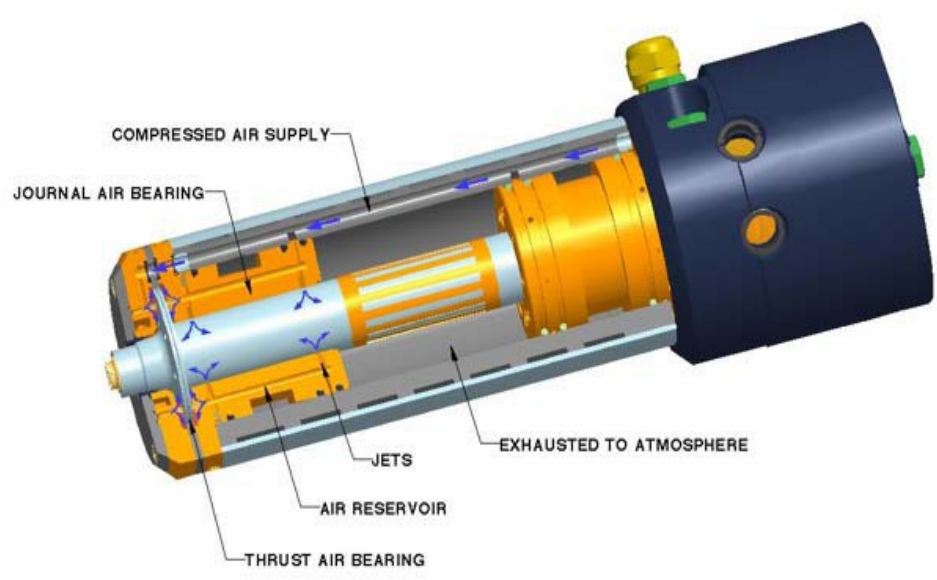
To allow crankshaft to run, air is supplied to inflate bellows, so that crankshaft raises above bearing surface to maintain the required running clearance of 5-7micron.Bellows are deflated as soon as the load of crankshaft is supported by pressurized air in bearing clearance.This mechanism can be shown in figure below:



. Lifting the load.

8.4. For a smooth, trouble-free operation of air bearings, or system, the floor surface should be level, smooth and non-porous. Minor cracks and small holes can be easily filled with an epoxy resin type material. Hence effective machining is required for the components involved.

8.5. Air bearings can be used in manufacturing industries with use of an air bearing spindle driller which has far more advantages than conventional one in terms of high speed of rotation and less thermal growth. [4]



. Cut away of an air bearing spindle

9. Practicality

To validate these new foil-bearing capabilities, NASA set out to demonstrate the use of foil air bearings. A 150-hp turbocharger was modified to operate using foil air bearings. The turbocharger was run with a 1200 °F turbine inlet temperature and shaft

rotational speeds in excess of 60 000 rpm. This oil-free turbocharger was able to perform over 100 000 start/stop cycles without a failure. [5]

Acknowledgements

I take immense pleasure in thanking Prof. A. Venugopal, Dean Marine Engineering, AMET University and the dedicated team of Chief Engineers of the institute for sharing their experience, enlightening my mind with knowledge and providing me the information necessary for completion of this paper.

I would like to thank following firms, organizations for providing the material to get acquainted with air bearings, widen my knowledge on its working and for completion of the essay. The following firms also contributed various illustrations and information on their products, for which I thank them:

Central Manufacturing Technology Institute, Bangalore, India.
New Way Air Bearings, USA.
Glenn research centre, National Aeronautics and Space Administration (NASA), USA.
Hovair Systems, USA.
Specialty Components, USA.
American Solving Inc., USA.
Google- Search engine.
Bing- Search engine.

Finally, yet importantly, I would like to express my heartfelt thanks to my beloved parents for their blessings and encouragement, my friends/classmates for their help and wishes for the successful completion of this essay.

References

[1] David Roberts, HOVAIR systems, http://www.hovair.com/airbearing-info/airbearing-info-index.htm, USA.

[2] D.K.Sanyal, Chapter 6, Principle and Practice of marine diesel engine.

[3] Gopi Krishna S, Prakash Vinod, P V Sushil Kumar, Design Considerations of Nanometer Resolution Aerostatic Spindle Bearing for Ultra Precision Machining, Manufacturing Technology Today, January 2010.

[4] GSI Westwind, Air Bearing Technology, 2nd edition: January 2007.

[5] NASA, National Aeronautics and Research Center, 2008, http://www.nasa.gov/centers/glenn/aboutglenn/index.html .

[6] Robert M. Gresham, George E Totten, Lubrication and Maintenance of Industrial Machinery, CRC press, 2009.

[7] Specialty components, http://www.specialtycomponents.com .

[8] New way air bearings, USA, http://www.newwayairbearings.com .

[9] Y.Nakayama, Introduction to fluid mechanics, Editor: R F Boucher, 1999.