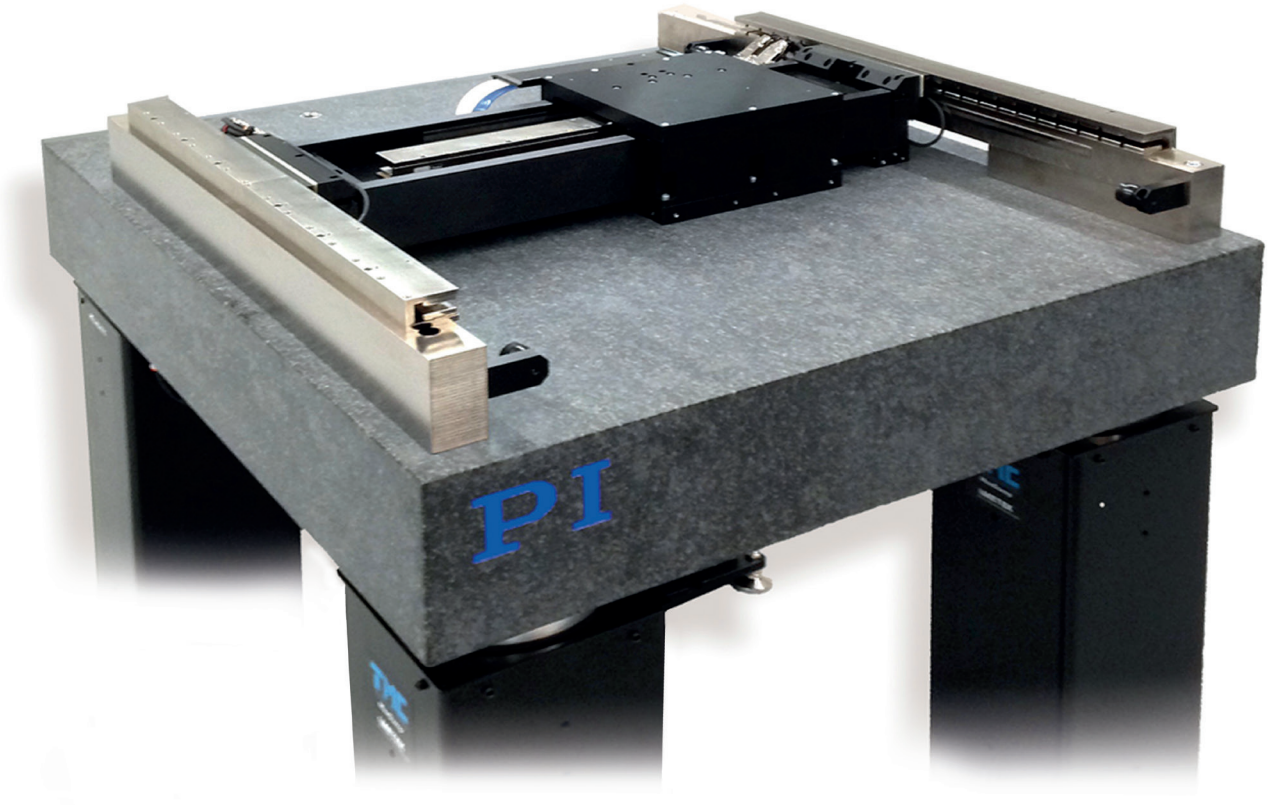
Air Bearings: When to Use and When to Avoid in Your Motion Application

All Positioning Stages are not Created Equal



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Introduction

Most motion applications are perfectly well-served by mechanical bearing guidance; but there are many cases where precision, angular repeatability, and geometric performance must be optimal or where submicron bearing rumble is problematic. An air bearing stage can help in these situations. An air-bearing stage is a rotary or linear positioner that floats on a cushion of air, using one of several preload mechanisms, nearly eliminating mechanical contact and thus wear, friction, and hysteresis effects. These are the most common indicators that an air bearing stage might be the right choice for your application (s. Fig. 1).

1 Frictionless High-Precision Positioning

A direct drive motor and high-resolution encoder can position a moving carriage supported by an air bearing to within nanometers in a linear application or within tenths of arcseconds in rotational applications. The lack of friction and mechanical contact means there is minimal hysteresis or reversal error, making it highly repeatable and ideal for many inspection and manufacturing operations. Stiction is virtually eliminated, improving resolution capabilities and reducing in-position “hunting” (limit cycling) and position repeatability can be obtained within a few fundamental encoder counts.

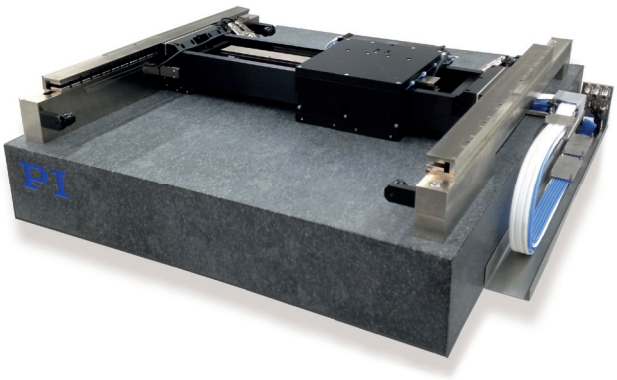

Fig. 1 Three motor planar XY air bearing stage with active yaw control (Image: PI)

Similar precision can be obtained by piezo flexure guided stages, however over much smaller travel ranges. Magnetic levitation is another option.

2 Velocity Stability and Scanning

The lack of mechanical bearing elements means there is nothing to get in the way of smooth, controlled velocity (stability to better than 0.01%). Experiments and processes like inertial sensor testing, tomography, wafer scanning, and surface profiling require continuous motion at a tightly controlled speeds are best served by air bearing systems.

3 Very Low Error Motions

Linear air bearing stages have incredibly straight and flat travels, and pitch, roll, and yaw errors can be measured in tenths of arcseconds. Rotary stages can have tilt (wobble) errors less than 1 arcsecond.

Additionally, the angular performance of an air bearing is remarkably repeatable. This guarantees optimal part quality and measurement reliability for applications like mirror and optics inspection, semiconductor inspection, and medical device manufacturing.

4 Travel Requirements are Greater Than a Flexure Stage Can Provide

Piezo-driven flexure stages and actuators can satisfy many high-precision positioning applications. However, these designs are usually limited to a few millimeters of travel. Use an air bearing linear stage for travels of 25 mm or more (s. Fig. 2). PI manufactures linear air bearings with travels up to a meter, and even greater with a custom design.

Fig. 2 Miniature air bearing linear stage (Image: PI)

5 Wobble-Free or High-Speed Rotary Motion is Needed

Rotary air bearings (s. Fig. 3) are exceptionally stiff and can deliver highly precise rotary motion. Radial, axial, and wobble error motions are much smaller than most mechanical bearing solutions can provide, and the rotary motion is very smooth, since there are no roller elements. Rotary positioning stages generally can achieve speeds up to 600 RPM, while air bearing spindles are used in higher speed applications. Rotary bearing designs can be mounted with the plane of the table in either the horizontal (i.e. turntable) or vertical orientations.

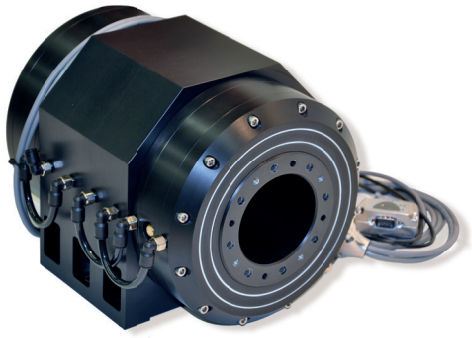

Fig. 3 Rotary air bearing (Image: Nelson Air)

6 Minimal Maintenance

There are no contacting parts to undergo wear and tear, and no regular maintenance procedures to be performed like lubrication. An air bearing stage is essentially maintenance-free. Further, the system is highly stable, since there is no wear; the performance characteristics should not change over the life of the system. There is little need for recalibration. Moving cables and hoses are often the only items subject to wear in an air bearing system.

7 Cleanliness

Because air bearings are wear free, they generate virtually no particulates that can become airborne. This makes them ideal for cleanroom applications like optics inspection, wafer inspection, bio-pharma research, and flat-panel display inspection. For extremely clean applications, it is recommended that the air bearing operate using 99.9 % pure nitrogen.

8 Precise Force Control and Sensing

Air bearings are virtually frictionless, which means when they are coupled with a direct drive motor or voice coil, they are ideal for micro and nanonewton force control applications (s. Fig. 4). Such applications can include pick-and-place of delicate items, materials testing, and coordinate measuring applications.

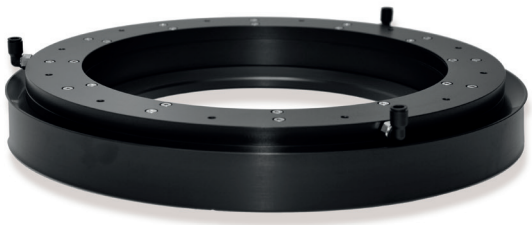

Fig. 4 Spherical air bearings can be used to simulate zero gravity (Image: Nelson Air)

9 When Would You Avoid an Air Bearing for Your Motion Control Application?

9.1 Vacuum Environments

While it is not impossible to operate an air bearing in a vacuum, it is challenging. Vacuum applications should generally be avoided and instead use mechanical bearing, maglev, or flexure systems (s. Fig. 5).

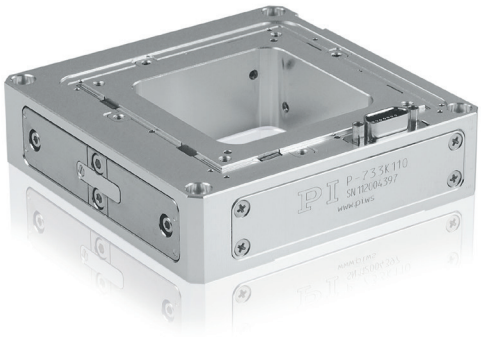

Fig. 5 A flexure-guided, UHV-compatible XYZ piezo nanopositioning stage (Image: PI)

9.2 Very Dirty Applications

Air bearings are generally used in clean environments. Applications where heavy amounts of dust, dirt, debris, and fluids are present should generally be avoided.

9.3 Pressurized Air or Nitrogen is not Available

Air bearings require a continuous supply of clean compressed air or nitrogen. If the application does not allow for such a supply to be present, an air bearing cannot be used.

Author

Matt Reck is Air Bearing Product Line Manager at PI (Physik Instrumente) LP in Auburn, MA. He has many years of experience in the design of air bearing stages and project management of complex motion systems.

Experience with Air Bearing Technology

PI is building on over 200 man-years of in-house air bearing experience and offers comprehensive precision air bearing motion control and positioning products and systems. With 4 decades of experience in piezo nanopositioning systems design and motorized precision positioning equipment, the new air bearing systems capabilities are a natural and logical extension of PI's precision motion offerings.

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