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**Air Bearings
Aid Assembly
of Flat Panel
Displays**

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Air Bearings Aid Assembly of Flat Panel Displays

Many manufacturing processes for flat panel displays (FPDs) require precision motion control for feature generation and inspection. Aerostatic bearings are an excellent choice for many of these processes, because they allow precise, repeatable motion; are clean-room compatible; and are maintenance-free.

bearing stages inherently move with less error than stages equipped with mechanical bearings, due to the exacting part tolerances and mechanical alignment required to maintain the thin film of air that acts as the bearing. Furthermore, the noncontact nature of an air bearing reduces vibration and other factors that affect repeatability. Motion errors of less than 10 microns and less than 10 arc-seconds can be expected from large-format air-bearing stages, but even that is not acceptable for some FPD processes.

The ABL9000 stage uses air bearings, noncontact linear motors and noncontact optical encoders to provide precise, repeatable X-Y motion without the introduction of wear-induced inaccuracy. The ABL9000 is a planar air-bearing: X-Y motion is achieved with an air-bearing carriage that floats above a precision-lapped granite surface. The mechanics are arranged in an H-bridge configuration, where the Y-axis carriages ride along precision granite rails and are connected by a cross beam.

The bridge that couples the Y carriages together provides lateral air-bearing support for the X-axis carriage. The flatness,

Motion errors of less than 10 microns can be expected from large-format air-bearing stages, but even that is not acceptable for some FPD processes.

parallelism and perpendicularity of the air-bearing surfaces of this bridge must be excellent for the straightness, yaw and lateral bearing stiffness of the X axis to meet the demanding specifications of the FPD industry. Because the vertical bearing surface is the granite surface plate itself, excellent flatness, pitch and roll performance is achieved. Granite can be lapped to incredible flatness tolerances and is dimensionally stable over time. It provides an excellent reference surface for precision X-Y motion.

Aerotech's BLM series of direct-drive

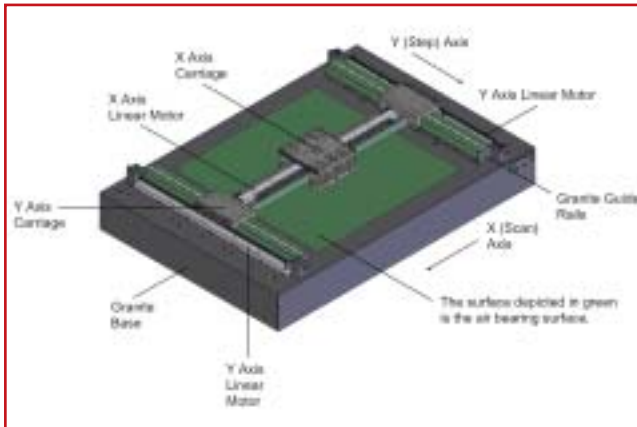


The ABL9000 stage uses air bearings, noncontact linear motors and noncontact optical encoders to provide precise, repeatable X-Y motion without the introduction of wear-induced inaccuracy.

Aerotech faced several challenges in expanding its ABL9000 series of planar air-bearing stages to handle FPDs. These challenges were mainly due to the sheer size of the panels and the staging required to move them. Fifth-generation panels (1,100 by 1,250 millimeters) can require stage travels up to 1,500 millimeters, while typical chucks can weigh up to 95 kilograms. The mass and inertia of such a positioning system are a challenge for the devices that control and drive the stage. The size of the air-bearing parts for these stages made it difficult to achieve the required geometric tolerances.

For the most stringent processes, the motion of the panel must be controlled with submicron translational error and sub-arc-second rotational error. Minimizing rotational error (pitch, yaw and roll) is particularly critical, as small rotations can result in large translations in X, Y, and Z at the edge of the panel. Air-

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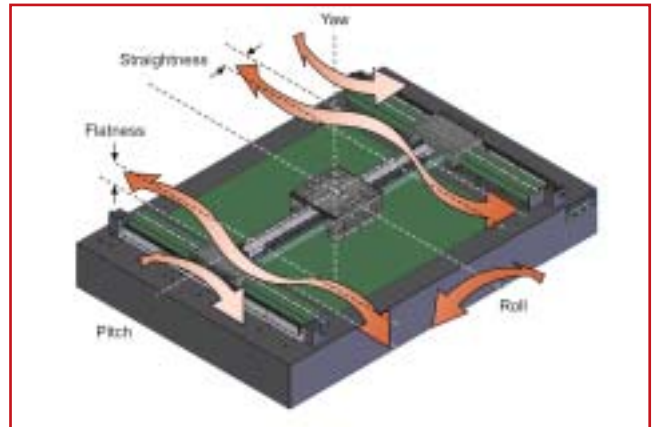
The ABL9000 is a planar air-bearing. X-Y motion is achieved with an air-bearing carriage that floats directly on a precision-lapped granite surface. The mechanics are arranged in an H-bridge configuration, where the Y-axis carriages ride along precision granite rails and are connected by a cross beam.

linear motors drive the X and Y axes for most applications. These motors are ideally suited to this design, due to their high force-constants and compact size. BLMH or BLMX high-force-output motors are used in applications with large accelerations or abnormally large moving masses.

High-resolution optical encoders provide positioning feedback on all axes. The encoder scales on most FPD positioning systems are glass, so that thermal expansion of the glass substrate

is automatically matched by thermal expansion of the encoder scales. Alternatively, thermal monitoring and real-time accuracy correction can be applied using Aerotech's Automation 3200 motion controller. The stage temperature is independently measured and input into the controller, which then calculates a corrected stage position in real-time based on the materials' coefficients of thermal expansion.

Signals from the controller are amplified by digital amplifiers and sent



During manufacturing, the motion of a flat panel display must be controlled with submicron translational error and sub-arc-second rotational error. Minimizing rotational error (pitch, yaw and roll) is particularly critical, as small rotations can result in large translations in X, Y, and Z at the edge of the panel.

to the linear motors. The controllers are configured to run in "gantry" mode on the Y axis. Both carriages of the Y axis assembly have their own motors and feedback devices. The gantry mode sends motion commands to both the master and slave axes simultaneously, while still allowing each carriage to be independently servo-controlled. The master and slave axes can also be independently calibrated to eliminate yaw error of the Y axis statically and dynamically.

The stiffness of the bearings that support the stage and the FPD is critical to achieve the dynamic performance required in many manufacturing processes. Transitional vibrations that occur immediately after acceleration and deceleration of the stage must be small in magnitude and dampen out quickly. Bearing stiffness also has a direct influence on the servo performance of the stage, due to the resultant natural frequencies of the system and the drive-to-feedback coupling.

In general, air bearings can be made stiffer by reducing the air gap between the bearing parts, but there are problems with reducing the air gap too much. The flatness and parallelism tolerances of the bearing surfaces obviously need to be smaller than the air gap itself to maintain the bearing effect of the air. As the air gap approaches 1 to 2 microns, it can be cost-prohibitive to consistently manufacture

Air Bearings at a Glance

Gas bearings rely on pressure distribution from a thin film of air to separate two precision-machined surfaces. Any change in the gap between the surfaces must be resisted by a corresponding change in the pressure distribution. Gas bearings have nonlinear stiffness characteristics. The air gaps must be kept very small to provide the high stiffness values required in a precision machine. As a result, geometric tolerances of the parts must be very small for the bearing to function correctly.

Gas bearings can be aerostatic or aerodynamic. For linear bearings, aerostatic designs are the only practical choice. With this type of bearing, pressurized air or nitrogen is injected between two flat surfaces. The gas must be filtered and dried for the bearing to operate correctly. A flow restrictor is typically required between the pressure source and the flat surfaces to keep the bearing stable. The bearings can be inherently compensated or orifice compensated.

The orifice-compensated bearing offers approximately 30 percent more stiffness than similarly sited inherently compensated bearings.

Air bearings can be modeled in a system as nonlinear springs. They have relatively low stiffness when lightly loaded, so preload is required to reduce the air gap and, correspondingly, to increase stiffness. Common types of preload include gravity, magnets, vacuum and air-on-air.

production-level quantities of acceptably stiff air-bearing stages.

In addition to manufacturability, a phenomenon called *pneumatic hammer* must be considered when reducing the air gap. Pneumatic hammer is a self-sustaining instability in an air-bearing film that produces large error motions and effectively makes a stage uncontrollable. Large payloads, high inertias and small air gaps increase the probability of pneumatic hammer in an air bearing. Aerotech's air bearings have high lateral and rotational stiffness, high load capacity, and no propensity to pneumatic hammer.

Solid modeling and finite element analysis were used to design the critical stage parts. For ultimate servo performance, the stiffness and natural frequency of the stage parts had to be increased and the moving mass had to be decreased. The most obvious

example of this is the bridge between the Y carriages, is available in either aluminum or ceramic.

Many FPD manufacturing processes use the raw encoder signal from the stage to trigger events in the manufacturing process. A classic example is the pulse-synchronized-output (PSO) option on the controller. With PSO, encoder counts are monitored and a pulse of programmable duration, intensity and trajectory is output to a laser or similar device. The hardware calibration on the MXH encoder multiplier provides calibrated encoder output to the PSO or to any other third-party controller or data acquisition system.

Depending on the specific FPD manufacturing process, there are two main modes of operation for the stage. The first is *scanning mode*, where the panel is moved in a serpentine pattern. The

panel is processed while it is moving under a fixed objective. This high-throughput process takes advantage of the high bearing stiffness and servo performance of the ABL9000. In this case, the stage is tuned to minimize transitional errors after the turnaround of the previous scan.

The second mode of operation is called *step-and-repeat*. In this mode, the stage is stepped to a location and allowed to settle into position. These manufacturing processes usually require nanometer-level stability when the stage is in position. The stage is typically set up to have resolution of 1 to 10 nanometers, and is tuned for quick settling and low jitter. Accuracy and repeatability are usually the main concerns in this mode of operation.

For more information on air bearing stages, call Aerotech at 412-963-7470, visit www.aerotech.com, or **Reply 20**

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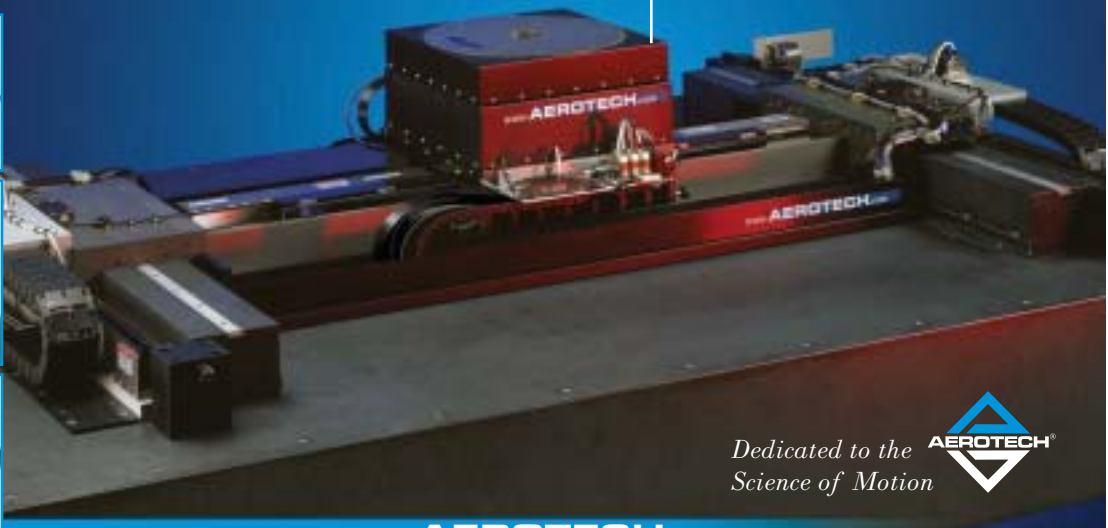


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