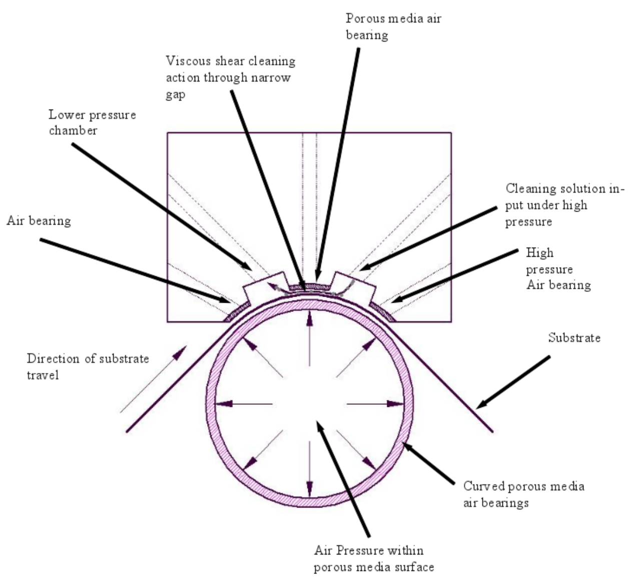
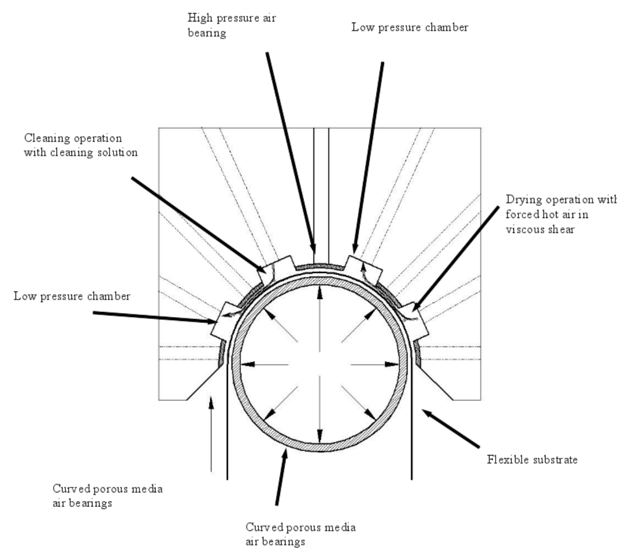
New Way Air Bearings
Aston, PA
Drew Devitt and Mike Wright

New Way Air Bearings has developed equipment using porous media air bearings to manipulate thin materials called webs (see attached abstract) without physically contacting the web. The new process offers distinct advantages over current processes, a precise mathematical model for the process and its parameter dependencies have yet to be determined.

Questions:

1. How do boundary layers of air molecules on a surface effect the force that can be exerted on the surface through friction of air flow?
2. What is the relationship between fluid pressure (at the bearing?), fluid velocity in the gap and the forces that are transferred to a surface?
3. Given a temperature difference between the input air and the web, what is the energy transfer between the air and the web? Can this be directly compared with a heated or cooled roller bearing?
4. If the web is wet, how do these variables affect the removal of moisture from the web?
5. If the web has unwanted particles on the surface, how do these variables affect the removal of particles from the web?





THE USE OF VISCOUS SHEAR IN AIR BEARING GAPS FOR PRECISE WEB TENSION AND TEMPERATURE CONTROL

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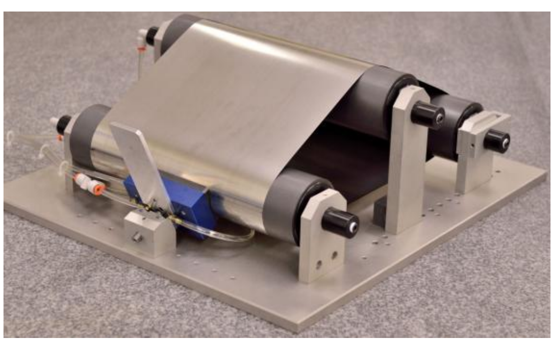
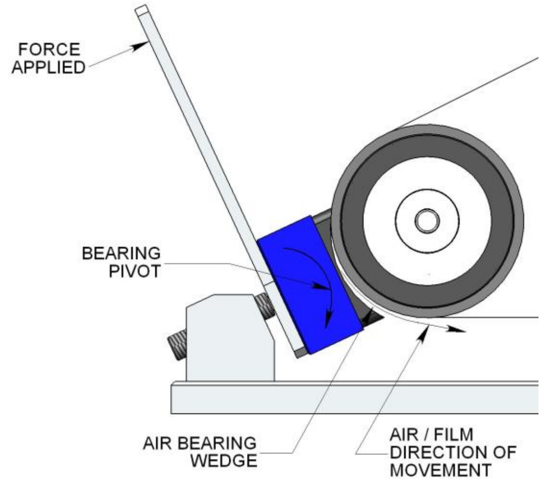
SUMMARY
Air bearings enabled the precision and speed needed in motion control systems for manufacturing advanced IC circuits. But today the substrates for manufacturing circuits are changing. Flat-panel display glass substrates can be meters square, substrates for solar applications and printed electronics on roll-to-roll substrates are demanding completely new precision motion systems. Air bearings are again providing breakthrough enabling technology by acting directly on the substrates. So flat-panel glasses are controlled through processes by air bearings without contact rather than being vacuumed to a Chuck. This research explores flexible films flowing over "Air Turns" rather than contact rollers and viscous shear in the air films for motion control, cleaning, drying, and precision temperature control. This would satisfy demands from the printed electronics industry for non-contact precision manufacturing of flexible displays, OLED lighting, PV, and Printed batteries.

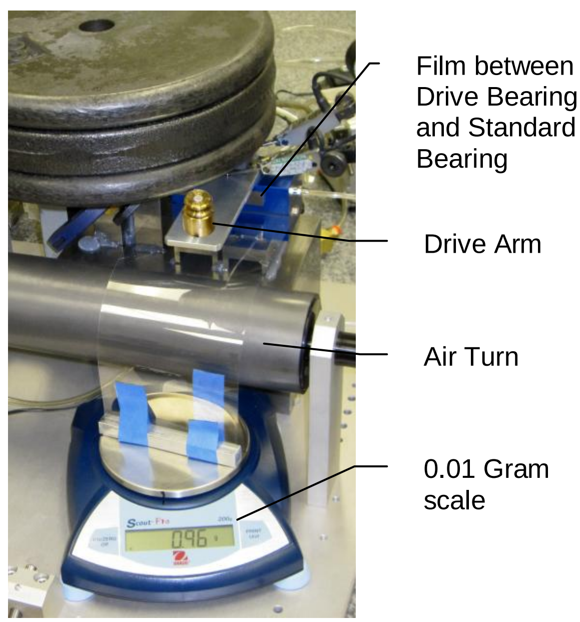
SHEAR FORCES TO CONTROL WEB TENSION
An air turn would be an air-bearing-based, usually non-rotating mechanism which flexible films would float over and around that would replace contact rollers. The elimination of contact roller friction means uniform tension between many air turns and the possibility of much better control of web tension.



By sandwiching the web between two air bearing films, high pressures may be exerted on film in compression. Air shear in these air bearing gaps, acting directly on the flexible film, will be used both for driving the flexible film, controlling film tension, and for centering the film on the roll.



PURPOSE OF TEST
A test fixture was built to measure the pull exerted on a piece of film under varying test conditions.



A weight was attached to one end of a piece of flexible film, and the film was draped over a frictionless New Way Air Turn air bearing. A high precision scale was positioned so that the weight was resting on top of the platter of the scale. The other end of the film was sandwiched between a pair of air bearings. The lower bearing was a stationary support bearing that was affixed to the test fixture to ensure that it did not move. The upper bearing on point contact floated parallel to the support bearing on a cushion of air and had angular freedom of movement in all directions. A set of weights were positioned on top of the fixture in a three point stance with one of the positions being the tooling ball that was located in the center of the upper bearing. This weight provided a downward force on the direction-control bearing and squeezed the air film to increase the stiffness of the air gaps between the bearing faces and the film. A drive arm was attached to the back of the direction-control bearing, and loads applied to the ends of the drive arm would cause the bearing to rotate slightly out of parallel with the support bearing which would cause the air in the gap to move towards the larger opening at the opposite side from the load. The air shear from this movement would pull on the surface of the film and create a force which could be measured as a change in the weight measurement displayed by the scale.

The test was repeated with (3) different configuration directional-control bearings. The first test was performed with a stock New Way air bearing. The second test was performed using a bearing with a groove that ran partially across the face of the bearing perpendicular to the direction of the film travel. A third test was performed using a bearing that had two grooves that ran partially across the face of the bearing parallel to the direction of the film travel. A hole was drilled at the ends of each groove to allow air to be fed into the groove. Each hole was plumbed independently, and the air could be fed into either hole to create a directional flow in the groove. The hole at the opposite end of the groove could be left open as an exhaust, or it could be plugged, which would create an increase in bearing-face pressure as well as some directional flow. Air fed into both holes would create additional pressure in the bearing face without any directional control.

The results of this testing showed that a single 50 x 100 mm air bearing could generate over 30 grams of shear force on the flexible film. And this force could be controlled with a resolution to 100th of a gram. So here we have a technique that can control tension between rollers in a continuous line, and can be used to create a shear force across the roller essentially taking wrinkles out and potentially being able to stretch and align a pattern on a web without contact with either side of the web.

TEMPERATURE CONTROL

Additionally this technique can be very effective at driving the temperature of the web acting on both sides of the web simultaneously. Because of the high relative pressure and resulting high velocities of air in the air gap, the boundary layer of air associated with the surface of the film can be scrubbed. This is essentially increasingly convective film coefficients (wind chill) and so more effectively driving the temperature of the web than heated or cooled rollers that are in contact with the web. This paper will further attempt to quantify this effect, showing the models and thermal transfer math to explain actual test results.

Other Functionalities

This same shear force or boundary layer scrubbing can also be very effective for cleaning and conditioning films before other processes. This technique may also dramatically reduce drying times for the same reasons it is very effective at transferring temperature. If time allows, we will also look into comparing drying times of viscous shear between air bearing lands and conventional air knife type drying applications.