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

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INTRODUCTION

Air bearings have enabled the precision and speed required 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 the use of viscous shear in the air films for motion control, cleaning, drying and precision temperature control. This would help satisfy demands from the printed electronics industry for non contact precision manufacturing of Flexible Displays, OLED Lighting, PV, Smart Packaging and Printed Batteries.

SHEAR FORCES TO CONTROL TENSION

An air turn is an air bearing based, usually non-rotating roller 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.

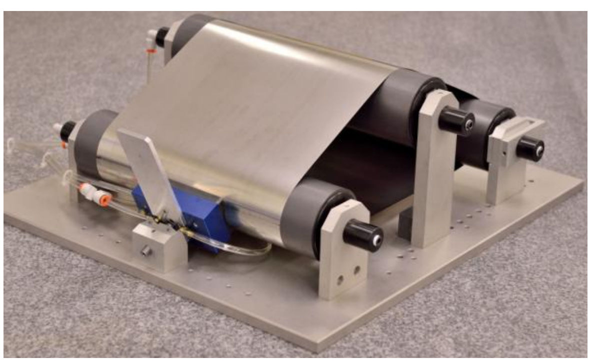


FIGURE 1.

By sandwiching the web between two air bearing films, high pressures may be exerted on the film in compression. Air sheer in these air bearing gaps, acts directly on the flexible film for: driving the flexible film, controlling film tension between rollers, creating a spreading tension across the web (along the length of a roller) and centering the film on the roller.

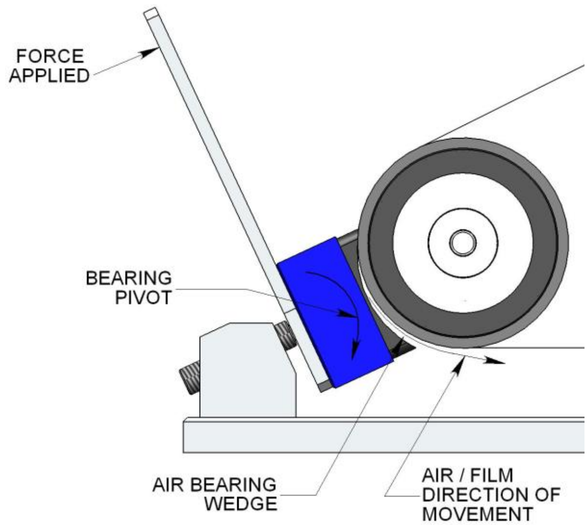


FIGURE 2.

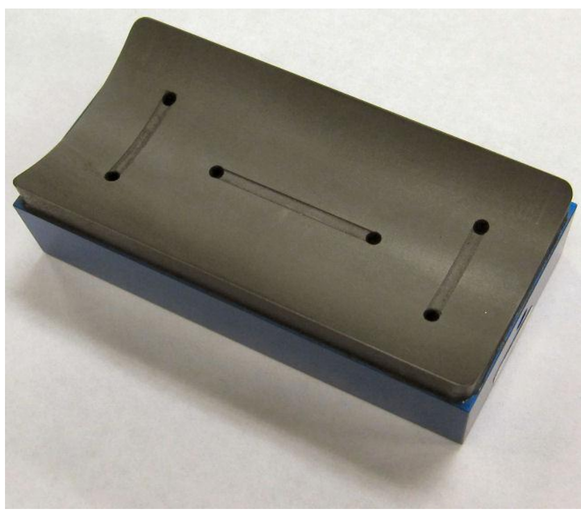
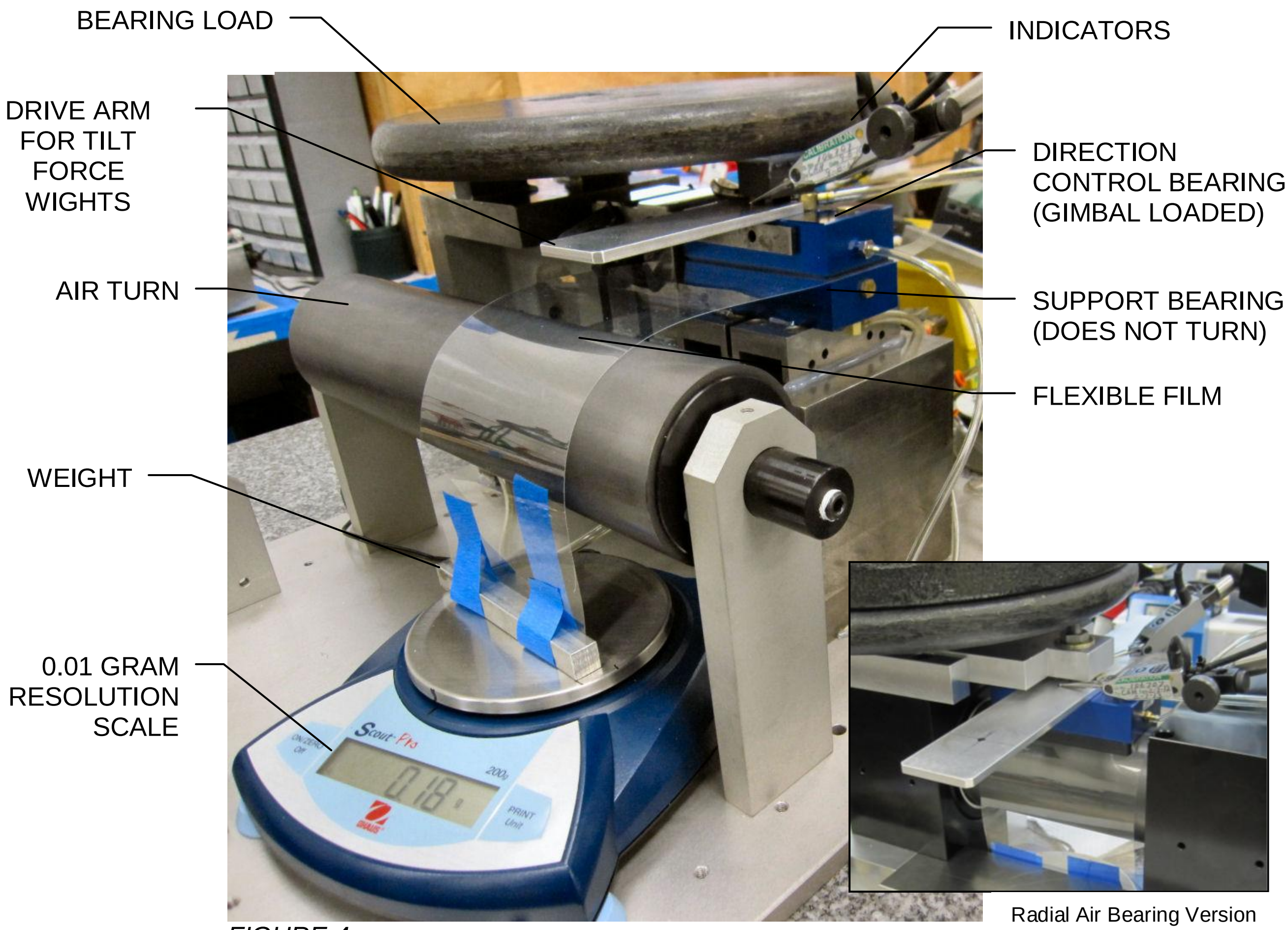


FIGURE 3.



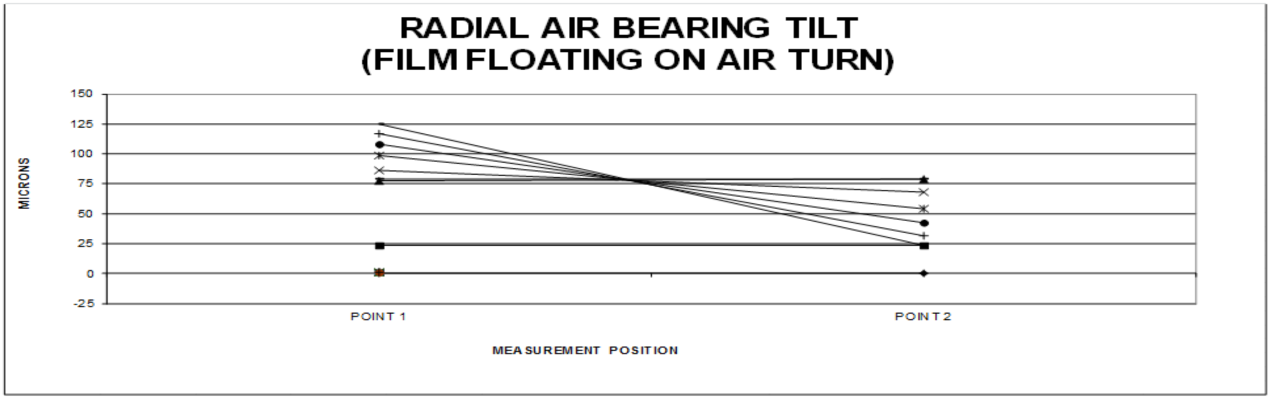
Radial Air Bearing Version

FIGURE 4.

TEST SET UP

A test fixture (Figure 4) was built to measure the pull force exerted on a piece of film under varying test conditions: Load, air pressure, air flow, and tapers in the air gaps. 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 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, loaded by point contact, floated parallel to the support bearing on a cushion of air and had angular freedom of movement, electronic indicators were positioned at each edge. 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 pressure in the air gaps between the bearing faces and the film. A drive arm was attached to the back of the direction-control bearing, and weights applied to the ends of the drive arm would cause the bearing to tilt 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. This set up was reconfigured to also test radiused bearings on an Air Turn. (See inset.)

TABLE 1.



LOAD ON FIXTURE	PRESSURE IN GAP	DIRECTION CONTROL BEARING					LOAD DATA	BEARING LIFT			SCALE DIFFERENTIAL
		FACE		GROOVE		TOTAL BEARING FLOW	MASS	SIDE AWAY FROM LOAD	SIDE TOWARDS LOAD	DRIVE ARM TILT ANGLE	
		PRESSURE	FLOW	PRESSURE	FLOW			POINT 1	POINT 2		
(N)	(KPA)	(KPA)	(SLPM)	(KPA)	(SLPM)	(SLPM)	(GM)	(UM)	(UM)	(DEGREES)	(GM)
222.41	24.70	0.0	0.0	0.0	0.0	0.0	0	0.00	0.00	0.000	
222.41	24.70	413.7	2.9	0.0	0.0	2.9	0	23.40	23.75	0.000	
222.41	24.70	413.7	2.9	68.9	45.4	48.4	0	77.35	79.15	0.002	0.00
222.41	24.70	413.7	2.9	68.9	45.4	48.3	250	86.25	68.00	-0.024	4.38
222.41	24.70	413.7	2.9	68.9	45.4	48.3	500	98.80	53.85	-0.060	10.72
222.41	24.70	413.7	2.9	68.9	45.3	48.2	750	107.95	42.20	-0.088	15.52
222.41	24.70	413.7	2.9	68.9	45.3	48.2	1000	116.70	31.45	-0.114	19.91
222.41	24.70	413.7	2.9	68.9	45.4	48.4	1250	124.95	23.35	-0.135	23.84
222.41	24.70	413.7	2.9	68.9	45.5	48.5	0	79.20	79.15	0.000	

TEST CONDITIONS

The data in table was taken using the New Way Porous Media Radial Air Bearing shown in figure 3 which has grooves and feed/exhaust holes for experimental purposes. In this case additional air pressure was fed into both the holes in the single center groove. This grove is directly under the point loading. The air fed into this groove was a 20 times multiple of the air feeding the face of the bearing even at one third the pressure, yet the total flow of 48 SLPM is still reasonable. This test was repeated many times varying the dead weight load on the bearing, air pressure to the grooves and groove configurations. Higher loading contributed to similar forces at lower air flows. Tilt in the gap was the dominant variable and interestingly resulted in a very linear plots.

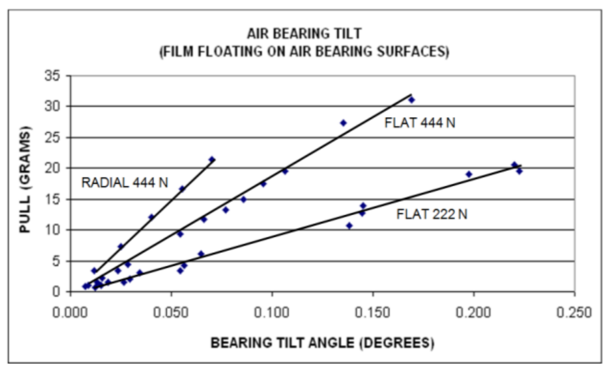


FIGURE 5.

RESULTS SUMMARY

The results of this testing showed that a single 50 x 100 mm air bearing could generate over 30 grams of sheer force on the flexible film across the 50mm direction. 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 by acting on both sides of the web simultaneously. Because of the high relative pressure (1 to 3 atmospheres) and such 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 increasing 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. There are two reasons for this: First, there isn't a lot of contact between a film and a roller, as both have surface roughness that greatly minimizes actual contact between the film and roller; and second, it leaves an insulating air layer. As the roller and the film are driven at the same speed, this layer is stationary relative to the roller and the film. At higher speeds more air is entrained though dynamic effects so the layer gets thicker but is still static with respect to the roller and film.

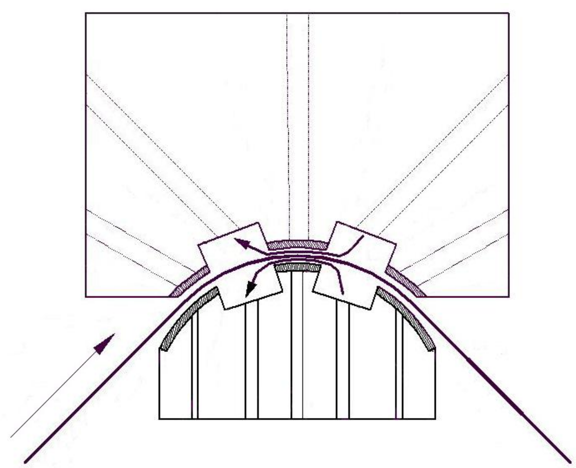


FIGURE 6.

OTHER FUNCTIONALITIES

This same sheer 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. The illustration makes the point that cleaning and drying can happen in immediately sequential and contained processes, dramatically reducing the space used in cleaning and drying today.

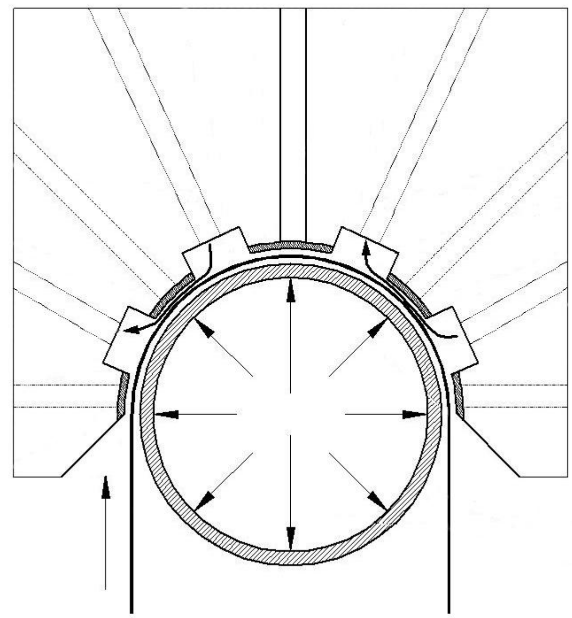


FIGURE 7.

CLOSING COMMENTS

It is recognized that air knives and air bars for turning and drying webs are not new. What New Way is now offering is higher pressure/lower flow web handling components that create much higher gas velocities relative to the film surface. The smaller gaps associated with this technology also reduce flows, and increase the precision with which the web may be handled.

REFERENCE

[1] United States Patent US 8,123,868 B2 Devitt