

Impact of Flotation Nozzle Design on Web Handling

Abstract

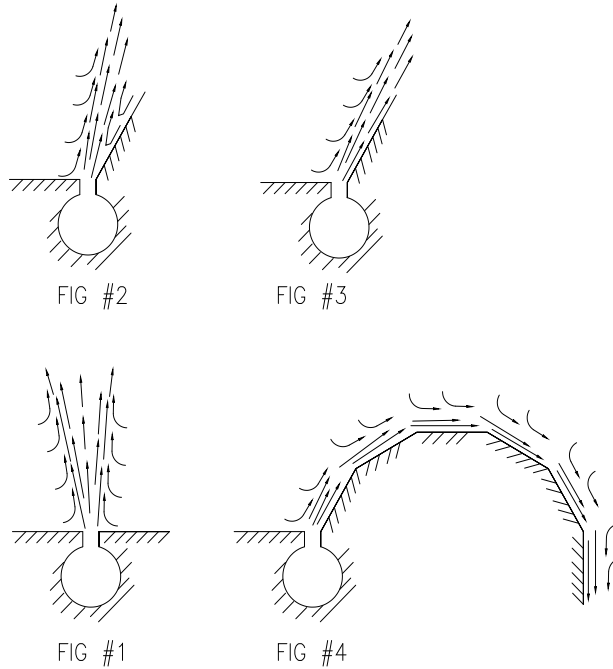
A number of different flotation nozzle designs are available and each is appropriate for application depending on the web handling issues facing the user. Flotation nozzle designs suitable for one or two sided transport are available. The impact of flotation clearance, the benefits of a flat or curved form of transport, the influence on web tracking, the need for tangential devices resulting from frictionless transport and how these nozzle designs need to differ based on location/use in the machine are all important. In some cases flotation is not the correct choice.

To accomplish web flotation it is necessary to make use of the Coanda Effect. A basic understanding of the Coanda Effect is useful for anyone wishing to float a web. Let's first consider a simple case of two-dimensional flow. In Figure #1 is a plenum chamber with an exit slot leading to a larger volume. If the fluid in the plenum has a higher pressure than that on the opposite side of the slot, the plenum fluid will emerge from the slot to produce an air jet. The boundaries of this jet will normally be turbulent at some distance from the slot. These turbulent boundaries swirl and entrap molecules of the surrounding air, imparting momentum to these entrapped molecules at the expense of the jet's momentum. The velocity of the jet will also produce a low pressure at the jet boundaries tending to enhance the induced flow into the jet.

At the slot, the jet will have a definite momentum, a product of the mass-flow and velocity, which can be determined by the area of the slot and the pressure drop across it. As mixing takes place between the jet and the ambient air, the jet broadens out. As this happens, the average velocity decreases and its average mass increases until, at some distance from the slot, the jet itself disappears in random molecular motion.

All of this is very conventional and can be found in most books dealing with fluid dynamics. Henry Coanda found that if we introduce a boundary on one side of the emerging jet a non-symmetrical nozzle is created and something unusual begins to happen. In Figure #2 we can see that the induced flow into the emerging jet will be hampered on the side where the new surface has been introduced. The induced flow into the jet will rapidly evacuate the ambient molecules from the space between the slot and the new surface, creating a low pressure region. This low pressure region (in a two-dimensional model) cannot be relieved by additional ambient air because of the physical restriction of the surface. This region of pressure causes the jet to be deflected toward the surface, as in Figure #3. This further reduces the pressure between the jet boundary and the surface, which in turn leads to further deflection of the jet toward the surface. Finally, and very quickly, the jet lies right on the surface.

At some distance along the surface, the jet can be caused to turn again by changing the direction of the surface. Figure #4 shows the jet being turned 180 degrees by successive surfaces.



So how does the Coanda Effect help us float a web?

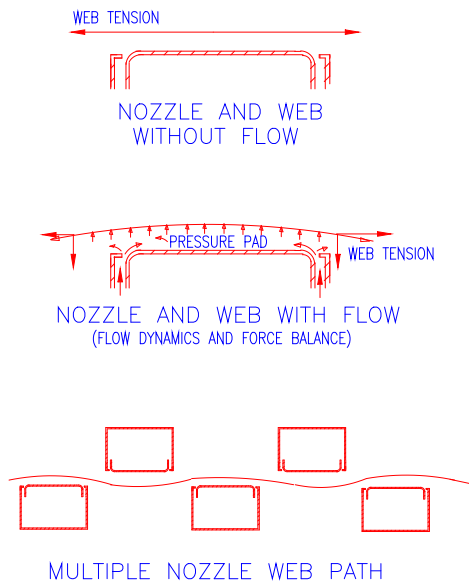


FIGURE 5

Figure #5 shows the positioning of two opposed Coanda Effect slots separated by a metal plate and opposed by a web. As a result of capturing the turbulent jet and induced air a cushion of air is created between the flotation nozzle and the web allowing non contact levitation. When these flotation nozzles are positioned in an alternating configuration a web can be transported in a sinusoidal path along almost infinite distances.

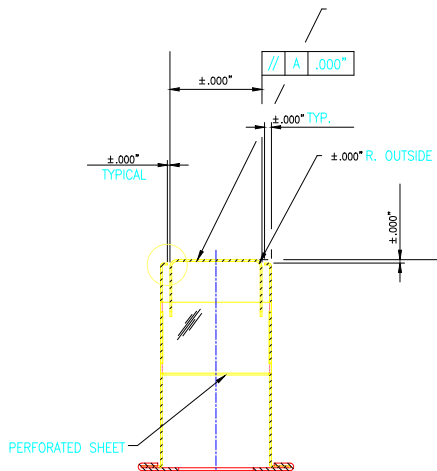
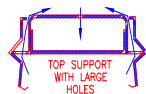
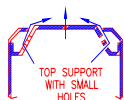


Figure 6

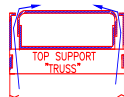
While it appears easy enough to position two Coanda radii air jets opposing each other there are several key dimensions which must be exactly matched to each other to produce a nozzle that will transport a web without severe flutter and the possibility of the web touching the metal surfaces of the nozzle. Those key dimensions are labeled in Figure #6. A perforated plate should always be used to allow even air distribution throughout the nozzle, in a cross web direction. Even air distribution is especially important when flotation nozzles are used to dry a web. Placing the perforated plate at a proper distance from the slot discharge insures that pressure peaks and valleys are eliminated instead of worsened.



TOP SUPPORT WITH LARGE HOLES



TOP SUPPORT WITH SMALL HOLES



TOP SUPPORT "TRUSS"

HOLES CAUSE PRESSURE PEAKS AND VALLEYS

Figure #10

PRESSURE PROFILE USING A PROBE 1/8" BELOW THE NOZZLE SLOT GAP WITH AIR PRESSURE @ 4" W.G.

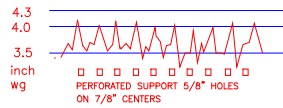
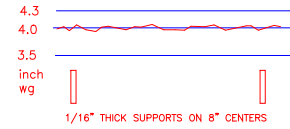


Figure #11

Figure #10 and #11 illustrate what can happen if a flow distribution perforated plate is placed too close to the slot discharge area.

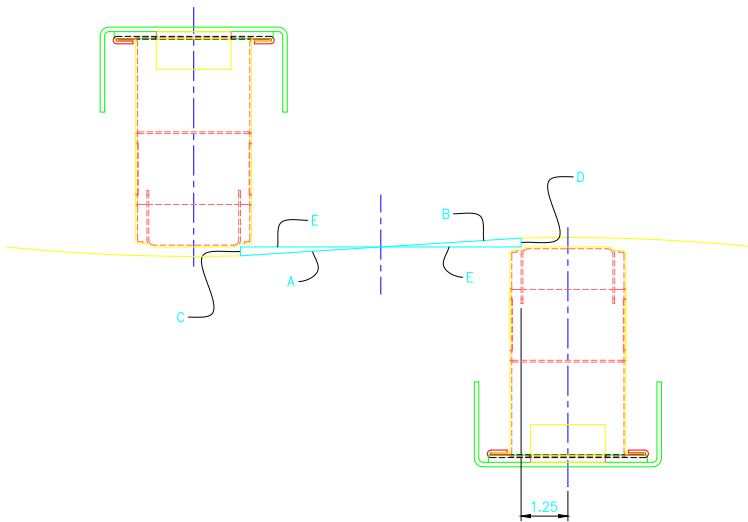


Figure #7

Proper design of a flotation nozzle for flotation clearance, figure #7, can be exactly predicted once a nozzle air velocity and web tension are chosen. This clearance can be varied as desired by changing either the web tension or air velocity.

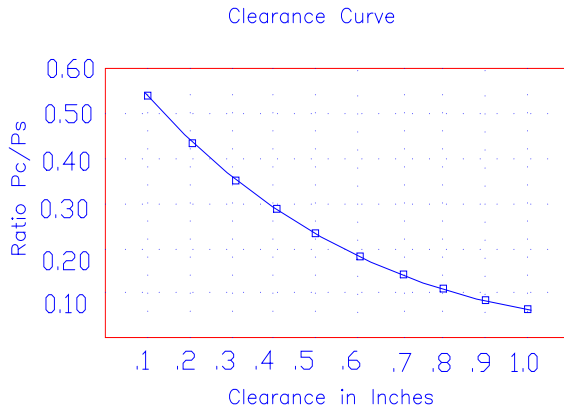


Figure #8

The reason flotation clearance can be determined so accurately is a result of the predictability of the nozzle "cushion pressure" as it relates to air supply pressure entering the nozzle cavity. Figure #8

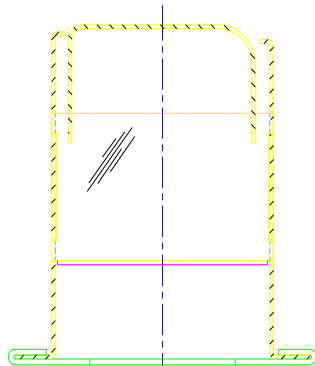


Figure #9

In some cases a non-symmetrical nozzle design is suitable if a modest unidirectional flow benefits the system design. This design is sometimes used at the entry and exit of a dryer to minimize the possibility of hot air escaping from the insulated dryer enclosure.

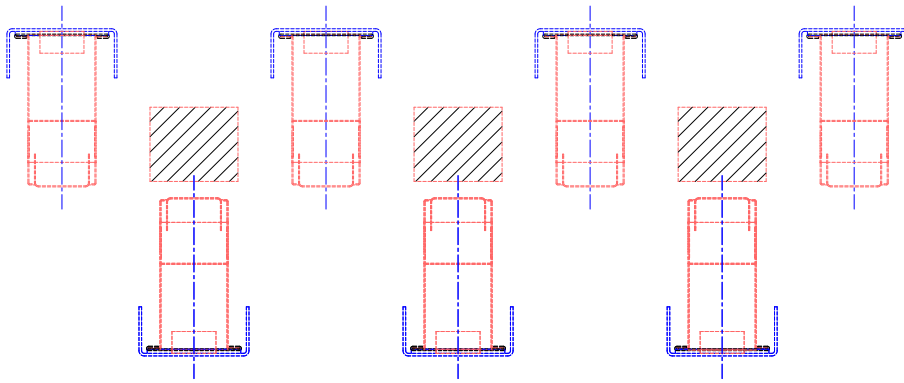


Figure #12

In some cases a web needs to be heat treated without contact. Infrared modules can be placed between flotation nozzles, Figure #12, without disturbing the flotation path. Other energy sources such as ultraviolet or radio frequency can also be used like the infrared placement.

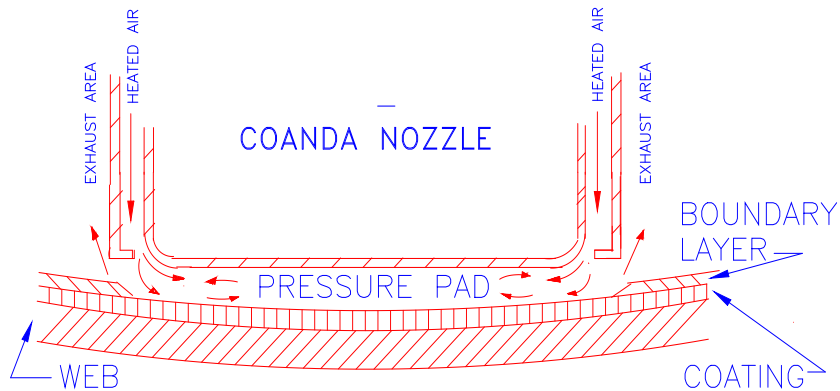
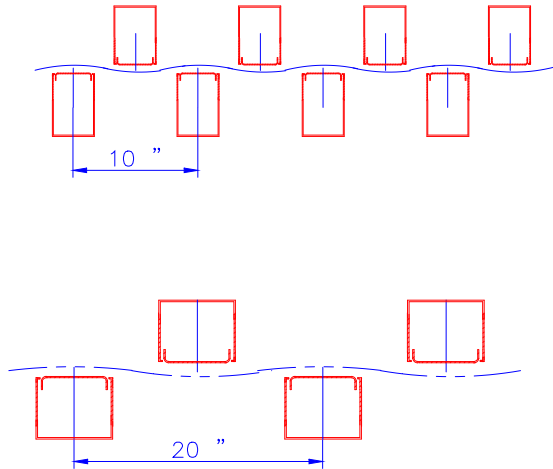


Figure #13



A FLATTER WEB HAS LESS TRACKING PROBLEMS

Figure #14

Earlier we discussed the need to precisely match the Coanda Effect radius size with the distance between the opposed slots and the "Z" direction distance of the slot discharge to the metal plate separating the two slots (Figure 13). The matching of these dimensions can be "scaled" (Figure #14) to allow different sizes of flotation nozzles suitable for different uses. For instance, if a metal plate approximately 2.5" inches is chosen, stable flotation heights up 1" will can be achieved. With a 5" plate a stable flotation height of 2" is achievable and with a 10" plate a clearance of 4" can be obtained. Different sizes of flotation nozzles are necessary because of the various needs of different webs. Webs ranging from very thin films to thick metal coils can be transported using flotation technology.

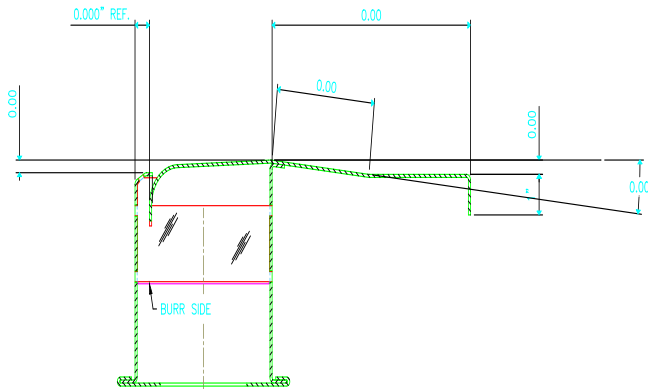


Figure #15

In some cases flotation is required without air movement on one of the two sides of a web. In that case an "airfoil" nozzle is the only choice available. When the "airfoil" nozzle design is opposed by a web, the web bulges at the point of the positive pressure jet discharge and entrained air, resulting from the Coanda radius. When a single jet flotation nozzle (Figure #15) has a Coanda Radius the air flow is unidirectional, it causes a positive pressure in the area of the slot discharge. The air travels across the face of the nozzle eventually discharging, causing a negative pressure at the point of relief. The opposed web, then, has a curvature away from the nozzle near the slot discharge and towards the nozzle at the point where the air leaves the face of the nozzle. This positive and negative pressure effect allows a web to float without an opposing nozzle

(force) as is needed with the pressure pad design. The "airfoil" flotation alternative offers many advantages especially when flotation is used with drying solvent based pressure sensitive adhesives where any air impingement on the coated side of the web has the possibility of creating coating flaws.

Unfortunately, the "airfoil" type of nozzle design requires a small flotation clearance in order to perform properly. The maximum clearance cannot be varied based on web tension but rather the flotation clearance will always be approximately the same as the air jet size. Most webs have some flutter in them entering the flotation section of a machine and having a web clearance of only 0.110 to 0.150" produces intermittent web touching on the metal nozzle surfaces. Because a web touching the metal surfaces is not acceptable, airfoil flotation nozzles are usually only applied when single sided flotation is absolutely necessary for process reasons. Airfoil nozzles can be "scaled" just as pressure pad flotation nozzles but overall mass air flow needs to be taken into consideration causing energy use issues.

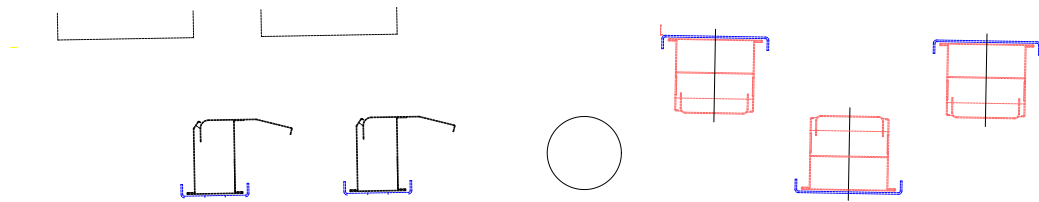


Figure #16

In some applications a combination of both the airfoil and the pressure pad flotation design is advantageous. (Figure #16)

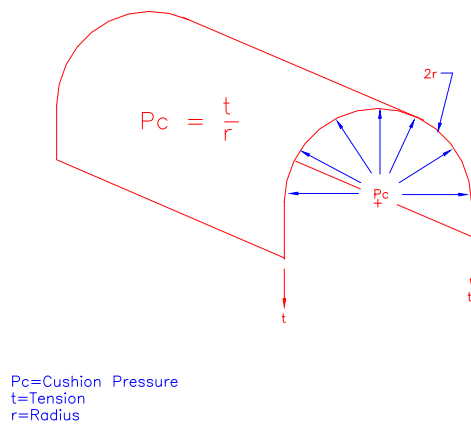


Figure #17

Nozzle cushion pressure versus web tension is well known. When details of the web tension and cushion pressure are combined with the known curvature of a web over the face of a pressure pad style nozzle, a web can be turned. (Figure #17).

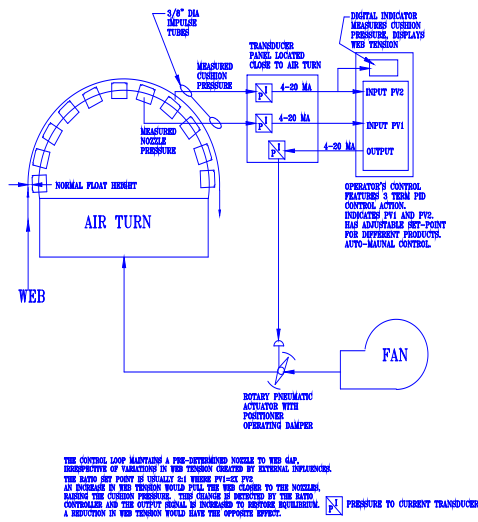
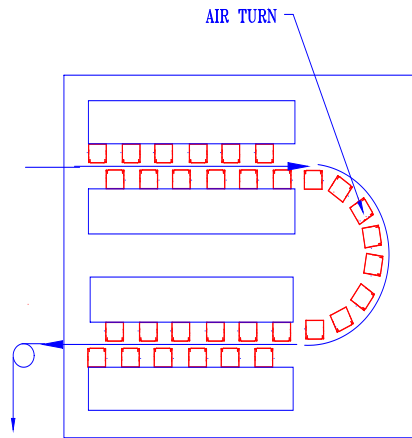


Figure #18



MULTI-PASS DRYER

Figure #19

The use of air turning devices provides additional options to non contact transport of webs (Figure #18 and #19).

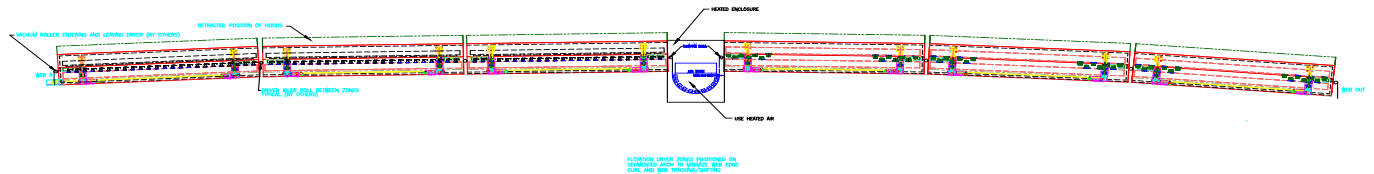


Figure #20

Figure #20 depicts a flotation system which makes use of both air foil flotation nozzles, pressure pad flotation nozzles and air turning devices. Since many webs, especially films, have a built in "banana shape", the webs tend to "track" in one direction or the other. When a long flotation system is required, having the benefit of steering a web through the use of an airturn provides tremendous advantages (Figure #20).

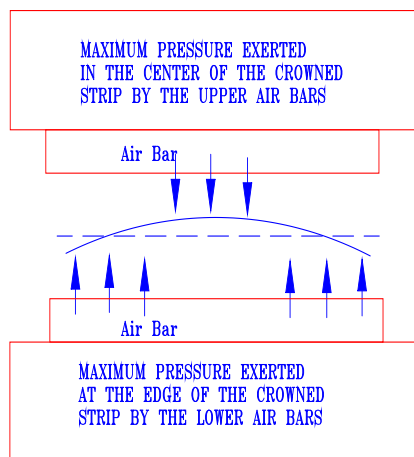
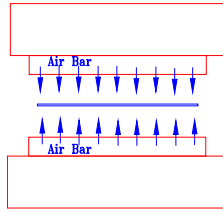
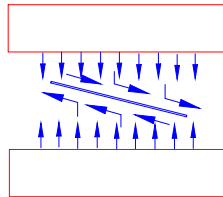


Figure #21



Strip Chamber
Flotation Oven



Strip Chamber
Catenary Oven

Figure #22

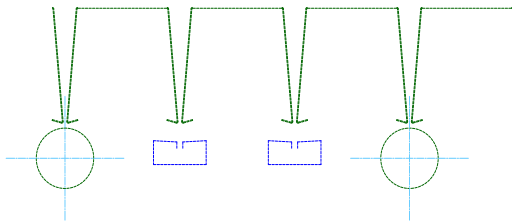


Figure #23

In some cases when severe web curl exists or in the case of a metal strip web that "bounces" (Figure # 21 and #22) flotation can only resist the mechanical forces of the web modestly. In those cases the use of rollers are needed such as shown in Figure #23 (slot impingement without flotation) and Figure #20 (flotation system).

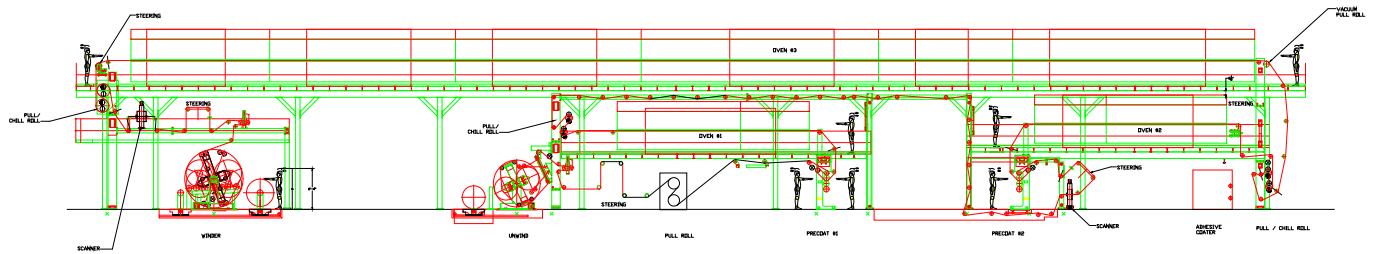


Figure #24

Figure #24 shows a typical web coating line that uses flotation combined with drying.

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