ISSUE FOCUS: FORMING

Modified Foil Blade Design Improves Forming Table Drainage, Turbulence

Enhancement of conventional foil blade design allows better forming table
Activation on fourdriniers without typical corresponding drainage increases

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Drainage, turbulence, and sheet formation are inextricably linked during the papermaking process on fourdrinier machines. Good sheet formation requires the proper level of turbulence at the proper table position and at the proper timing intervals. Conventional foil blades have inherent limitations in that the design parameters (such as blade angle, blade length, and foil blade spacing) that influence turbulence have a corresponding influence on drainage.

Drainage and turbulence are linked such that the final fourdrinier table design is often a compromise between achieving an acceptable level of micro-turbulence but without excessive drainage at a particular table position. A new modified foil blade (Figure 1), called a Turbo Blade (manufacturing by Weavexx), breaks the link between turbulence and drainage of conventional foil blades and provides new opportunities for optimizing the design of the fourdrinier table.

FORMATION AND RETENTION. It is an old adage in papermaking that sheet formation and retention are opposing factors. That is, those things that tend to improve sheet formation tend to decrease retention and vice versa. A corollary to this is: those things that tend to improve micro-turbulence tend to increase drainage. This is expected as the forces that generate turbulence and enhance formation on the fourdrinier table are the same forces that affect drainage.

However, these two factors – turbulence and drainage – can act as opposing influences in achieving an optimal foil table setup for good sheet formation. This is particularly true since changes made at a given table position not only have good local effect at the particular table position but also have global effect on the drainage and turbulence at subsequent positions downstream.

DRAINAGE AND TURBULENCE. Figure 2 shows the drainage and turbulence characteristics of a conventional foil blade as the divergent foil blade angle is changed. Notice that drainage and turbulence are linked. Blade angles that increase or decrease turbulence cause a corresponding increase or decrease in drainage.

A similar link between drainage and turbulence can be shown for foil blade length, foil blade spacing, machine speed, sheet consistency and any other parameter of a foilized table. Except for changes in fabric tension, anything done to a foilized table to affect turbulence will have a like effect on drainage. Table 1 shows these relationships.

The link between drainage and turbulence carries over to the overall table design (Figure 3). The drainage and turbulence profiles parallel each other on a typical fourdrinier table. There is a one-to-one relationship between drainage and turbulence on standard foilized tables.

Optimal sheet formation often requires a turbulence profile as shown in curve A (Figure 4) and drainage profile as shown in curve B. The drainage and turbulence profile displayed in Figure 4 shows a retardation of drainage relative to the level of turbulence at the early part of the table. This is exactly the drainage

FIGURE 1: A new modified foil blade, called the Turbo Blade, breaks the link between turbulence and drainage associated with conventional foil blades by providing a mechanism for retarding drainage. This allows the use of foil blades to increase turbulence without a corresponding increase in drainage.

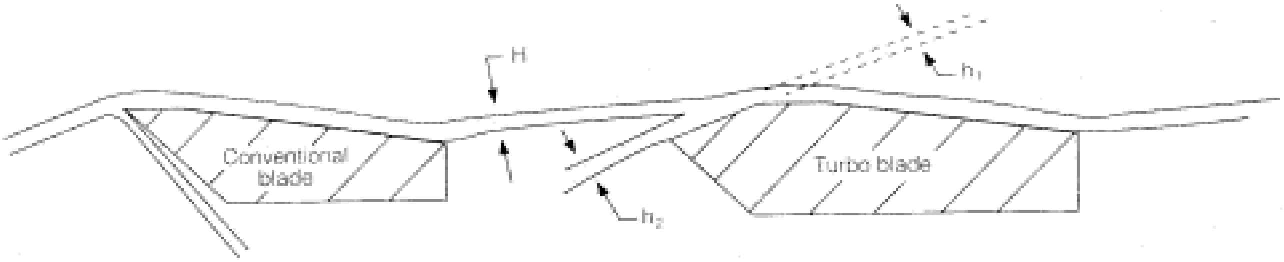


FIGURE 2: Use of a conventional foil blade links drainage and turbulence, which is shown in the drainage and turbulence characteristics of a conventional foil blade as the divergent foil blade angle is changed. Blade angles that increase or decrease turbulence cause a corresponding increase or decrease in drainage.

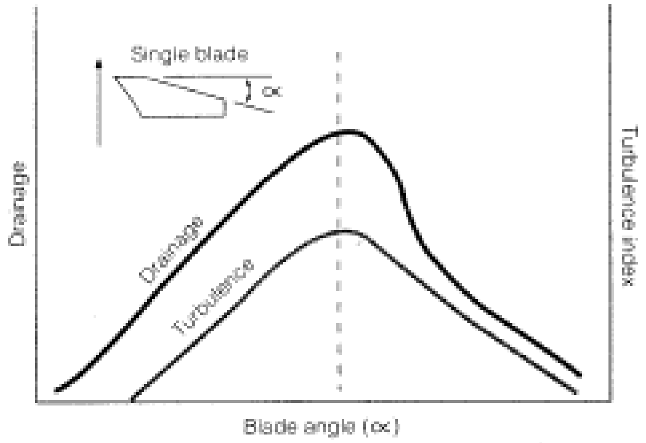


FIGURE 3: On a standard foilized fourdrinier table, the drainage and turbulence profiles parallel each other.

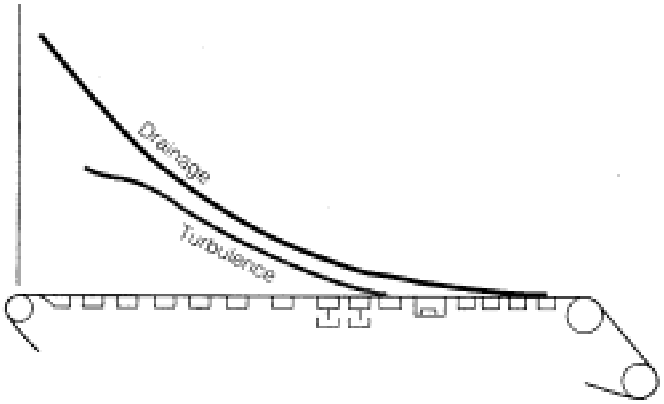
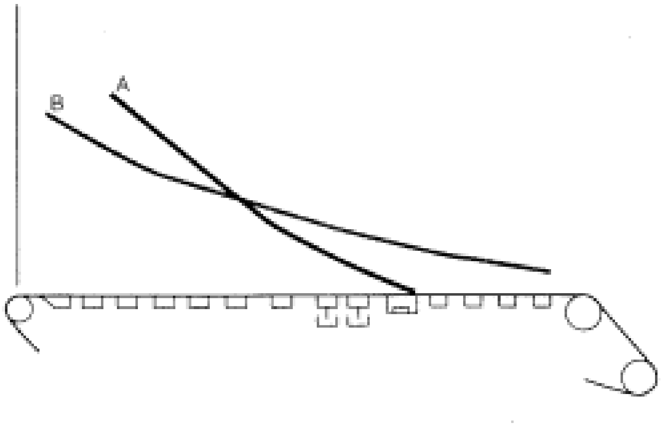


FIGURE 4: Optimal sheet formation often requires a turbulence profile as shown in curve A and drainage profile as shown in curve B. This drainage and turbulence profile shows a retardation of drainage relative to the level of turbulence at the early part of the table.



and turbulence profile needed for optimal sheet formation on most fourdrinier type machines and the Turbo Blades provide a mechanism for achieving it.

BREAKING THE LINK. The new modified foil blades break the link between turbulence and drainage associated with conventional foil blades by providing a mechanism for retarding drainage. This allows the use of foil blades to increase turbulence but without a corresponding increase in drainage. Figures 5A and 5B show the difference in operation between a conventional foil blade and modified blade.

With conventional foil blades, all of the water extracted by blade A and presented to blade B is doctored off by the leading edge of blade B. H_1, the thickness of the layer of water doctored off by foil blade B.

With modified blades, part of the water extracted by blade A and presented to blade B is put back into the sheet. This has the effect of retarding drainage:

$$H_1 = h_1 + H_2$$

The relationship between h_1 and h_2 is a function of the convergent angle *B* and is shown in Figure 6.

This relation is, of course, contingent upon the condition that $L \times \tan B > H_1$. That is, that the position of the leading edge of the convergent nip of the Turbo blade is at or below the layer of water extracted by the previous foil blade. Note that for a modified blade with a convergent angle of 28°, 50% is reintroduced into the sheet. These percentages may vary slightly depending on the resistance of the forming fabric and the consistency of the sheet.

PRINCIPLE OF OPERATION. The action of a modified blade can be likened to directing a hose at a brick wall. If the wall is perpendicular to the stream of water, 50% of the water will be deflected up and 50% will be deflected down (Figure 7A).

If the angle of the stream of water relative to the wall is changed (Figure 7B), the amount of water directed upward and the amount of water directed downward also changes. The relationship between h_1, the amount

TABLE 1: Except for changes in fabric tension, any change in the parameters of a foilized table will have a like effect on drainage and turbulence.

Parameter	Drainage	Turbulence
Blade Angle	Increase	Increase
Blade Spacing	Decrease	Decrease
Blade Length	Increase	Increase
Machine Speed	Increase	Increase
Sheet Consistency	Decrease	Decrease
Fabric Tension	Increase	Decrease

All relations shown are for foil blades operating with blade angles smaller than the maximum drainage angle, i.e., on the left-hand side of the curve shown in Figure 1.

deflected upward; h_2, the amount deflected downward; and H can be described as follows:

$$h_1 = H_1 (1 + \cos B)$$

$$h_2 = H_1 (1 - \cos B)$$

The modified blade application differs from the brick wall analogy in that the portion of water directed upward (h_1) is resisted by a fabric and fiber mat. A portion of this upward directed water (h_3) is redirected downward again according to the convergent turbo nip angle, such that $h_3 + h_4 = h_1$. This redirection of the water layer imparts energy to the sheet by converting the kinetic energy in h_1 into a hydraulic pressure force (Figure 7C).

The hydraulic impulse force generated by the change in momentum of the h_2 layer of water is dependent on the divergent angle of the preceding blade (amount of water presented to the modified blade), the machine speed, and the angle *B* of the convergent nip of the modified blade. This force can be expressed as follows:

$$F_1 = p/gh_1\ \mu \sin B$$

Where:

$H_1 = H/2 (1 + \cos B)$

P = Density of water

G = Gravitation constant

h_1 = Thickness of layer directed at the sheet

μ = Wire speed

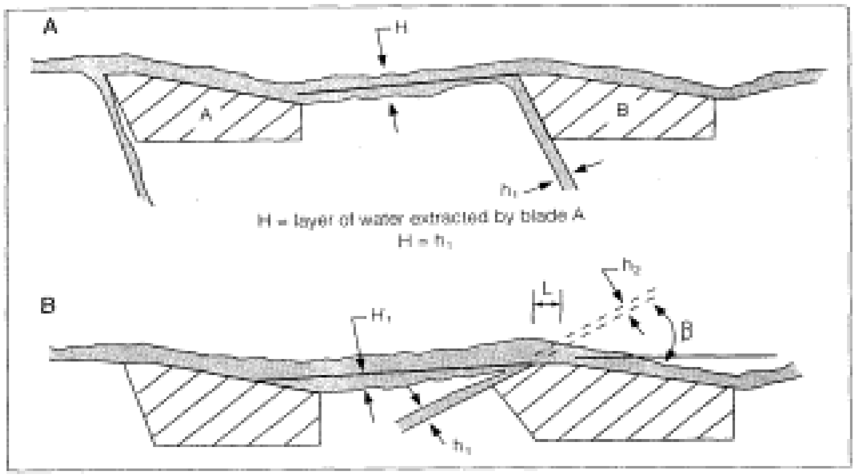
B = Turbo angle

H = Layer of water extracted by previous foil blade

The sheet experiences only a part of this force, as some of it is absorbed by the forming fabric medium such that:

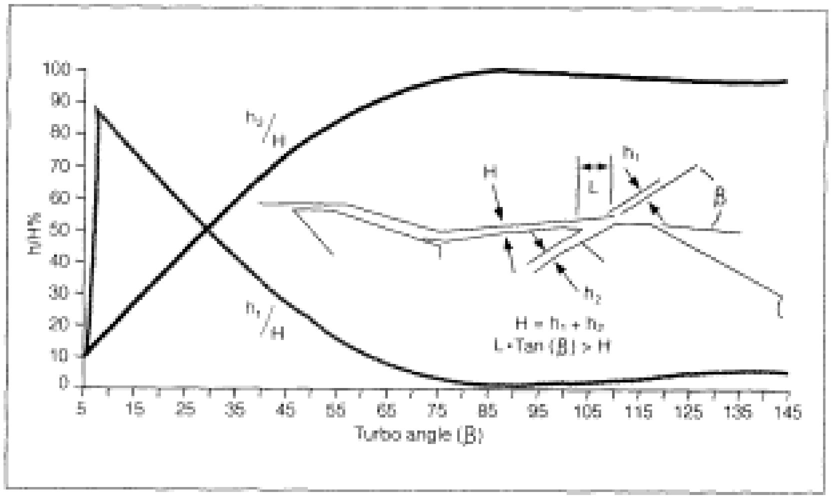
$$\frac{F_{trans}}{F_1} = \frac{CFM^1}{1000}$$

FIGURES 5A & 5B: **With conventional foil blades, all the water extracted by blade A and presented to blade B is doctored off by the leading edge of blade B (5A). With modified foil blades, part of the water extracted by blade A and presented to blade B is put back into the sheet, which has the effect of retarding drainage (5B).**



$$F_{(slurry)} = CFM \times F_1$$

FIGURE 8: **Modified foil blade drainage retardation efficiency, based on the design shown in Figure 5B.**



1000

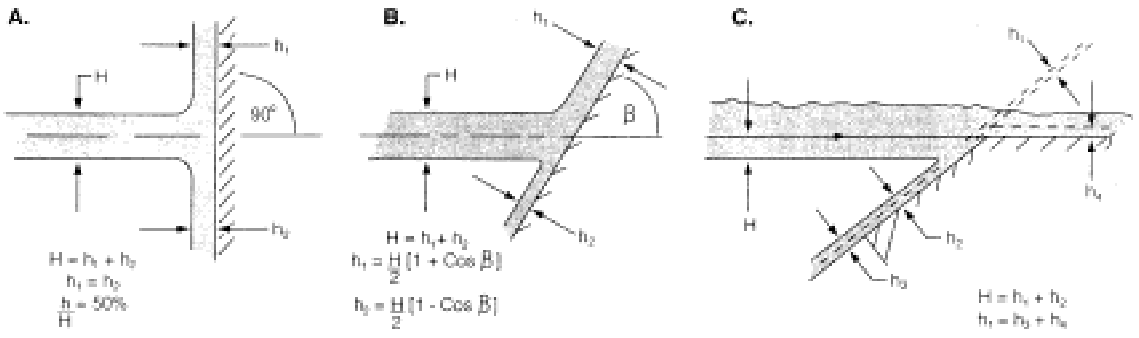
Figure 8 shows the relation between the hydraulic impulse force (F_1) and the turbo angle *B* for a paper machine running at 2,000 fpm and presenting 12 gpm/in. to the modified blade.

Notice that the maximum impulse force occurs at a turbo angle of 60°, an angle much greater than the angles that give highest drainage retardation shown in Figure 6. The actual turbo angle used for any application will depend on many factors, not the least of which are the relative merits of retarding drainage versus high impulse force for the particular application.

BLADE SPACING. Foil blade spacing has a major influence on the level of turbulence generated over a bank of foil blades and, therefore, on the formation of the sheet. Closer blade spacing has a threefold effect:

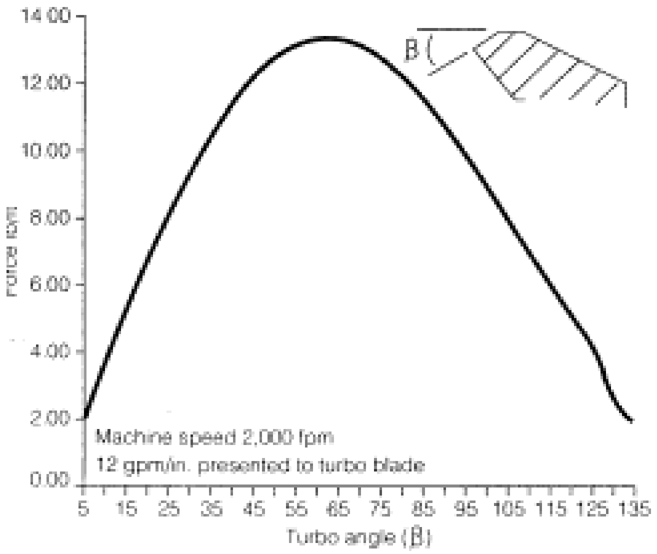
1. Larger acceleration forces on the fabric/slurry as it travels over and deflects down/between successive foil blades.
2. Higher impulse frequencies operating on the sheet. This is conducive to preventing reflocculation.
3. A finer scale of turbulence, i.e., more micro-turbulence peaks per unit area. (Blade spacing and scale of turbulence are approximately inversely proportional.)

FIGURE 7A, 7B, 7C: The action of the modified blade can be compared with directing a hose at a brick wall. If the wall is perpendicular to the stream of water, 50% of the water will be deflected up and 50% will be deflected down (7A). If the angle of the stream of water relative to the wall is changed (7B), the amount of water directed upward and the amount of water directed downward also changes. In the modified blade application, the portion of water directed upward (h_1) is resisted by the fabric and fiber mat. A portion of this upward directed water (h_3) is redirected downward, again, according to the convergent turbo nip angle, such that $h_3 + h_4 = h_1$. This redirection of the water layer imparts energy to the sheet by converting the kinetic energy in h_1 into a hydraulic pressure force (7C).



Closer blade spacing, however, implies more blades per unit forming length, and, again, thought should be given to excessive drainage. Modified blades can provide a mechanism to offset the associated increase in drainage when using more blades at closer blade spacing to increase the level of micro-turbulence on the table.

FIGURE 8: **A graph shows the relation between the hydraulic impulse force (F_I) and the turbo angle β for the paper machine running at 2,000 fpm and presenting 12 gpm/in. to the modified blade.**



The percentage drainage retardation of a single modified blade is shown in Figure 6. The actual percentage drainage retardation for a bank of modified blades will be somewhat less because foil blades are very efficient at removing additional water presented to them.

APPLICATION. Turbo blades have been applied on basis weights and machine speeds from 100-lb./800 fpm to 32-lb./3,200 fpm. The actual configuration and setup depend on many factors. The following are examples:

- A slow-speed machine making a 100-lb./3,300 sq. ft. sheet at 800 fpm might be set up with high outgoing blade angles (3° and 4°) and shallow ingoing turbo angles. The high outgoing angle will generate the maximum level of micro-turbulence, and the shallow turbo angles will provide a high level of drainage retardation.
- A medium-speed machine making linerboard at 1,700 fpm might be set up with low-to-mid-range outgoing blade angles (1° and 2°) but steeper ingoing turbo angles (30° to 60°) to give maximum impulse force to the underside of the sheet.

Whatever the machine speed and grade structure, blades with an ingoing nip at table positions greater than 1.2% sheet consistency should not be used since such conditions are prone to worming of the sheet.

Finally, there is no one best table setup for optimizing sheet formation on fourdrinier paper machines. Optimal table design depends on many factors such as headbox delivery, fiber reflocculation times and stock drainage rates. Each of these factors must be considered in determining the best drainage and turbulence profile down the table for optimum sheet formation.

Turbo blades provide a cost-effective tool for improving sheet formation on fourdrinier machines. When used in conjunction with other sound principles of table design, their use can result in significant improvements in sheet formation.