Wet sheet–open draw transfers on wet process nonwoven lines

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ABSTRACT: Wet–sheet web transfers between process steps are usually of the open draw type on wet–process mat lines producing fiberglass mats and sheets composed of synthetic fibers. These open draw transfers can cause many operational problems and sheet quality defects. Increased line speeds, wider machines, and lighter weight mats often exacerbate these problems. This paper explores factors affecting these transfers and discusses methods to reduce or eliminate their effects to increase operating efficiencies and reduce product quality defects.

KEYWORDS: Fiber mats, nonwovens, open draw, problem solving, web transfer, wet process.

Introduction

The most common operating problems encountered on wet–process mat lines producing glass fiber and synthetic fiber sheets are open draw transfer problems. These are the single largest cause of mat defects and sheet breaks which reduce operating efficiencies. Wrinkles and transfer breaks account for as much as 75% of defects and unscheduled downtime. While some of the problems are symptomatic of other process problems which manifest themselves as draw or transfer problems, it is possible to address many of these through operating procedures or the design of process equipment.

To understand and solve open draw transfer problems, we must understand the dynamics of the transfers and the effects of various factors influencing the transfers. We will start with an "anatomy" of an open draw transfer, examine the geometric and aerodynamic forces influencing web transfers, and then explore various methods of addressing the problems to arrive at some practical solutions.

Open draw transfer

Figure 1 shows a typical web transfer from an inclined wire forming section to the wet web saturator. In this picture, we see the web on the downward slope of the fabric run following the apex roll. The web leaves the forming fabric well ahead of the forming section drive roll. The web then travels unsupported to the lead–in roll of the saturator section. Here the web mates with the saturator fabric which wraps the lead–in roll at this point.

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During this transfer, several forces act on the unbonded wet web and many factors affect it. These forces and factors divide into the following categories:

- The geometry of forces which act on the sheet at the precise point of separation from the fabric
- The "pick–off point" factors affecting the separation force
- The web wet strength factors affecting the tension and energy absorption forces
- The aerodynamic forces which act on the web through the transfer.

Factors affecting web transfers

Geometry of forces

Figure 2 illustrates the three forces acting directly on the web at the point of separation from the forming fabric. The vector diagram shows the geometric relationship of these three forces: the separating force, the tension force, and the energy absorption force. An analysis of the geometry of the pick–off point shows that the tension force is always the greatest at this point. The separation force and energy absorption force are the vector resolutions of the tension force at the point of web separation from the fabric.

We define these geometric forces as follows:

- Tension Force. This is the force generated in the sheet across the open transfer by pulling the sheet or web at a faster line speed than the speed of the forming conveyer fabric and incoming web. This speed differential is

draw. One expresses it as a percentage increase in speed. The speed differential transmits through the web from the saturator fabric.

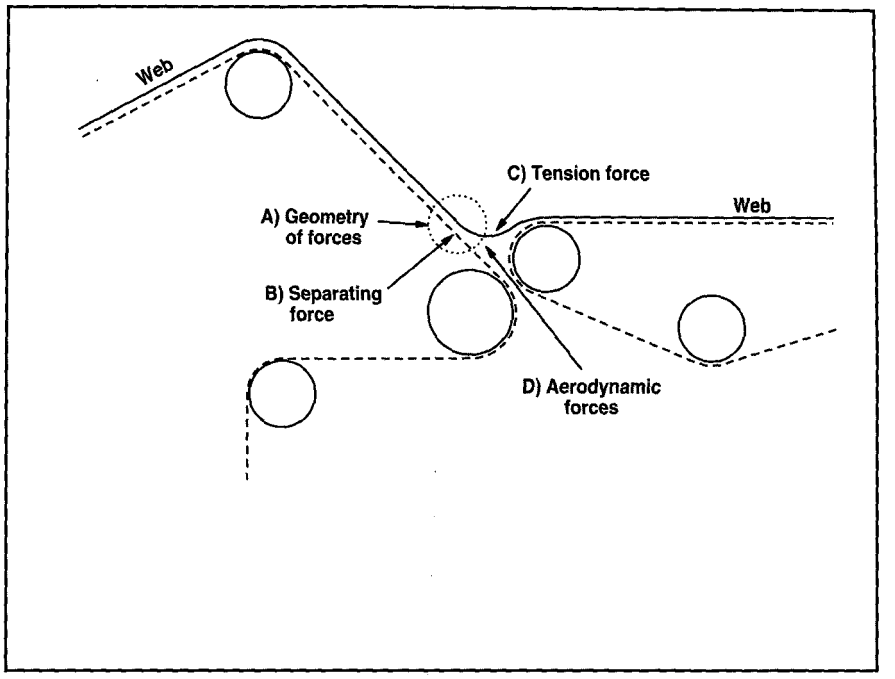
- Separating Force. This is the force required to separate the sheet from the fabric.
- Energy Absorption Force. This is the force which results from resolution of the tension force. A component of the energy absorption force causes a deformation in the sheet structure. The energy absorption force is the energy absorbed in stretching the sheet by the realignment or movement of fibers in the web.

If we examine these forces and their relationship to one another, we can better understand one of the phenomena we sometimes observe at these transfers. If the geometry is not stable, i.e., the web position and point of separation are constantly changing, then we can assume that one or more factors in the web transfer are changing. **Figure 3** shows two draws with two sets of geometric relationships for the forces. In diagram A of this figure, we see the web picks off at a high point and stretches tightly across the draw. This may be the result of either a low separating force required to detach the web from the fabric or a high tension force. This geometry will often appear more stable and will show fewer wrinkles at the transfer partly due to the extra stretch of the web.

In diagram B of Fig. 3, the sheet picks off at a lower point. This gives a steeper angle and results in a higher separating force relative to the tension and energy absorption forces. This may be the result of either a higher separation force requirement or a lower tension force being present. While this geometry may tend to show more wrinkles, it is also likely to cause more internal deformation in the mat.

From this discussion, we see that for a given separation force requirement the tension force necessary may be greater or less depending on the geometry of the transfer. We will discuss geometry in more detail below as part of the practical solution section.

1. An open draw



Tension force

There are two primary factors which affect tension force: quantity of draw and the web wet strength. The quantity of draw is the speed differential between the two sections. It is one of the determining factors in the magnitude of the force generated in the wet sheet. The web wet strength is the capacity of the sheet to absorb energy and resist deformation when subjected to the tension force.

The combination of quantity of draw and the web wet strength determines the absorbed energy in the sheet. This deformation or absorbed energy is always less than the tension force. The sheet will therefore break in the open draw portion of the sheet or at the point of separation. The major portion of the energy is absorbed at the point of separation, i.e., the point of the resolution of forces.

Several factors affect web wet strength as follows:

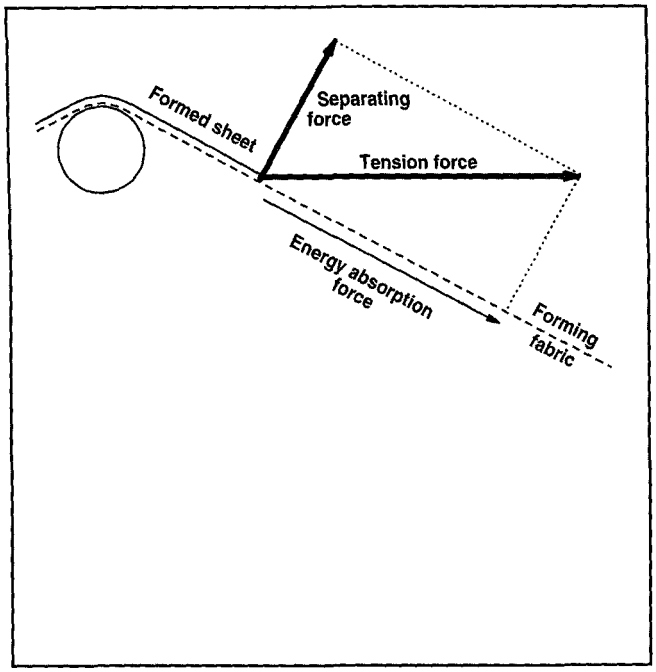
- Fiber length and fiber diameter which determine the number of fibers for a given basis weight
- Degree of fiber dispersion which also affects the number of fiber intersections along the length of a fiber
- Mat weight which has a major effect on the total wet strength
- Formation quality which can also affect the wet strength
- Directionality of formation which affects the energy absorption
- Moisture content and the white water chemistry which affect the strength of the "wet bonds"
- The surface treatment and surface characteristics of the fibers which affect the ease with which they slide over other fibers in the deformation process
- Uniformity of all of the above factors.

Separating force

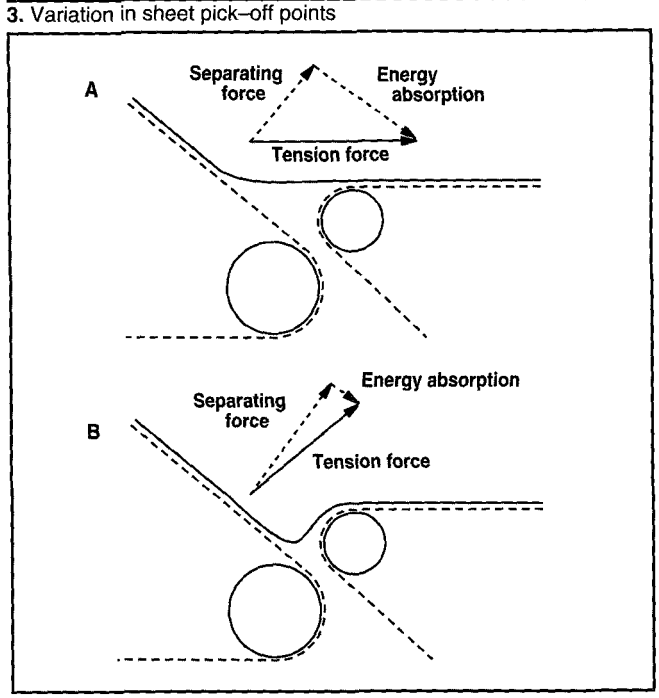
Many factors affect separating force including the following:

- Surface tension and tackiness of white water or fluid
- Surface contact area of the fabric, contact surface characteristics, and openness or air permeability of fabric or web

2. Resolution of forces



3. Variation in sheet pick–off points



- Pick–off point location either over closed roll or open fabric
- Stapling of fibers into the fabric from forming or suction boxes which will cause picking and increase the separating force
- Fiber orientation or formation affecting fiber to fabric contact
- Moisture content of the sheet and the fabric which affect the air permeability of the sheet.

The above factor concerning pick–off point location affects the effective permeability of the fabric. If both the web and the fabric are "closed sheets" with low permeability, air will not penetrate the fabric. A vacuum will form between the sheet and the fabric as the sheet tries to separate from the fabric. This will increase the separating force required.

Aerodynamics

In addition to geometric forces, there are also aerodynamic forces which can act upon the wet web while unsupported in the transfer. These come from many sources and are often difficult to control while still maintaining easy access to the sheet. Some of these sources are as follows:

- A hot oven wire in cooler air will generate air currents due to the expansion of the air.
- A broke chest located below the open transfer is a source of air currents. Changes in the level and agitation of the stock in this chest also generate air currents.
- Medium and high-pressure showers generate air currents.
- A boundary layer builds up along a fabric surface and carries along with each fabric into the pocket created when the sheet contacts the fabric. At this point, the entrained air can cause air pressure to build up and cause the sheet to balloon.
- The same boundary layer will build pressure and force the air through the wire when the wire mates with a roll. This is a more serious condition because the roll also entrains air and increases the pressure buildup at that point.
- Random air currents from doorways and exhaust fans also cause problems.

As speeds increase, the boundary layer entrained air increases dramatically. This is why windage problems increase with speed. **Figure 4** shows a configuration with virtually every type of random air current known. Measurement of the air pressure at point A of this figure inside the transfer triangle was 0.1–0.2 inches in a water column. This pressure caused considerable ballooning and deformation of the sheet.

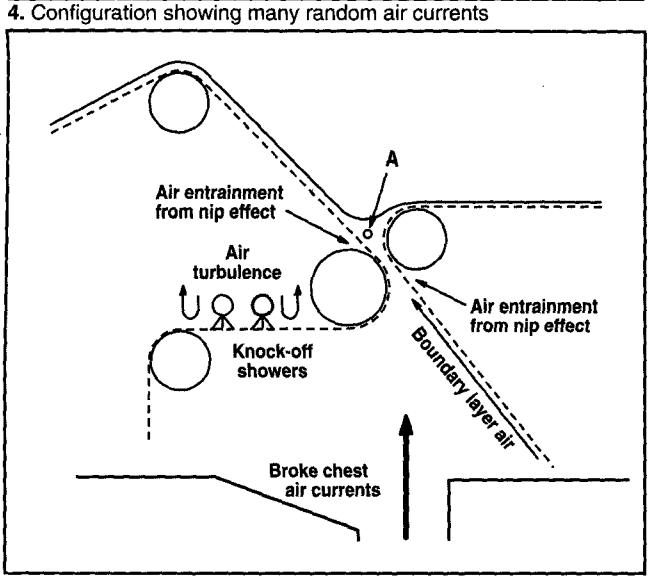
Practical solutions

With an understanding of the dynamics of these open transfers and the factors involved, we can now identify the operating problems and pose solutions. One must also remember that process control factors may appear to be draw problems. The discussion below will address some operating problems and their solutions.

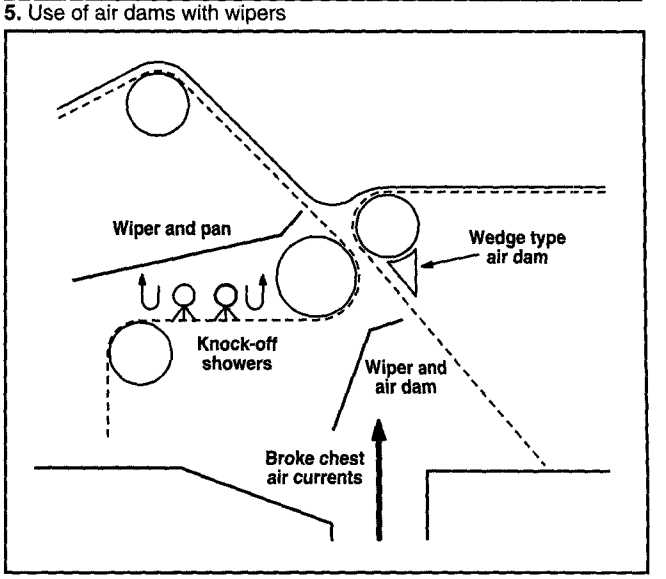
Draw control

Maintaining the speed differential of the two wire sections affects the stability of the draw. If there is poor regulation of the speed of the two fabrics or a variation in speed relative to each other, then the tension force generated will not be stable. If this tension force varies, then the transfer will not be stable and various problems are likely to result.

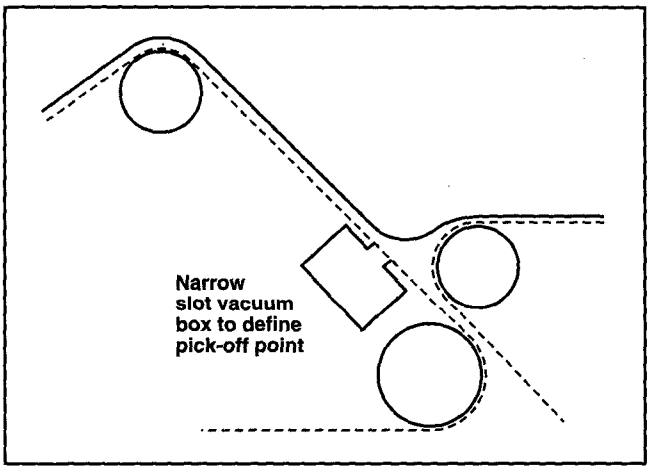
4. Configuration showing many random air currents



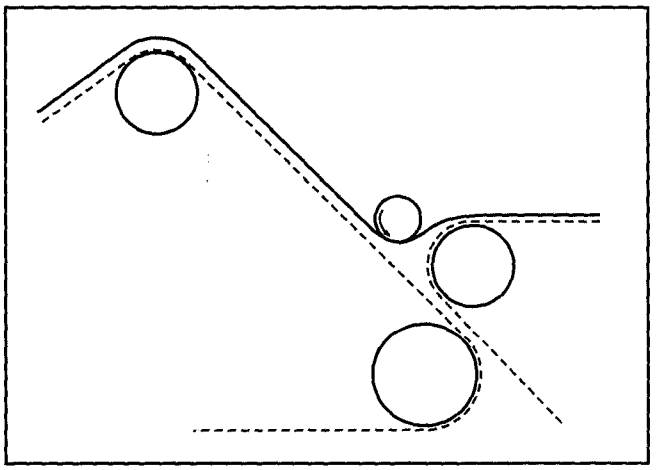
5. Use of air dams with wipers



6. Pick–off vacuum box



7. Transfer stabilization roll



Various draw sensing devices, speed regulation of the drives of the sections, etc., will contribute to the stability of the draws. There has been some use of sensors to determine the location of the sheet in the draw and adjust the relative speed or draw between sections to maintain the position of the sheet.

White water chemistry and microbacteria control will contribute to the stickiness of the fabric and sheet. The sheet wet strength, sheet construction, and geometry discussed previously are factors affecting the energy absorption of the sheet. These require consideration as well.

Wire cleaning, normal wire wear, and wire design are areas of normal process control which will significantly affect the open draws of the process.

Equipment additions and modifications are another solution to problems with open draws. The paper industry has operated at high line speeds for many years and has a wealth of technology for application to the similar processes under consideration here.

For very lightweight sheets such as tissue and tea bag paper and high speeds up to 6000 ft/min, manufacturers eliminate the open draw by using a transfer fabric. The fabric or felt in combination with suction boxes makes a positive, direct transfer of the sheet from one fabric or wire section to another by applying vacuum to the sheet through the pick–up fabric. These sections have precisely matched line speeds. The operation then carries the sheet to the next process step for another transfer. This sophisticated and expensive method in the glass mat industry might be technological "overkill," however. A major operating problem would be the contamination of the forming white water with binder solution as well as the required cleaning of the transfer fabric.

Short of elimination of the draw, the paper industry technology does, however, offer a number of possible solutions which have had successful application on more than one glass mat machine.

Reduction of air currents

Air dams and spoilers have blocked air currents particularly on the oven wires of some ovens. **Figure 5** shows air dams with wipers which corrected some of the air currents encountered in the example shown in Fig. 4. Here a block or spoiler reduces the air entrained in the nip between roll and fabric, and an air dam with wiper blocks the broke chest air and boundary layer air from the saturator fabric. The relative positioning of rolls and fabrics will help reduce the boundary layer air.

Geometric considerations

The positioning of the transfer can help to maximize the separating force for a given tension force in the sheet. We know that a large percentage draw may be detrimental to the sheet structure and properties. We can make process or machine adjustments to improve the transfer geometry. Using a high draw may pull the wrinkles out of the sheet under some conditions. The deformation of the sheet will be higher, however.

Another consideration in the geometry is to minimize the unsupported length of the sheet during the transfer. While the sheet is unsupported, aerodynamic forces as well as gravity and the tension force act on it. Minimizing this length reduces the exposure and the consequent deformation of the sheet.

The paper industry has used two pieces of equipment for years to improve the stability of open draws: pick–off vacuum box and transfer stabilization roll.

Pick-off vacuum box

This technique has frequent use on paper machines to define or fix the sheet pick–off point and to reduce variations due to nonuniform process or sheet properties. As **Fig. 6** shows, the intent is to use a vacuum slot to prevent the sheet from releasing until the exact point where the vacuum releases. This has two distinct purposes. The first is to define the geometry of the transfer. The second is to ensure that the sheet releases at a specific point regardless of process or product variations and nonuniformity. This helps to reduce wrinkles from wet streaks and other process variations.

Transfer stabilization roll

Several glass mat machines have successfully used the transfer stabilization roll shown in **Fig. 7**. The purpose of this roll is to shorten the unsupported length of the sheet and to stabilize the draw by reducing flapping of the sheet. In addition, this roll helps to block air flows in the transfer area and reduce windage problems.

Summary

The open draw transfers on a wet–lay mat–line for synthetic fiber sheets are complex mechanisms influenced by many forces and factors. When problems occur, we should first analyze the conditions to determine if some process variable is the cause. If it is, then take corrective action. We may also study the geometry of the transfer or look for ambient air currents which may contribute to the problems. Finally, we should determine if recent process changes have created a condition which only the implementation of geometry changes or the addition of auxiliary equipment can address. When designing new lines or implementing major changes, one must give open draw transfers careful consideration and make allowances for possible auxiliary equipment which may be necessary.

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