Fabric development for impulse drying

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ABSTRACT

Impulse drying applies heated roll technology using temperatures higher than 150°C to the shoe press technology. With increasing knowledge and understanding of the process, impulse drying is about to emerge into the paper industry and revolutionize the papermaking process. Over the past several years, significant strides in press fabric development for impulse drying have been made. The results of the study will show that, with the appropriate press fabric, pressing at elevated temperatures with extended nip residence time is beneficial for lightweight basestock. Not only does sheet dryness increase, but improvements in other paper properties occur.

Application:

These improvements are certain to impact furnish economics, sheet runnability, and machine speed; these parameters are all critical to the papermaker's profitability.

A COOPERATIVE EFFORT BETWEEN Albany International and Beloit Corp. to develop press fabrics for the impulse drying process has been ongoing for many years. As a result of this work, significant strides have been made in understanding the relationship between the press fabric, the press environment, and the furnish. Furthermore, many of the original problems associated with impulse drying have since been resolved. Modifications to the fabric design, roll surface composition, and use of lower roll temperatures have all contributed to improving impulse drying technology and its readiness for commercialization.

Impulse drying is a pressing process that combines the technology of a single-felted shoe press with a heated roll. With roll temperatures typically greater than 150°C, the layer of the water in the sheet surface contacting the roll is converted to steam, and the water below is heated. Sprague and Burton *(1)* identified a steam front that helps to displace the liquid phase in the sheet and increase sheet solids. By using a shoe press configuration with nip residence times greater than 10 milliseconds, impulse drying takes advantage of not only the extended time at temperature to increase sheet dryness, but also takes advantage of the extended time under pressure to form stronger bonds between the fibers in the sheet.

Recently, impulse drying has been successfully demonstrated on a variety of furnish compositions including lightweight basestock, linerboard *(2)*, newsprint *(3)*, and recycled furnishes *(1)*. With the proper control and understanding of the process, significant improvements in sheet dryness, tensile, internal sheet strength, compressive strength, density, and smoothness have been measured. These improvements can impact the overall papermaking process by providing the following benefits:

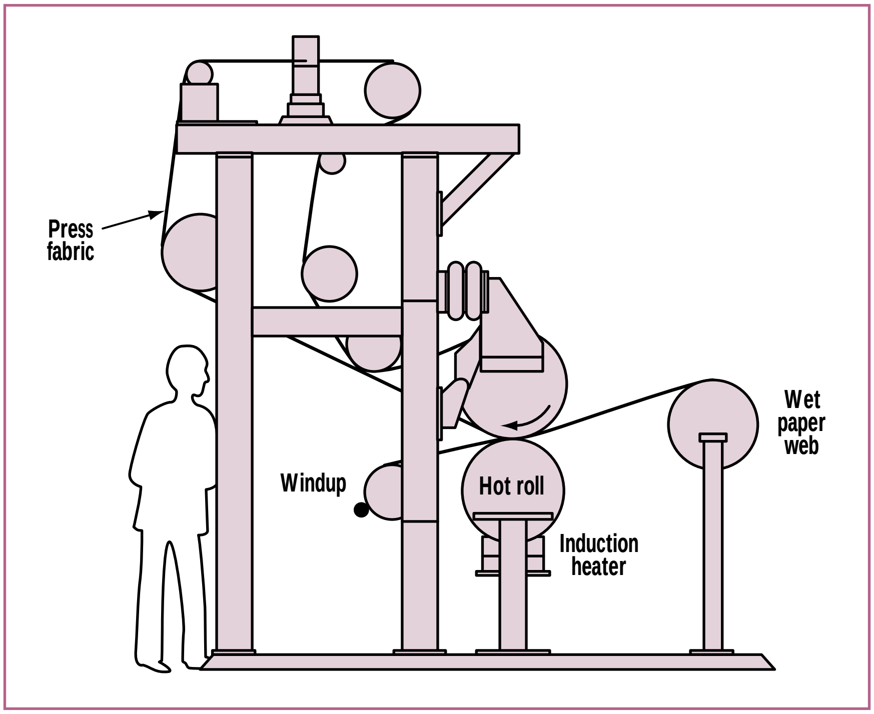
- Furnish savings (a new composition with a higher percentage of recycled or lower-cost pulp)
- Energy savings (increased sheet dryness into the dryer section and a warmer sheet entering the dryers, reducing the warmup zone)
- Improved runnability (a drier and stronger sheet with fewer breaks)
- Capital savings (reduces the number of dryer cylinders required, reduces the length of the machine and building, and reduces the size of the dryer hood and airflow requirements).

Because there are risks associated with any new technology, the fallback position must be sound. With impulse drying, this fallback position is a shoe press at ambient roll temperature that has known benefits in many paper and board grades.

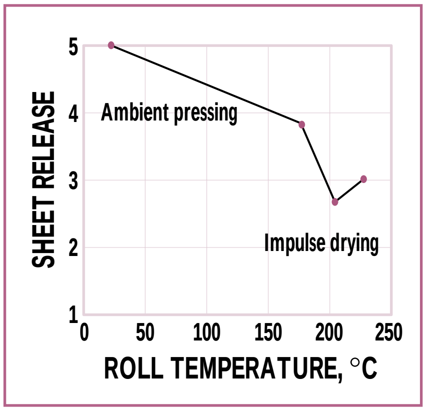
PRESS FABRIC REQUIREMENTS

Press fabrics have been shown to play a critical role in the success of the impulse drying process. Fabrics for impulse drying must meet the same mechanical and chemical resistance requirements as press fabrics for conventional press sections but must survive the extreme temperature conditions. The surface of the fabric must provide a temperature-resistant barrier that can withstand direct contact with the heated roll for extended periods of time. The surface also must promote easy sheet release for good sheet runnability and allow water to penetrate as the sheet is being dewatered. The body of the fabric must provide sufficient void volume to readily accept and hold the water removed from the sheet.

The standard polyamide 6 and 6.6 fibers that are currently used in press fabrics for conventional press sections lack the temperature resistance needed for impulse drying. As an alternative, more exotic, commercially available high-temperature-resistant fibers are being evaluated.



1. Hot-roll press setup



2. Effect of roll temperature on sheet release

CONSTANT PARAMETERS	
Roll surface	Beloit "A" roll
Nip residence time, ms	20
Press load, MPa	4.1
Furnish	50-g/m² lightweight basestock
VARIABLE PARAMETERS	
Press fabrics	Candidate J Candidate M Candidate S
Roll temperatures, °C	22 (ambient) 177 204 227

I. Trial conditions

Although these fibers generally provide adequate temperature resistance required for impulse drying, they are prohibitively expensive, brittle, and fall short on providing good abrasion resistance, sheet release, and dynamic resiliency required for impulse drying. Furthermore, most commercially available high-temperature-resistant fibers are relatively fine in diameter due to their intended applications, limiting their use in press fabrics.

Fabric structure, together with roll temperature and nip residence time, are the most important parameters controlling sheet runnability, sheet dryness, sheet quality, and paper properties. Also important are press load, ingoing sheet dryness, and furnish composition. The performance of the press fabric is controlled by the fiber type, fiber diameter, and fabric structure. Extensive trial work has resulted in press fabric structures that exhibit the appropriate temperature resistance, sheet release for runnability, dewatering capacity, and rewet resistance required for commercializing impulse drying.

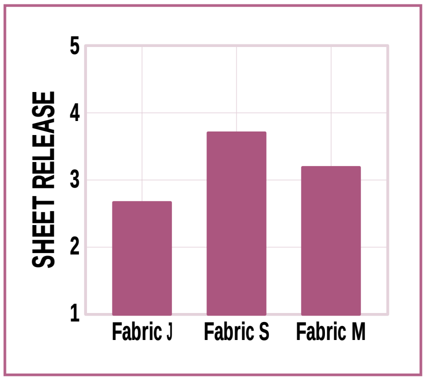
The advantages and disadvantages of impulse drying lightweight basestock handsheets will be discussed, with a specific focus on the effect of press fabric structure. The performance of three fabric structures will be compared, one containing a commercially available material and the other two containing proprietary materials. A lightweight basestock furnish was chosen for the fabric development work because of its sensitivity to the fabric and its potential for sheet property development.

EXPERIMENTAL PROCEDURE

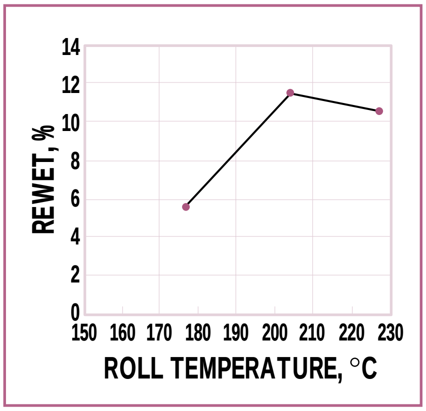
The experimental procedure used to conduct the fabric development study is summarized in **Table I**. This procedure was developed to evaluate new fibers and fabric structures. The procedure uses handsheets that are hand-fed into an impulse drying apparatus such as a heated roll press (HRP).

The HRP (**Fig. 1**) is a high-temperature pressing apparatus used to simulate impulse drying conditions of a shoe press except for the pressure profile, which is a haversine due to the press geometry. The HRP is a single-felted press consisting of an induction-heated plain bottom roll and a vented top roll. The HRP apparatus is useful for continuous sheets, hand-fed handsheets, and fabric evaluation studies.

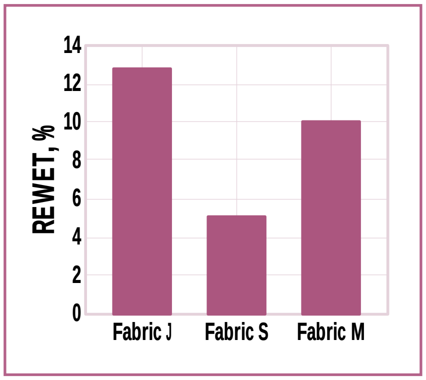
The three fabrics compared in this study (Fabric J, Fabric M, and Fabric S) were part of a single, multisectional fabric. Each fabric was constructed with the same base fabric, an equal number of batt fiber layers, and the same manufacturing procedure. The principal difference among the three fabrics was fiber type. Fabric J was produced using



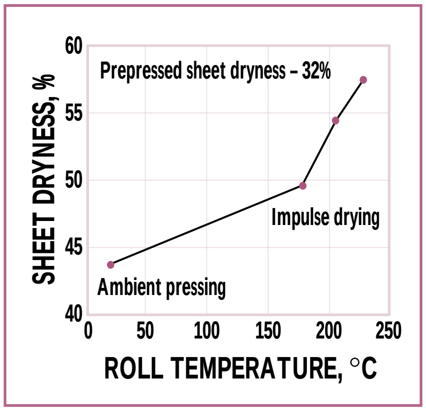
3. Effect of press fabric on sheet release



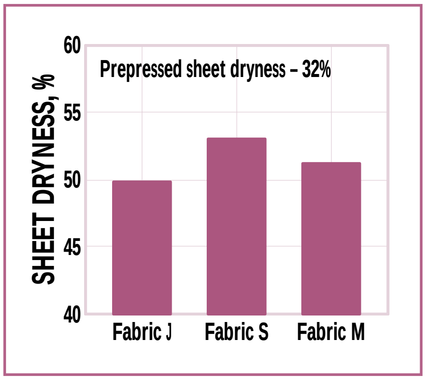
4. Effect of roll temperature on rewet



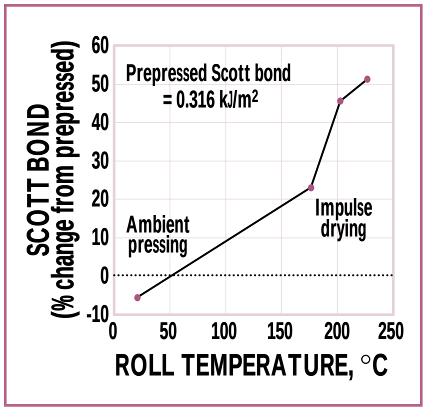
5. Effect of press fabric on rewet



6. Effect of roll temperature on sheet dryness



7. Effect of press fabric on sheet dryness



8. Effect of roll temperature on internal sheet strength

commercially available high-temperature- resistant fibers. Fabrics M and S contain proprietary materials developed to provide high temperature resistance and improve sheet release. Fabric S was further modified to enhance water removal and minimize rewet.

Handsheets used for this study were formed with a commercial furnish that represents a typical lightweight basestock. The furnish, which is reported to be difficult to dewater, is normally converted into paper using a fourdrinier and three roll presses. The furnish was made into 50-g/m^2 handhseets and prepressed to 32% solids using two single-felted roll presses. The handsheets were then hand-fed into the impulse drying apparatus and subsequently dried between two TAPPI blotters using a steam-heated cylinder.

EXPERIMENTAL RESULTS

The fabric evaluation study was designed to measure the following responses:

- Sheet release
- Sheet rewet
- Sheet dryness
- Internal bond strength
- Sheet air permeability
- Sheet smoothness
- Density
- Opacity.

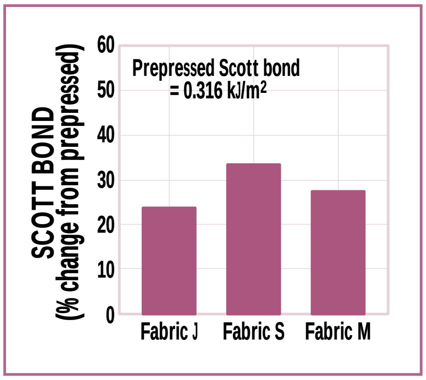
Because a handsheet is free to shrink after it passes through the heated roll nip, tensile properties will vary and therefore are not reported. When a continuous sheet is used and the sheet is constrained in the machine direction, tensile property variation is eliminated and increases in sheet strength are typical.

An analysis of variance was performed on the responses to determine the significant main effects. The results shown in the figures represent values collapsing across the roll temperature of the fabric structure.

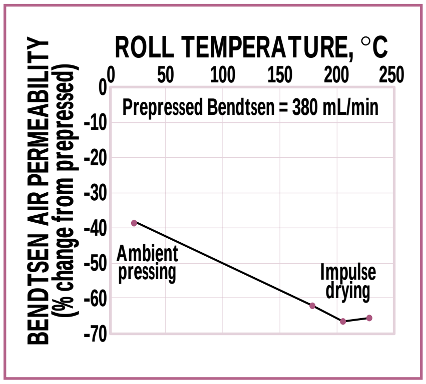
Sheet release

Sheet release from the fabric has been determined to be an important fabric property affecting sheet handling during impulse drying. Two important parameters affecting sheet release are roll temperature and fabric type. As roll temperature increases, the sheet is more difficult to remove from the fabric. Through our work, we have found that sheet release can be controlled by fabric structure.

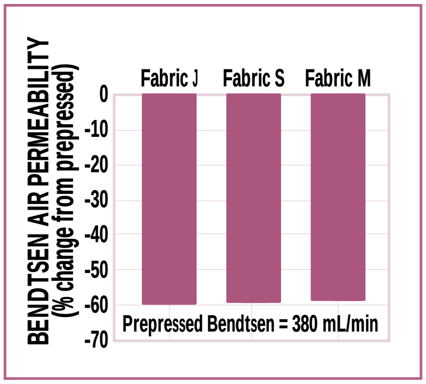
Release behavior relative to roll temperature and fabric structure is shown in **Figs. 2 and 3**, respectively. A release ranking of 5 indi-



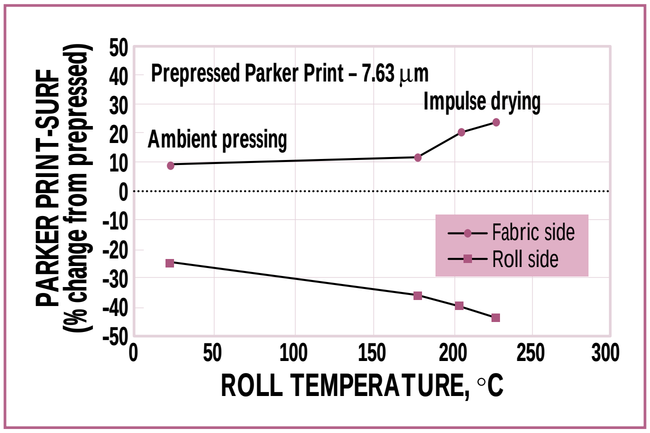
9. *Effect of press fabric on internal sheet strength*



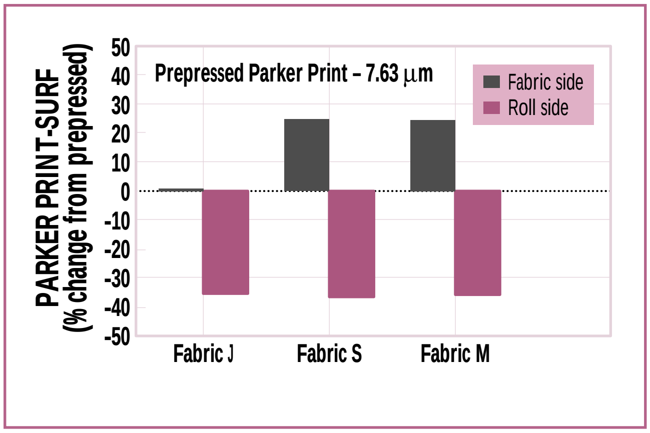
10. *Effect of roll temperature on sheet air permeability*



11. *Effect of press fabric on sheet air permeability*



12. *Effect of roll temperature on sheet smoothness*



13. *Effect of press fabric on sheet smoothness*

cates that the sheet independently released from the fabric, while a ranking of 1 indicates that the sheet adhered to the fabric and could not be removed. Our experiences have shown that a minimum release ranking of 3 is needed to provide acceptable sheet handling for a commercial application. Among the three fabrics tested, Fabrics M and S, which were designed with enhanced surface properties, exhibited acceptable sheet release.

KEYWORDS

Drying, forming fabrics, high temperature, machine clothing, paper properties, presses, properties, separation, shock drying, temperature, water removal.

Sheet rewet

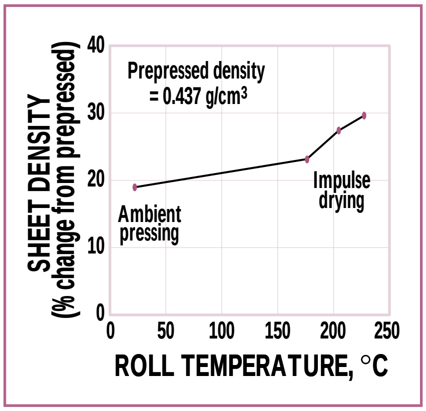
During impulse drying, most of the handsheets follow the press fabric after exiting the nip, resulting in a significant level of rewet. An air knife was used to remove the sheet from the fabric immediately after the nip to simulate the path of a continuous sheet so that the level of rewet could be evaluated.

The amount of rewet was determined by measuring the difference in dryness of handsheets removed from the fabric with and without the assistance of the air knife. Handsheets removed with the air knife represent no rewet.

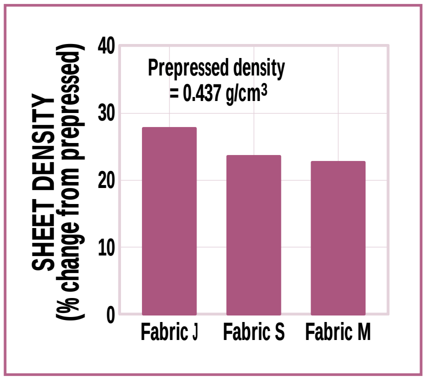
The amount of rewet that occurs is dependent on roll temperature and press fabric structure. As we have shown in the sheet release discussion, sheet release from the fabric becomes more difficult as roll temperature increases. The opportunity for rewet increases unless the fabric structure is designed to limit rewet. **Figure 4** shows the relationship of roll temperature to rewet. As roll temperature increases, the level of rewet also increases due the change in release properties of the fabric. **Figure 5** compares the rewet level produced with each of the three candidate fabrics. As designed, Fabric S allows the least rewet to occur, while Fabric J allows the most.

Sheet dryness

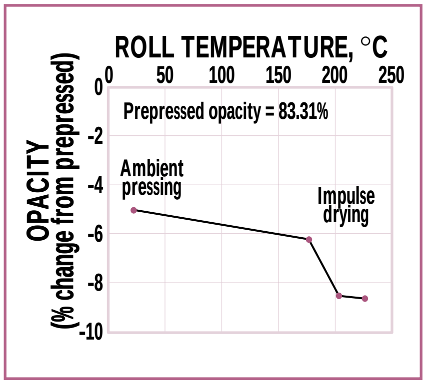
The property of sheet dryness as the sheet exits the press nip is one of the most important paper properties to the papermaker. A drier sheet results in a stronger product that is less apt to break as it is being transferred to the dryer section. A drier sheet also provides an opportunity to increase the speed of a machine that is limited by drying capacity and may present an opportunity to reduce the



14. Effect of roll temperature on sheet density



15. Effect of press fabric on sheet density



16. Effect of roll temperature on sheet opacity

length of the warmup zone in the dryer section.

Roll temperature has been found to have the greatest effect on sheet dryness. Increases in sheet dryness by as much as 20 points over conventional pressing have been measured depending on the furnish and fabric type. During this study, the use of impulse drying produced as much as 14 points of added dryness over ambient-pressed sheets. This effect of roll temperature on sheet dryness is shown in **Fig. 6**. The values shown represent dryness values obtained with the use of the air knife.

Fabric structure also has a major effect on final sheet dryness. **Figure 7** shows that Fabric S produced handsheets with an average dryness of 53%, 2 points higher than handsheets impulse dried with Fabric M and 3 points higher than handsheets impulse dried with Fabric J. The final sheet dryness values shown in Fig. 7 were also obtained with the use of the air knife. Difference in sheet dryness between the fabrics would be exaggerated if the air knife were not used.

Internal bond strength

Scott bond is an indicator of the *z*-directional strength of a paper sheet. Low Scott bond values usually indicate incipient delamination. Historically, delamination *(4)* has been the most significant obstacle impeding the commercialization of impulse drying with many types of furnishes. Our studies have shown that delamination can be controlled by using the proper combination of fabric type, roll temperature, and roll surface.

Within the roll temperatures studied, no obvious delamination of the lightweight basestock was observed. **Figure 8** shows that Scott Bond values continue to improve with increasing roll temperature. However, at roll temperatures within this temperature range, delamination has been observed with similar furnishes when using an inappropriate combination of press fabric structure and roll surface.

Figure 9 shows the influence of press fabric structure on internal sheet strength. The internal sheet strength improved with all fabrics but showed the most improvement with Fabric S.

Sheet air permeability

An increase in air permeability of a sheet may be an indicator of delamination. Under the conditions evaluated, air permeability of the impulse- dried sheets was reduced in all cases compared with the ambient-pressed handsheets, indicating no delamination. (**Fig. 10**). The press fabrics in this study had no effect on air permeability of the handsheets (**Fig. 11**).

Sheet smoothness

Sheet smoothness affects the print quality of a sheet. In general, the roll side of a sheet becomes smoother as it is pressed in a nip. Further improvement in smoothness on the roll side of the sheet can be obtained with impulse drying. As roll temperature increases, sheet smoothness continues to increase (**Fig. 12**). The press fabric has no influence on the smoothness of the roll side of the sheet.

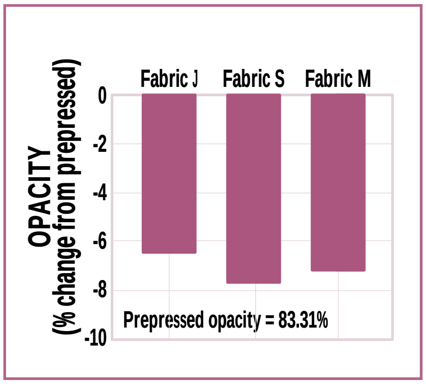
Conversely, the fabric side of the sheet becomes increasingly rough as the roll temperature increases and is affected by the fabric structure. Fabric J, which was constructed with finer-diameter surface fibers than Fabrics M and S, produced a smoother sheet (**Fig. 13**).

Two-sidedness may be reduced by using either of the two methods: (a) adding a second impulse drying unit with the heated roll on the opposite side of the sheet or (b) softnip calendering. Adding a second impulse drying unit may eliminate the need for calendering.

Sheet density

Impulse drying slightly increases sheet density over pressing at ambient temperatures. Increasing the impulse drying roll temperature results in further densification of the sheet (**Fig. 14**).

The fabric structure has an effect on sheet densification. Sheet density appears to be influenced by the fiber diameter of the surface fibers in the fabric (**Fig. 15**). Fabric J, comprising finer-diameter surface fibers, produced sheets with higher density than Fabrics M and S, having coarser surface fibers.



17. Effect of press fabric on sheet opacity

Sheet opacity

Pressing the handsheets at ambient roll temperature has a detrimental effect on opacity. Use of impulse drying further increases this loss in opacity (**Fig. 16**). Fabric structure had a minimal but statistically significant effect on opacity. Fabric J showed the lowest loss in opacity, while Fabric S showed the highest (**Fig. 17**).

The loss in opacity may be minimized through the use of fillers and or furnish changes, which may be economically attractive.

CONCLUSIONS

Press fabrics play an important role in the impulse drying process. With the appropriate fabric structure, roll temperature, and roll surface composition, impulse drying is a viable process for lightweight basestock paper grades. Improvements in sheet dryness, internal sheet strength, sheet smoothness, density, and air permeability have all been measured. These improvements have the potential to impact the overall papermaking process by providing improved runnability along with energy, furnish, and capital savings.

Further studies will be required using a continuous sheet to examine changes in the sheet tensile properties and the impact of impulse drying on subsequent manufacturing processes, i.e., drying, calendering, coating, and printing. **TJ**

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