Enhanced Capabilities in Wet-end Paper Machine Clothing

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Abstract

The increased demand for higher paper machine production and efficiencies as well as lower total operating costs, particularly with energy consumption, has led to the development of two new concepts in Forming Fabric design. By increasing the ratio of paper side to wear side CD yarns in a sheet supporting binder (SSB) triple layer structure from 2:1 to 3:1, a significant step change in sheet support and fiber support index (FSI) of 15 – 35% has been achieved. Increasing surface sheet support contributes to improvements in retention of fines and fillers as well as sheet properties such as formation, porosity, roughness and print quality. Forming fabrics may also be manufactured with a heated compaction process that flattens the surface knuckles and reduces the fabric caliper and internal void volume by 5 – 15%. This provides improved vacuum dewatering efficiency resulting in higher couch solids and a cleaner return run of the wet end of the paper machine. Cleaner operation contributes to fewer wet end breaks and sheet defects. These two new concepts are shown separately and in combination to provide these anticipated benefits on several high speed publication grade machines.

Introduction

The two key basic requirements for forming fabrics in the wet-end of the paper machine are drainage capabilities through the structure and retention of fiber on the surface [1]. Traditionally the performance of forming fabrics has been affected by the weave pattern in combination with the material or monofilaments used. The key properties are mechanical (dimensional stability and wear), drainage and retention. These properties are usually discussed in terms of number of support points or fiber support index (FSI), the shape of drainage channels and permeability, typically air permeability. Also the type of fabric, e.g. double layer (DL), triple layer (TL), self support binding (SSB), is of importance as they have different dewatering behavior.

Papermaking today is very complex complex, not only because of higher speeds and the need for more efficient production but also by the fact that energy consumption and environmental considerations have become the more critical concerns. In order to meet these demands, the focus has turned more towards structural properties and material characteristics used in forming fabrics. SSB type triple layer structures (both MD and CD bound) are the most common styles used worldwide today on publication grade machines and were the focus of this study.

This paper discusses the performance of forming fabrics from a structural point of view as well as in combination with effects from enhancement processes that modify the surface and/or the structure of forming fabrics. The effect of these processes resulted in much smoother fabric surfaces, thinner or lower caliper structures as well as increased stability. Besides improved sheet properties, such as formation, smoothness and printability, these concepts are advantageous in reducing fabric water carrying, improving fabric cleanliness, increasing sheet solids and the overall improved machine operational efficiencies. These functional effects were generated by significantly increasing the number of fabric support points and surface enhancement.

Structure/Fabric Characteristics – High Support

We will discuss two different concepts or modifications of structures. The first concept relates to the effects resulting from increasing the number of support points or FSI on the paper side of a forming fabric. Increasing the support points generates a smoother and more uniform surface for the sheet to be formed on. In order to generate this surface, the number of machine and cross machine direction strands are increased and finer diameter base elements or yarns have to be used which in turn also results in a thinner structure as shown in Table I. Several SSB type fabrics are listed in Table I and grouped into two main categories. Fabrics A, B and C are three versions of one design widely used in commercial publication grade applications. They differ in the level of fineness to the paper side surface as measured by mesh (number of MD x CD yarns per unit area) and yarn diameters. Fabric A is most commonly used for Woodfree fine paper applications, Fabric B for Newsprint and LWC and Fabric C for the most demanding printing customers producing rotogravure SC magazine. Fabric C is increasingly being used on very high speed gap formers for other grades where the low caliper is critical for water carrying and sheet solids.

Table I Key characteristics for the SSB structures used in fabric/sheet contact studies. Fabrics are grouped by ratio of number of CD topside to bottom side yarns. A, B and C are similar structures of 2:1 CD ratio. D, E and F are similar structures of 3:1 CD ratio.

Fabric ID	Paper Side Mesh x Count MD x CD /cm	Yarn diameters MD : CD [mm]	Support points No per cm²	FSI	Caliper [mm]	Air Perm [m/s]	CD Ratio Top:Btm
A	28.5 x 39.0	0.13/0.21 : 0.13/0.30	1,130	180	0.89	1.50	2:1
B	34.5 x 42.0	0.11/0.18 : 0.11/0.25	1,450	200	0.72	1.50	2:1
C	38.0 x 43.0	0.10/0.17 : 0.10/0.24	1,635	210	0.68	1.50	2:1
D	28.5 x 47.0	0.13/0.21 : 0.13/0.30	1,340	207	0.85	1.50	3:1
E	34.5 x 58.0	0.11/0.18 : 0.11/0.25	2,000	255	0.71	1.46	3:1
F	38.0 x 58.0	0.10/0.17 : 0.10/0.25	2,200	261	0.71	1.51	3:1

Fabrics D, E and F are three versions of a recently developed structure that has increased the level of paper side sheet support by altering the ratio of top side to bottom side CD yarns from 2:1 up to 3:1. This increases the number of CD yarns on the paper side as shown in the fabric mesh x count and the number of support points or FSI and slightly reduces the number of wear side CD yarns. For example, Fabric B and E in Table I have the identical MD mesh of 34.5/cm and the same MD yarn diameters of 0.11 / 0.18 mm but the higher CD count of 58.0/cm compared to 42.0/cm provides the greater number of support points and FSI. These structures have also recently been introduced into the publication grade markets. Figure 1 shows the difference surfaces between these two concepts.

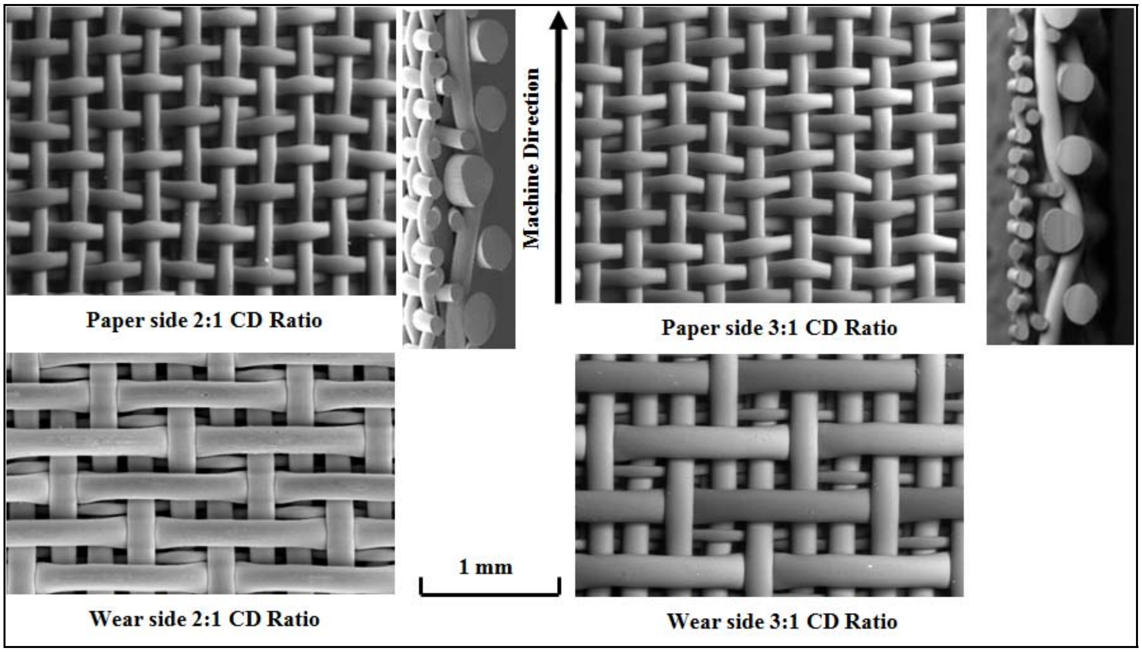

Figure 1 Paper side and wear side comparison of 2:1 (left) and 3:1 (right) CD yarn ratio structures. Note the increased number of CD yarns on the paper side and the more open wear side of the 3:1 CD ratio fabric on the right.

As shown in Table I, the air permeability is similar for all structures and that the caliper is more or less the same except for structures A and D which are somewhat thicker. The latter is explained by that these structures have coarser CD-yarns on the wear side of the fabrics. In Figure 2, micro x-ray computed tomography model images of structures A and F are shown. When comparing these structures it is obvious that fabric F has a significantly finer top surface.

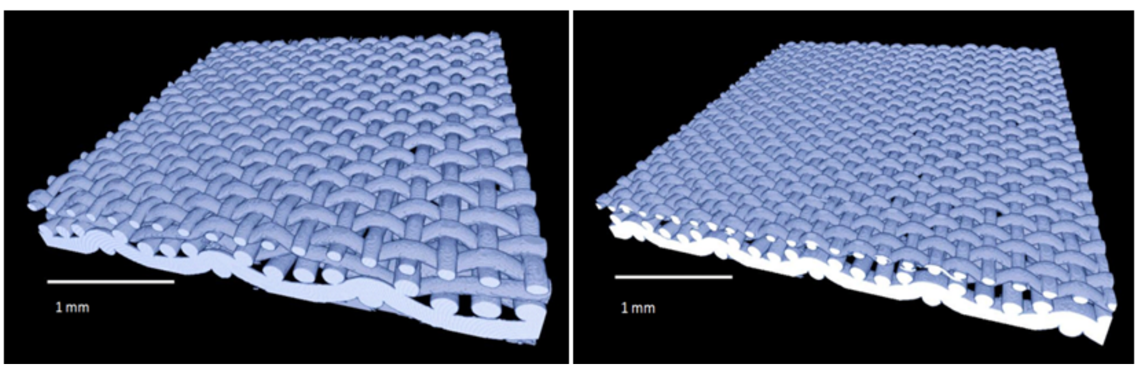

Figure 2 Micro x-ray computed tomography model images of structure A (left) and structure F (right).

By using x-ray micro tomography it is possible to study fabric structures in 3D. Fabrics are x-rayed in infinitely thin layers which are then combined into 3D images with high resolution. Specific data or characteristics for each layer can then be obtained and summarized for the complete structure. This gives the possibility to quantitatively measure the bulk, or alternatively, void volume in structures.

The images in Figure 2 indicate that the finer fabric has a thin uniform "membrane" on the paper making surface and a more open and rigid support structure underneath. The 3D models were used to determine the open area through the depth of the structure as shown in Figure 3 and represented in graphical form in Figure 4. The top yarn layer is approximately 0.1 mm in thickness and has an open area of 30 – 35 %. This is the bottle neck or greatest restriction from a flow through point of view. Under this layer there is a frame work of coarser yarns with a significantly larger open area which will not create any constraints regarding flow. As both designs are built up from a similar structure on the bottom or machine side, both structures have a similar back side wear potential. The wear potential is represented by the area from -0.35 mm in depth and below as indicated in Figure 4. The more open back side of the 3:1 CD ratio Fabric E has slightly lower wear potential volume as seen by the separation between the two curves.

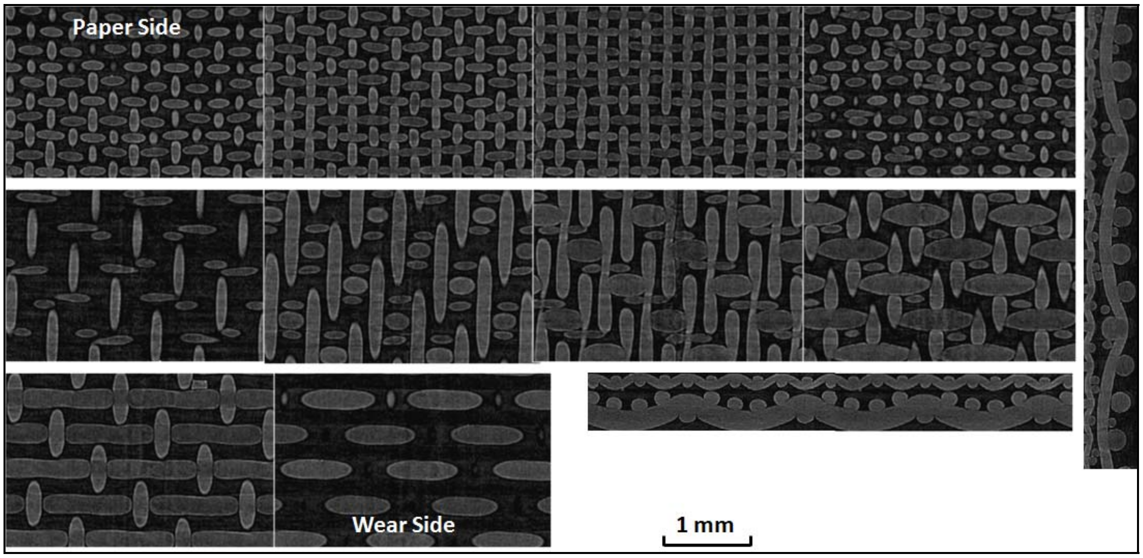

Figure 3 Cross sections of fabric B (2:1 CD ratio) from paper to wear side to demonstrate the changing open area through the structure.

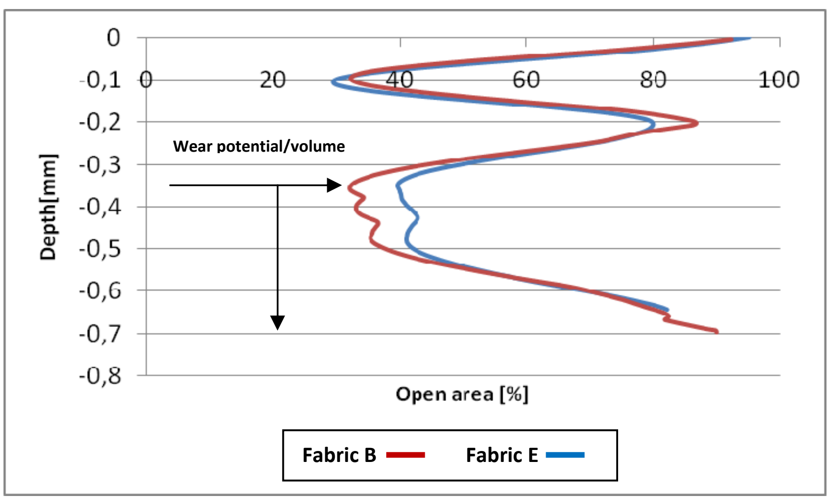

Figure 4 Open area as function of position or depth through the fabric, Fabric B (2:1 CD ratio - red) and Fabric E (3:1 CD ratio - blue). A similar relationship would be seen when comparing Fabrics A to D and Fabrics C to F.

Practical laboratory trials show that fabric E and F have a faster drainage as well as higher drainage capacity [2]. The data in figure 5 was obtained using the "Juupeli" vacuum assisted sheet former equipment at VTT [3, 4]. In this equipment a batch containing a mix from a full recipe of ingredients is dropped onto the fabric. This simulates both initial dewatering as well as downstream dewatering as vacuum is applied. This has also been proven in trials on full size commercial paper machines. Most interesting was that Fabric E was shown to have better drainage capacity when compared with fabric A as well as better retention of PCC. This is explained by the higher level of sheet support and smaller drainage openings. In Figure 5 data from laboratory trials on filler retention and drainage speed for fabrics A and E are compared.

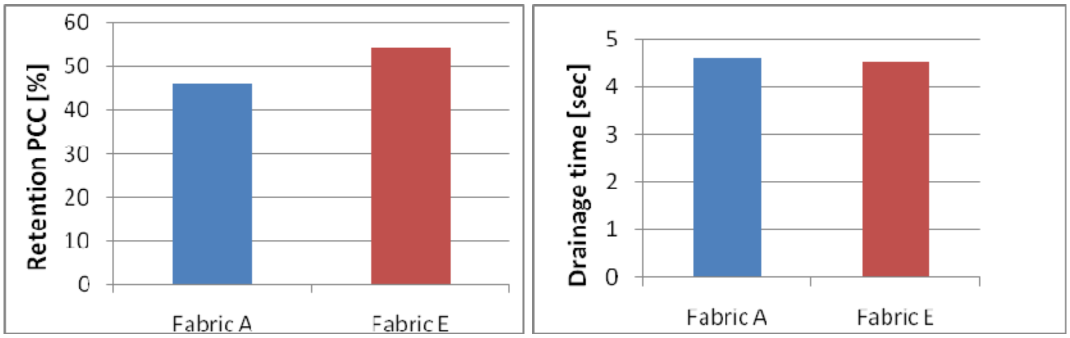

Figure 5 PCC retention and drainage time for Fabric A (blue) and Fabric E (red) obtained with the "Juupeli" vacuum assisted sheet former at VTT. Grammage 80g/m², pulp from eucalyptus, SR°30 with PCC.

Another feature seen when running a fabric on a paper machine, for example high support Fabric E, with a higher number of contact points per unit area or FSI is that the Former return run stays significantly cleaner. One reason for that may be that a finer surface with a lower plane difference (difference in relative elevation between MD and CD yarn knuckles) and the use of smaller diameter yarns, in combination with a higher number of holes per unit area (or rather shorter distance between the holes) results in smaller land areas. Sheet release at the pick-up point is easier with less fiber embedded into the fabric surface. This in combination with a shorter distance between the drainage holes, which creates a more uniform flow of water on the surface of the fabric, makes it difficult for contaminants to stick as well build up into larger conglomerates. The surface structure characteristics, like topography, play a significant role in adhesion of contaminants [5].

Structure/Fabric Characteristics – Surface Enhancement

The fabric surface characteristics may be altered by flattening out the top surface yarns on the paper side by a proprietary manufacturing process. This creates a more uniform and larger surface contact area and less plane difference between the yarns in the MD and CD directions. Another feature is that the internal woven structure is densified thereby reduced fabric caliper and internal void volume is achieved. In this study an SSB-fabric was enhanced and then compared with a non-enhanced fabric. The key data for the reference fabric and the enhanced samples are shown in Table II. The CD yarn density was lowered slightly in order to end up with the same air permeability and similar surface open area.

Table II Properties before and after enhancement of Fabric B from Table I.

Surface enhancement	Open Area at surface [%]	Caliper [mm]	Void Volume	Air Perm[1,2] (m/s)	Plane difference (µm)
Non-Enhanced	39	0.70	0.57	1.5	30
Enhanced	37	0.65	0.55	1.5	20

1. ASTM D737 – 96
2. The CD-yarn density was altered for the enhanced sample in order to reach the same air perm.

As shown in Table II the effect from the enhancement results in a lower fabric caliper of 7 - 10% and reduced plane difference at the surface. In Figure 6, the surfaces of non-enhanced and enhanced samples are shown together with an image from a cross section and close-up from each surface. The most obvious visual effect from the treatment is the flattened knuckle, seen in the SEM microphotograph, and densified structure, seen in the cross section image.

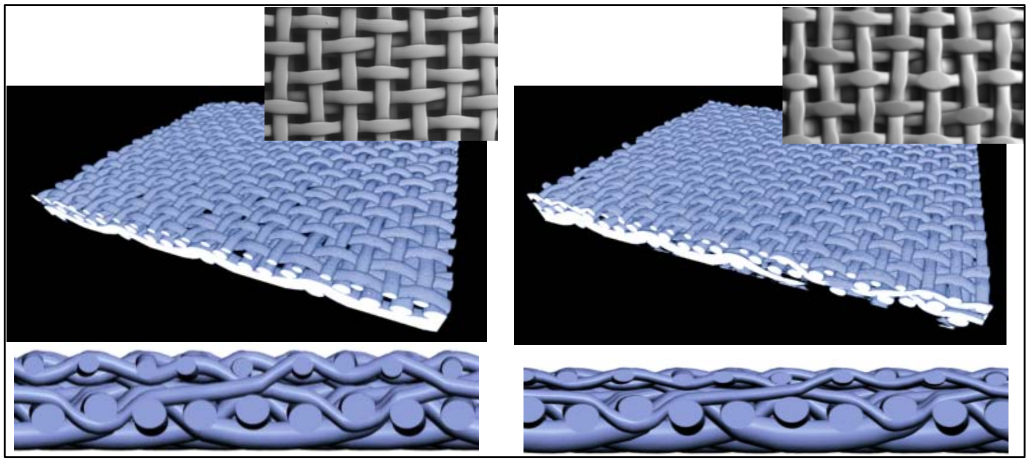

Figure 6 Micro x-ray tomography model images including a cross section image and a SEM microphotograph close up a non-enhanced sample (left) and an enhanced sample (right).

The actual effect from the enhancement process can be seen in the change in the open area inside the fabric. By studying the open area as function of through fabric depth data, generated through x-ray tomography, in Figure 7, it is seen that the surface is smoother and that the fabric is thinner. The paper side layer bottleneck has shifted higher towards the surface and closed slightly. Furthermore, the immediate effect from the densification, resulting in a thinner fabric, is that the volume of the most open void between the two layers, at approximately 0.22 mm depth inside the fabrics is significantly reduced. This is most positive as it is this void volume that retains water and reduces vacuum dewatering efficiency which in turn results in lower sheet solids after the couch roll. Laboratory trials have shown that a treated or smoother fabric surface, with smaller cavities, or voids, reduces transport of water back to the paper sheet, resulting in rewetting. The same was also seen for worn fabrics, fabrics that have been running on paper machines.

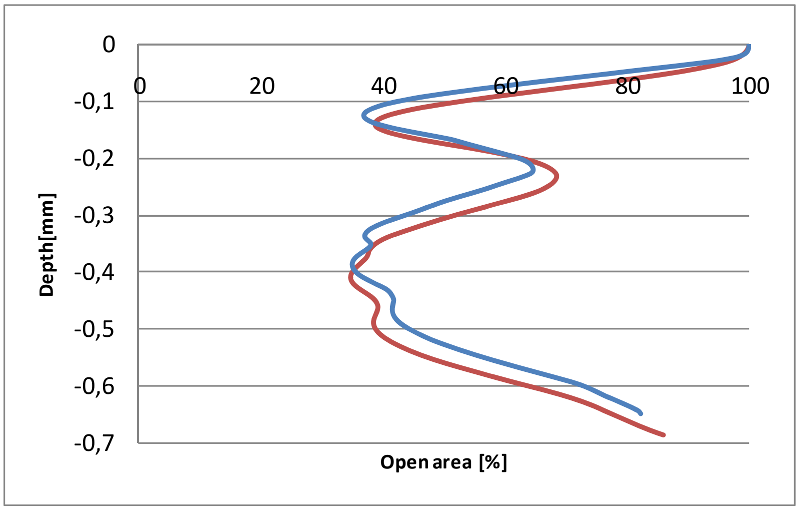

Figure 7 Open area as function of position or depth for non-enhanced (red) and enhanced (blue) fabric.

Results

It has been shown previously [6] that reducing forming fabric caliper has a positive impact on sheet solids after the couch and reducing steam consumption in the dryers. It has also been shown [7] that improved sheet structural uniformity and sheet surface smoothness allows for improved sheet drying with lower energy consumption. These demands become more critical as machine speed increases and the consequences of sheet non-uniformity have a greater impact on machine efficiencies and lost production. Increasing the level of fiber support and reducing the fabric caliper will provide positive outcomes in overall paper quality and machine operation.

Case 1: A Scandinavian Metso Optiformer with loadable blades producing SC-A magazine grades at 1800 mpm.

Both the inner and outer position fabrics were changed from Fabric B to C (like in Table I) with resulting improvements in sheet porosity (Figure 8) and PPS roughness (Figure 9). However, machine cleanliness and wet end breaks remained a concern so a high support Fabric E was evaluated on the outer position with the standard Fabric B on the inner. Monthly average wet end breaks were reduced by more than 4% during the two month life of the trial (Figure 10). Gains were also seen in top side Gloss, PPS Roughness and Missing Dots (Table III). This has since become the standard design on the outer position.

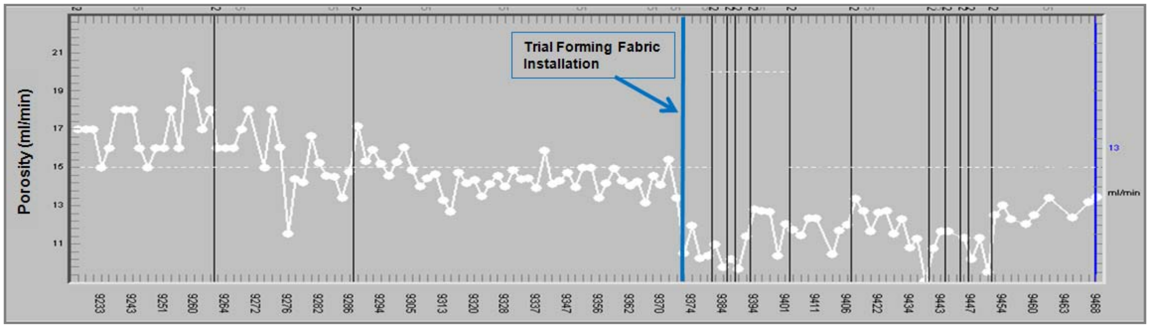

Figure 8 Sheet porosity before and after Fabric C trial set was installed for Case 1.

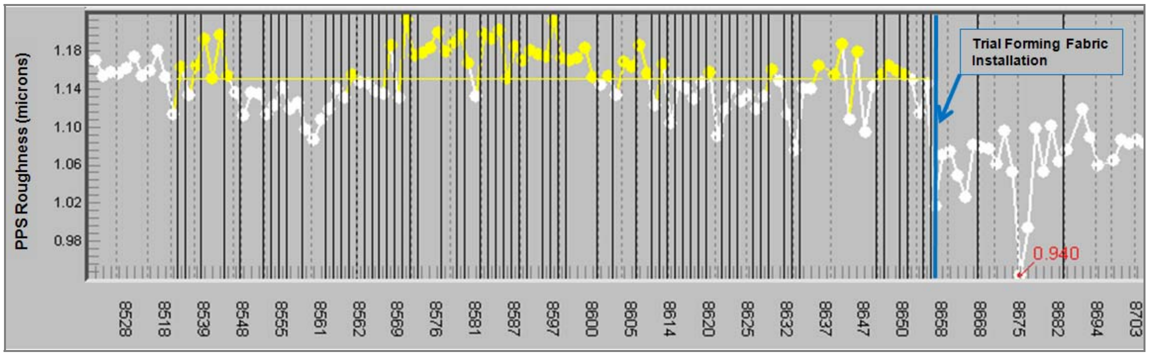

Figure 9 PPS Roughness before and after Fabric C trial set was installed for Case 1.

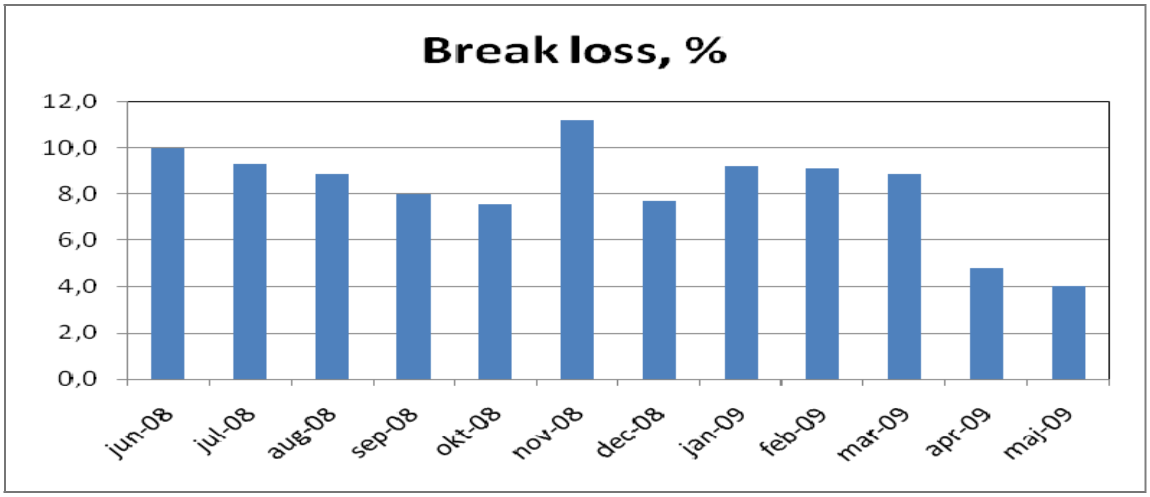

Figure 10 Monthly average lost production due to sheet breaks reduced from 9% to less than 4.5% during the trial run of high support Fabric E on the outer position of Case 1 during April and May.

Table III Data obtained from running Fabrics B (inner) and E (outer) on full size paper machine (1800 m/min) making SC paper compared to a set of Fabric B.

Fabric	Gloss [TS]	PPS [TS]	Missing dots [dots/unit area]	Sheet breaks* [%]
B	53,1	1,1	1,7	9,0
E	55,3	1,0	1,0	4,5

*Lost production

Case 2: A North American Voith Duoformer CFD producing light weight coated grades at 1250 mpm.

This machine suffered from limited drainage capacity in the former resulting in higher wet end breaks and speed limitations. The standard designs were competitive products similar to Fabric A and B in Table I on the top and bottom positions respectively. High support fabrics similar to Fabric D and E in table I were evaluated to increase drainage and machine speed. The top fabric was further enhanced with the ULTRAPLANE enhancement process to reduce caliper and possible water carrying. Increased dewatering through both fabrics provided an average of 0.8% improvement in couch solids and 1.0% gain in solids after the press section (Figure 11).

It is more typical that a 1% gain in solids at the former translates into a 0.25% gain after the press section. However, improved sheet formation and reduced press draws contributed to maintaining the solids gain through the press. Several press felt combinations were run during this timeframe but their changes did not correlate strongly to the gains in press solids. Dryer section steam consumption was reduced by 4.1% and the machine speed was able to increase 15 to 45 mpm on average depending on the sheet basis weight being produced. Equally important was the significant improvement in former cleanliness resulting in wet end breaks dropping from 2.0 to 1.4 per day on average (Figure 12).

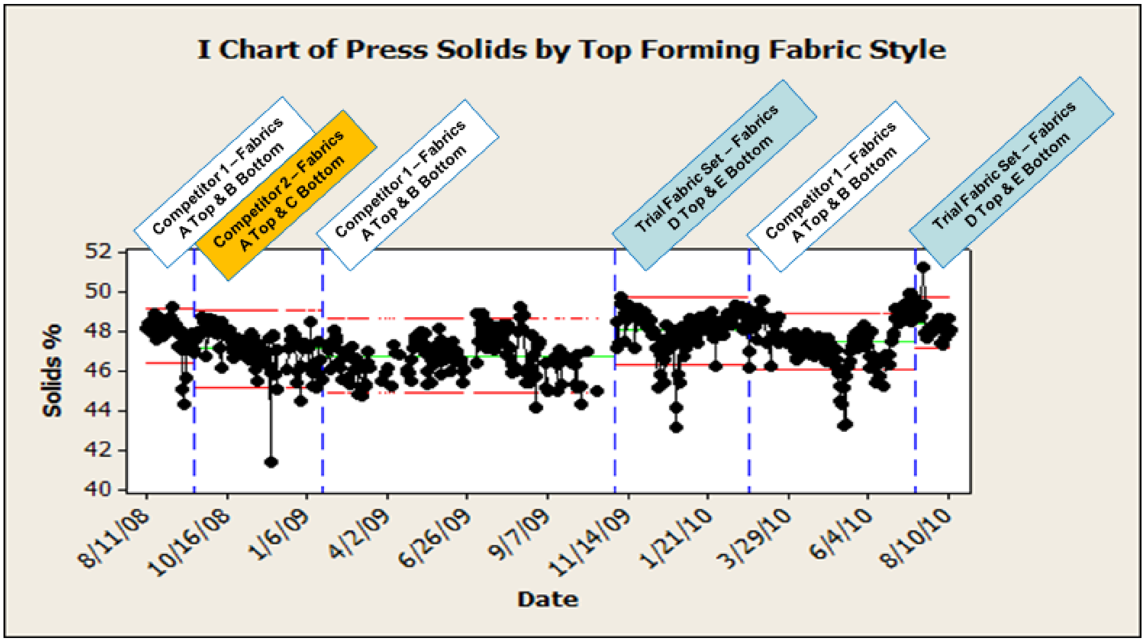

Figure 11 Daily average press solids were 47.2% with competitive fabrics running compared to 48.2% with a trial set of high support fabrics with the top fabric being surface enhanced.

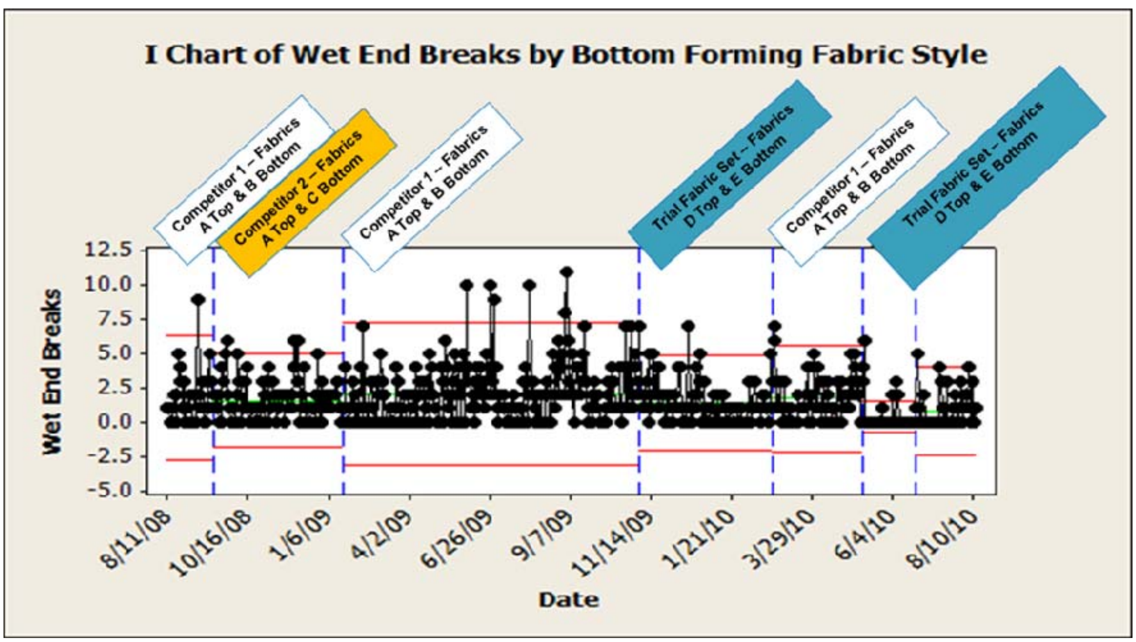

Figure 12 Daily wet end breaks reduced from an average of 2.0 with competitive fabrics to 1.4 per day with a trial set of high support fabrics with the top fabric being surface enhanced.

Case 3: A Continental European Voith Duoformer TQ-v producing SC-A magazine grades at 1650 mpm.

This goal of fabric design trials was to improve paper surface properties and profiles. The original design standard was a set of Fabric B (34.5/cm mesh, 2:1 CD ratio) in Table I. The initial trial of high support Fabric E (34.5/cm mesh, 3:1 CD ratio) on the outer position improved porosity but water misting at the separation point occurred and sheet moisture profiles became worse. A second top position trial of a more open Fabric E with surface enhancement added to reduce fabric caliper maintained the sheet density while reducing the 2 sigma profile variation as well as the water misting. The next step was to make another step change in sheet support by moving to Fabric F (38.0/cm mesh, 3:1 CD ratio) with surface enhancement on the outer position. Sheet porosity was lowered again as well as top side PPS roughness. The final step was to install Fabric F (38.0/cm mesh, 3:1 CD ratio) with surface enhancement on both positions. Paper properties are now more uniform with low levels of porosity and roughness with the reduction in 2 sigma basis weight profiles. This combination is currently the preferred standard of forming fabrics.

Conclusions

Papermaking requirements continue to advance with larger, faster and more productive paper machines worldwide. Demands of operating efficiency gains and particularly energy consumption reductions are more critical for all paper grades regardless of size, speed or age of machine. PMC clothing suppliers have responded by developing new structures that can enhance both the overall paper quality such as formation, porosity, smoothness and printability as well as the operational efficiency of paper machines at reduced energy and raw material consumption. Two significant develops were studied here. A new high fiber support structure provides a step change in support points or FSI which have been shown to improve the sheet surface characteristics, sheet structural uniformity and fiber / filler retention. A surface enhancement process has separately and in combination with the high support fabrics provided better machine operation due to greater sheet solids off the former, improved cleanliness of the former and fewer wet end breaks with resulting efficiency loss. These concepts have been proven on commercial publication grade machines worldwide, with a few examples shown here.

Acknowledgements

The authors would like to thank Rita Hansson of Albany International AB Halmstad, Sweden for technical input and valuable discussions.

Disclaimers

ULTRAPLANE is a trade name of Albany International Corp.

Metso and Optiformer are trade names of Metso Corporation

Voith and Duoformer CFD and Duoformer TQ-v are trade names of Voith Paper Holding GmbH & Co. KG

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