A New Family of Forming Fabric Structures Provides Higher Dewatering, More Sheet Bulk and Lower Drag Loads for Improved Life

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INTRODUCTION

Traditional forming fabric structures involve a series of design compromises in which fabric life, fabric stability, sheet formation, fiber retention, and fabric drive-load are traded off, one for another, in order to achieve a specific end result. This paper describes a new approach to fabric design in which all the aforementioned properties can be maximized without coincidental negative trade-offs.

This paper shows that a denser triple-layered structure, at similar permeabilities, will obviously have lower void volume and less internal water to remove while passing through dewatering elements.

Beginning with the paper making surface, all yarns should be identical in size for the most uniform paper surface possible, but this is usually not the case. This new family of fabrics is the result of a technology that begins with this as a premise. These same-sized yarns are then spaced in such a manner that the drainage holes are square in shape, accommodating fibers in all possible orientations, to maximize retention, thereby allowing for reduced headbox consistency, a squarer sheet, and consequent better formation. In the past, structures like these were thought not possible, because of fabric manufacturing considerations and the need for various mechanical properties in the fabric.

Historically, this type of embodiment would automatically result in loss of overall fabric life, but, in the case of these new designs, a binding yarn is incorporated which is simultaneously in the plane of the papermaking surface to enhance fiber support index (FSI), and conversely out of the wear plane on the machine side of the fabric.

As will be shown in the paper, this then allows for a larger diameter wear surface yarn opposite the papermaking side. These larger yarns are made from a super-tough material that maximizes abrasive wear while sliding easily over stationary elements.

A little addressed cause of total energy usage is the extra drag load created as large diameter wear yarns pass over stationary and vacuum elements, ie, the yarns used to increase life simultaneously increase the drag load and thereby require a larger horsepower demand. This obstacle has been largely surmounted by the usage of yarn materials which have inherently lower coefficients of friction and a low contact area to further reduce drag load and, therefore, drive amperage. A case study is included to demonstrate the point.

This paper follows, step by step, how each of those papermaking issues have been addressed through textile engineering and design. Certain common-sense problems which have historically been introduced into fabric design to address a problem in one area, will compromise performance in other critical areas. The new designs described herein, is the latest fabric evolution, and involve the attempt to address all the major forming fabric design issues with a single type of structure.
SHEET FORMATION CONSIDERATIONS

There is a large mass of water that must move through the forming fabric with little or no resistance to maximize overall water removal performance and resulting sheet consistency. The fabric must also deliver high retention values to improve formation and a smooth, non “hairy” sheet surface to promote improved creping. It was long thought that a “rough” wire side sheet surface will provide a sheet with higher bulk. We now know that, while this is a “micro” effect, a smooth wire side surface will improve Yankee adherence, therefore improving creping efficiency and providing a “macro” effect that far surpassed the aforementioned micro effect.

A fabric as designed in the following paragraph will also improve retention, which should then provide superior formation and sheet appearance, by producing a more uniform, “filled in” sheet. (1)

Figure 1. shows a classic instance whereby the sheet is made to be inherently two-sided, in this case, a crescent former, in which one side of the sheet is formed against a forming fabric and the other against the felt.

Crescent Formers Have Unique Fabric Requirements

Fig. 1. Shows that in a crescent former, all the water must move unimpeded through the fabric, while retaining as many fibers a possible.

FABRIC DESIGN CONSIDERATIONS

It is intuitively obvious that the forming fabric, upon which a sheet of paper requiring a high level of smoothness is formed, should be as monoplanar as possible. As the fibers mold themselves around the yarns which comprise the surface of the fabric, a certain amount of non-uniformity is introduced into the sheet because of the cylindrical shape of the component yarns. Larger diameter machine direction yarns contribute to stretch resistance, but disrupt the smoothness of the mat of paper fibers which are laid upon them. Similarly, larger diameter cross machine direction (CMD) yarns will reduce the manufacturing cost of the fabric and contribute to wear resistance, stability and drainage, but also disrupt the planarity of the sheet. In typical structures, one of these considerations machine direction (MD) vs. CMD yarn size, will win out, and a fabric is produced in which certain properties will be maximized and others sacrificed. The first main difference in the forming fabric structures described in this paper, is that yarns in both directions are of equal or nearly equal size to eliminate trade-offs in the papermaking surface.

MONOPLANARITY AND SQUARE DRAINAGE HOLES

Starting with the aforementioned design consideration of same sized yarns, it also makes sense to weave the papermaking surface in a plain weave. For those not familiar with the art, a plain weave structure allows each MD yarn to pass over one CMD yarn, before going under one CMD yarn to complete the repeat pattern. This puts support points or “knuckles” as close as possible to one another, compared with other, more complex weaves. Using same or virtually the same sized yarns in both directions of the paper forming surface and weaving them with close to identical spacing per linear unit of length or width, produces a surface that maximizes the property of monoplanarity with square-shaped drainage holes.
It may not seem immediately obvious why square holes represent an advantage. Because of the pressure drop that occurs when the sheet is extruded from the headbox, paper fibers are preferentially aligned in the machine direction. This may be mitigated to a degree by adjusting the jet-to-wire ratio, but the fact remains that there will be a predominant fiber orientation within the formed sheet. When drainage holes are longer in one direction than the other, the tendency for preferential fiber orientation can be exaggerated because non-retained fibers will fall through the “long side” of the hole preferentially. Square holes give the maximum sheet “squareness” effect, as it relates to that portion of MD/CD tensile ratio impacted by forming fabric design.

“Balanced” Sheet Side Surface

Fig. 2. Highlights the same sized MD and CMD yarns arranged in a plain weave on the papermaking surface. Note the high level on monoplanarity.

Unbalanced Fabric Surface Produces Non-Uniform Sheet Side

Fig. 3. An “unbalanced” weave on the sheet side induces texture and patterns to the sheet.

Figures 2 and 3 show diagrammatically the difference in surface geometry between balanced and unbalanced weaves, while Figure 4 shows how these differing weave patterns manifest themselves in the sheet surface. The top picture is a low light image of the surface of a sheet made on a standard sheet support binder (SSB) forming fabric. The bottom picture is of a sheet made with the plain weave surface with same sized yarns in both the machine direction (MD) and cross machine direction (CMD).
VOID VOLUME, DRAINAGE, AND RETENTION

Until recently, the premier line of SSB forming fabrics described in the literature required that they be woven on 24 or 20 harness (shaft) looms. In the last year fabric designers in Italy have developed a unique weave pattern which repeats on only 16 harnesses. This results in a much denser fabric with surprisingly low void volume. The water which resides inside the fabric has momentum of rest until it passes over a dewatering element. The less water that is contained in the fabric, the lower the energy required to move water from the sheet into the fabric and subsequently, out the fabric’s back side. Figure 5 shows a photographic comparison of the difference between the older “loose” weaves, vs. the 16-harness “tighter” weave. Figure 6 demonstrates that the resultant drainage vector for lower void volume fabrics moves water down and out of the fabric in a shorter distance.
Internal Voids in “Loosely” Vs. “Tightly” Woven Fabrics

Fig. 5. There is a high level of internal void volume in 20 or 24 shaft weaves vs. 16 shaft weaves

The Effect of Void Volume on Drainage Vector

In most tissue applications, water entrained within the forming fabric moves with the fabric at a high rate of speed. In order to move water from the sheet into the fabric, water within the fabric must exit through the fabric as quickly as possible and with as little force required as possible. High levels of entrained water in high void volume structures, require more force or longer time for the water to move through the fabric. This is only true when the permeabilities and calipers of the two types of fabrics are the same. This is represented visually in Fig. 6.
High void volume fabric (red) requires more time to exit the fabric

Low void volume fabric (blue) requires less energy to exit the fabric

Fig. 6 is a diagrammatic representation of how water entrained in the fabric in high void volume structures will take longer to exit the sheet because of the water’s higher momentum of rest. The x-axis represents the speed/distance of water moving in the fabric, and the y-axis represents the distance through the fabric that it must travel.

**MANY SMALL VS. FEWER LARGE DRAINAGE HOLES**

The advent of modeling tools using Computerized Tomography (CT) Scans to give volumetric measurements of the fabric structure and how those relate to the volume of water flow allowable, the size and number of the drainage channels, and the uniformity of those drainage channels have changed the way we now develop new structures. This tool also allows us to examine why designs of the recent past exhibit certain deficiencies. Since these images can be manipulated in 3 dimensions, it is easy to measure the uniformity of the fabric’s topography and the resulting imprint it will make upon the sheet. Similarly, it is not sufficient to know only the drainage capacity and rate of the fabric structure, but also its uniformity. If the structure is composed of few large drainage areas vs. many small areas for water flow, then water must move larger distances to get through the fabric, carrying with it a load of fines and/or fillers. If the object is to create a uniform distribution of fines in all 3 directions in the sheet, it is critical to develop structures which provide many small drainage areas, vs. fewer large drainage holes. Darcy’s Equations predict that porous media with more small holes, will drain faster than one with fewer large holes, at the same permeability. The 20 and 24 shaft patterns achieve their resultant permeabilities with few, larger holes, compared to the 16-shaft comparison.
Drainage Hole Uniformity as Measured by Computerized Tomography (CT)

Figure 7. Shows a comparison of the many, closer spaced drainage holes and super smooth sheet side topography of the 16-harness weave, compared to the old SSB style of forming fabric which has been state of the art for the last 10 years. The more infrequent, larger holes in older SSB structures induce the migration of fines and fillers laterally in the sheet and fabric toward the holes.

Retention

Forming and retaining the fibers delivered from the headbox is, after all, the primary purpose of a forming fabric. Higher retention values can allow lower headbox consistency and therefore improved formation. So in addition to the relatively minor advantages relating to machine cleanliness, improved retention can have a direct impact on sheet appearance, smoothness, and quality. High FSI numbers can be reinforced by forming the sheet as high as possible from the central plane of the fabric. Keeping the fibers up and level on the surface of the fabric creates a dense smooth mat, with wire side as similar as possible to the top side of the sheet, minimizing two-sidedness. (2)

Figure 8. The combination of a highly planar surface and uniform drainage holes to maximize retention potential by forming the sheet high above the fabric.
WEAR RESISTANCE AND DRAG LOAD REDUCTION

It is not just the sheet side and center of these styles of fabrics that have been re-engineered. The primary function of the back side of the forming fabric is to resist the abrasive wear of stationary elements while not constraining the flow of water through the structure. This will always be the case, but in previous fabric embodiments, the large diameter yarns used to resist wear have the negative side effect of increasing drag load from the coarseness of the pattern of those same yarns. This new structure has been developed in a pattern which, although it uses large diameter wear yarns (Fig. 9), has placed these yarns in a more widely spaced pattern which reduces the contact area and results in lower drag loads. It has been shown that “warp cover” (the product of the warp diameter and the number of warp yarns), predicts the amount of drag load that the fabric will induce. The pattern and spacing of these yarns allows the fabric to “skate” over stationary foil and vacuum units. On multiple applications, drive load reductions of up to 7% have been noted. On typical high-speed machines of average width, a 7% reduction in total drive load (the combination of couch and wire turning roll amperage) can significantly reduce energy consumption costs.

Back Side View of the 16 Harness Construction

![Back Side View of the 16 Harness Construction](image)

Fig. 9. The back side of these fabrics have a special lacing pattern to reduce drive load and wear.
This flat fourdrinier was a trial opportunity for the low warp cover fabric, documenting the drive loads at both the couch and wire turning rolls.

Results from a recent trial opportunity, in which the older style of SSB structure was replaced with the new, low warp cover fabric. This forming configuration is shown as Figure 10. Drive loads at the couch and wire turning rolls were documented, then compared at those same two spots after installation of the trial fabric. These results are shown below.

**Trial Results for Drive Load Trial**

- Couch roll drive *reduced from 99 amps to 93 amps*
- Wire turning roll amps *reduced from 152 amps to 141 amps*
- Total drive load *reduced by 6.8%*

**CONCLUSIONS**

1. Technique has been discovered to create triple-layered forming fabrics with lower internal void volume
2. This reduced void volume induces higher drainage rates to improve overall water removal and to set the sheet faster
3. A balanced weave pattern on the sheet side eliminates the tendency to mark the sheet and it promotes better creping
4. Darcy’s equations correctly predict that a porous medium, like forming fabrics, with more numerous, smaller, drainage holes, will drain faster
5. Better hand feel is promoted by more uniform creping
6. Lower operational drag loads and higher wear resistance can be obtained through the use of unique machine side weave patterns
REFERENCES

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Formation Considerations

- **Volume of Water**: Vast amounts of water must move through the fabric in Crescent Former Applications, with little or no resistance, to maximize water removal performance and sheet consistency.

- **Sheet Quality**: The fabric must deliver high retention to improve formation and a smooth «non hairy» surface for Yankee adhesion and better creping.

- **The Felt** must help dewatering through the forming fabric by presenting a smooth dense surface, thereby adding to the centrifugal force effect.
Creping

- There is no direct contact with the clothing at this stage, but uniform crepe generation is a direct consequence of the quality of the job done at the forming stage and the smoothness of the wire side of the sheet.
- An even and non hairy surface allows a precise action at the creping blade, directly into the Yankee coating layer.
- An even and non hairy surface plus precise creping generate a sheet with superior hand feel and bulk.
High Speed Tissue Forming Fabric Demands

- High dewatering capacity because of high *volume* of water and high *rate* of water removal.

- The ideal structure handles large volumes of water with minimal water carrying, internal to the structure (low void volume).

- Fabric must have a surface that is free of visual patterns and a smooth topography.
The Difference?
Comparison of 2 fabrics in SSB style

Older types of SSB made on 20 or 24 shaft Weave Patterns

SoftLite™ is made on a 16 shaft Pattern
Visual Representation of the Vectors that Affect Water Motion in the Fabric

x-axis is the distance water must move because of its forward motion with the fabric

Blue arrow is the resultant movement

y-axis is the vertical component of water moving through the fabric
Lower Void Volume Means Less Dewatering Time, i.e., Higher Dewatering Capacity

High void volume fabric (red) requires more time to exit the fabric.

Low void volume fabric (blue) requires less energy to exit the fabric.

Drainage resultant

Drainage resultant
Optical Computed Tomography (CT SCAN)

New Design

Surface topography

Dewatering Channels (more, smaller holes)

Standard SSB
Comparing the Planarity of Differing Weaves

“Balanced” Sheet Side Surface

Unbalanced Fabric Surface Produces Non-Uniform Sheet Side
Uniform MD and CMD Sheetshide Yarns Produce Many Small Support Points, Promoting More Drainage, Less Sheet Mark (Bottom Right) and Improved Creping for Better Hand Feel and Softer Sheets

Sheet made with unbalanced weave shown in low angle light

Sheet made with balanced weave has less fabric mark
High Speed Tissue Forming Fabric Demands

✓ High dewatering capacity because of many more, smaller pores to provide better water handling and high rate of water removal.

✓ Fabric must have a surface that is free of visual patterns and a smooth topography.

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Unique Back Side Weave Pattern Provides Lower Friction (Drive Loads) While Protecting MD Yarns from Abrasive Wear, This is Accomplished by Using Fewer, Larger Backside Yarns (Lower Warp Cover Factor)
Forming Fabric Cost Saving Case Study
Results Before and After Fabric Installation

- Couch Roll Drive Reduced from 99 amps to 93 Amps
- Wire Turning Roll amps Reduced from 152 amps to 141 Amps
- Total Drive Load Reduced by 6.8%
Conclusions

1. A technique has been discovered to create triple layered forming fabrics with lower internal void volume
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