

Process Solutions to Improve Paper Machine Performance in Forming Section with Essential™

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Abstract

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.

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. **Essential™ ESB** from Cristini 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 head-box 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 this new family of designs, a binding yarn is incorporated which is simultaneously out of the plane of the papermaking surface, 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. Because of this feature, this new family of structures is generically called ESB (Enclosed Strand Binder) designs, to differentiate them from the current SSB (Surface Strand Binder) top of the line structures. The term ESB is used generically in this paper to describe these internally bound fabrics.

Introduction

It is intuitively obvious that the forming fabric upon which a sheet of paper requiring a high level of smoothness or a surface upon which to print, should be as mono-planar 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 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 (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. Figure 1 is a visual representation of the fabric Design Matrix, which highlights, on a scale of 0-100 per property, the relative benefits of the best of modern multi-layered forming designs.

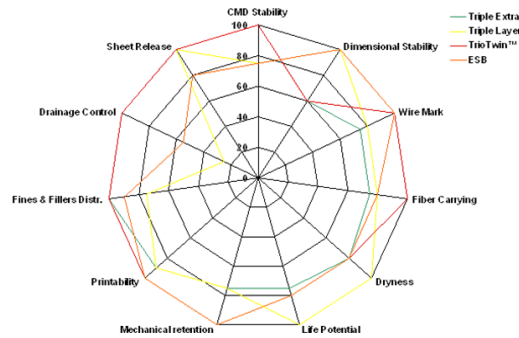


Figure 1 is the Fabric Design Matrix which enables one to give each fabric type a cumulative “score”.

Recognizing that not all applications require the maximum relative score for each fabric property, there are times when some features are simply not that important. In most cases, however, “more is better”. If the major cause for fabric removal is accidental damage, for instance, then properties like stability and life potential may not be paramount at that given time, recognizing, though, that when causes for those damages are addressed, then life potential moves up in its relative importance.

The key point is in recognizing that sacrifices need not be made unless extraordinary circumstances exist. There is an intrinsic benefit in supplying the best possible fabric in all regards possible to take advantage of benefits in as many areas as possible, whether problems are known to exist in those areas or not.

Mono-planarity 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 mono-planarity 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 head-box, 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. It has been widely reported by forming fabric manufacturers that square holes give the maximum sheet “squareness” effect, as it relates to that portion of MD/CD tensile ratio impacted by forming fabric design.



Figure 2 highlights the same sized MD and CMD yarns arranged in a plain weave on the papermaking surface. Note the high level on mono-planarity.

There are exceptions, however, when maximum drainage and sheet mono-planarity are *not* desired features. If the sheet drainage needs to be retarded on heavyweight sheets, for instance, to prevent sheet sealing on the wire, the weave pattern on the sheet side can be modified to a weave with longer “floats” which will effectively slow the rate of drainage. Similarly, on tissue sheets maximum bulk is a desired feature, so smoothness features are disrupted by using MD and CMD yarns of differing diameters and weave patterns. This results in a fabric surface with pronounced “hills and valleys” to induce non-mono-planarity and a resulting higher sheet caliper.

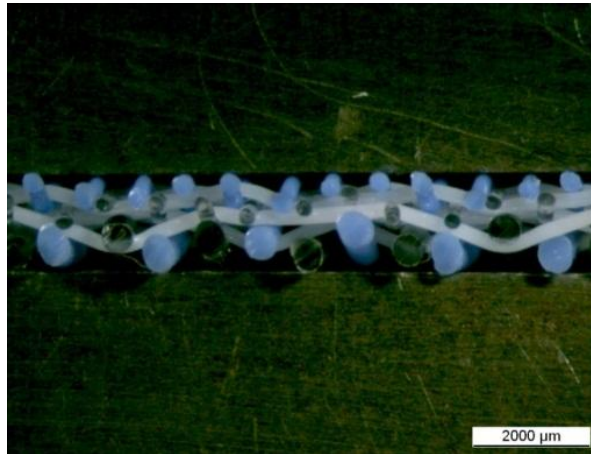


Figure 3 is the same ESB structure utilizing same sized MD/CMD yarns, but with a longer float weave pattern on sheet side to retard drainage rate.

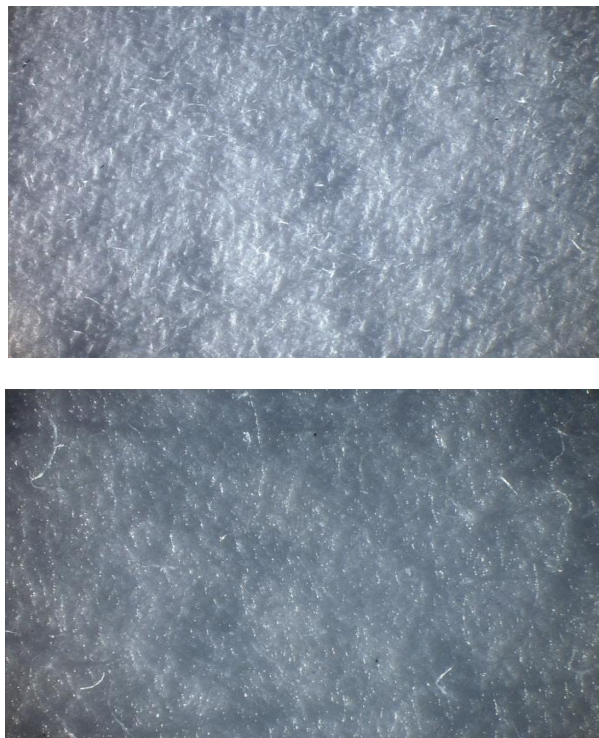


Figure 4 Low angle light photos clearly show the pattern created by a state-of-the-art 2.5 layer traditional fabric (top) vs. a virtual mark-free sheet from an ESB fabric with plain weave surface and same sized MD/CMD yarns.

Drainage and retention

Until the recent past the only tools that fabric designers had at their disposal were some basic equations such as Fiber Support Index (FSI) and Drainage Index (DI), both of which were developed to predict the performance of single layered forming fabrics “back in the day”, but that have severe limitations in accurately predicting performance of modern structures. Frequently the result is that the paper machine was the ultimate design tool with which to develop and refine new designs. 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 structure. This tool also allows us to examine why designs of the recent past exhibit certain deficiencies.

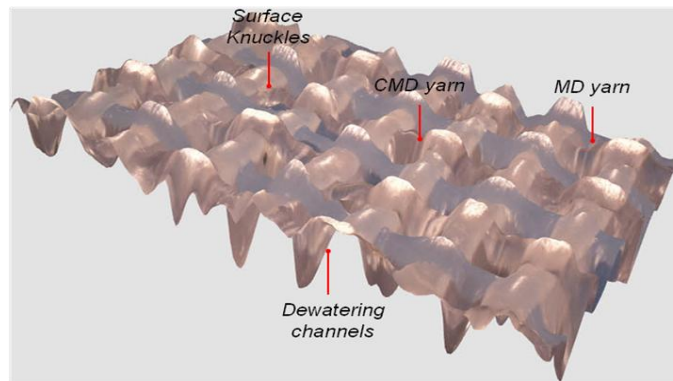


Figure 5 is the result of a CT scan with analytical software showing the channels created within a given weave structure. The numbers and sizes of holes can be mathematically calculated to determine total drainage and uniformity of sheet drainage.

Uniformity of Drainage and Surface Topography

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 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.

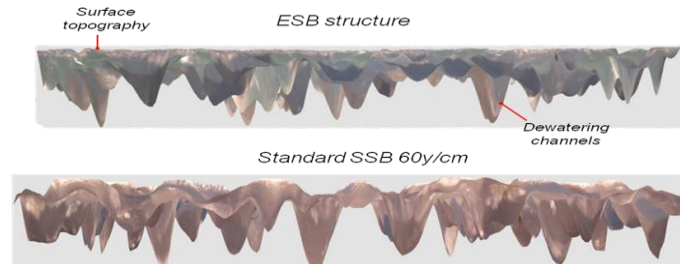


Figure 6 is a comparison of the many, closer spaced drainage holes and super smooth sheet side topography of the ESB, compared to the SSB style of forming fabric which has been state of the art for the last 5 years. The more infrequent, larger holes in older SSB structures induce the migration of fines and fillers toward the holes.

Retention

Forming and retaining the fibers delivered from the head-box 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.

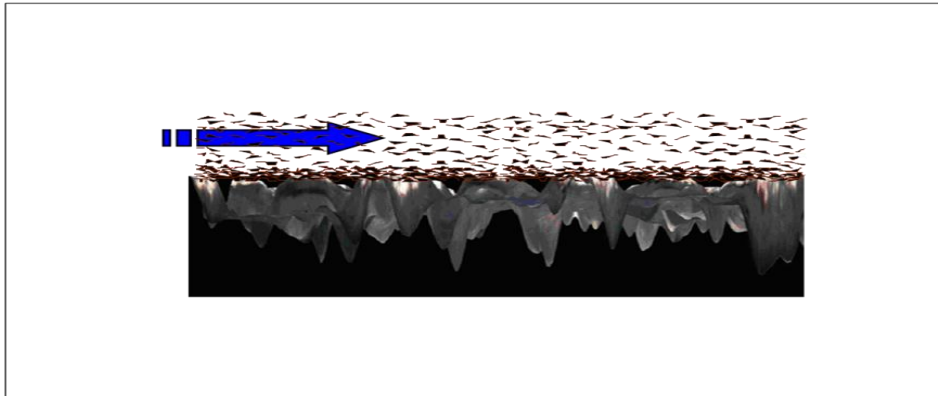


Figure 7 the combination of a highly planar surface and uniform drainage holes to maximize retention potential.

Fabric stability

High speed operation particularly on twin wire applications requires a high level of stability in both the MD and the CMD. MD stability is paramount because high tensions are required to prevent fabric distortion in the forming zone. Similarly, significant fabric stiffness and resistance to diagonal deflection (sleaziness) are required from the weave structure and yarns in the CMD. As was discussed in regard to fabric smoothness and drainage uniformity, there are typical trades that take place to maximize mechanical properties in either direction, which detract from the mechanical properties in the converse direction. The ESB product manages to maximize stability properties in *both* axes.

In true triple layered fabrics there are two separate fabrics, one on the sheet side and one on the machine side, that are bound together with a separate system of yarns, most commonly a large diameter bottom fabric yarn which weaves up from the machine side, or a small diameter sheet side yarn which weaves down from the top, both of which techniques being designed to “bind” the top and bottom fabrics together. As can be imagined, a top side yarn weaving to the back presents an opportunity for premature wear and subsequent fabric delamination, while a coarse back side yarn weaving to the top will disrupt the paper making surface and create a significant deformity in the smoothness and drainage surface of the fabric.

The ESB style fabric does neither of these, doing its job of binding the top and bottom fabrics while completely *internal* to the fabric structure. This is shown clearly in **Figure 8**. A side benefit to this form of binding is that the binding yarn serves to fill internal voids which would otherwise carry unnecessary internal water and retard drainage.

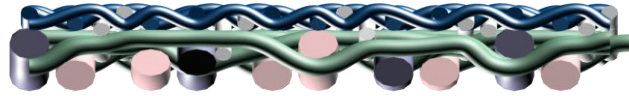


Figure 8 clearly shows that the binding yarn (green) is completely internal to the weave structure

The binding yarn, being internal to the structure, does not get exposed to wear on the machine side and does not disrupt the paper making surface.

Diagonal Deflection (Sleaziness)

The complex weave patterns necessary to perform the numerous tasks associated with modern forming fabric construction require the yarns to follow convoluted paths, but paths that intersect fairly infrequently so that the yarn systems can function somewhat independent of one another. The downside of this is that the infrequent interlacing result in a fabric which deflects rather easily in the diagonal, a term commonly referred to as sleaziness. Starting with plain weave top cloth, which is the “tightest” weave pattern, and then following with the unique internal binding yarn structure, the ESB achieves the maximum values available for this property. This type of fabric distortion is tested in a standard apparatus.

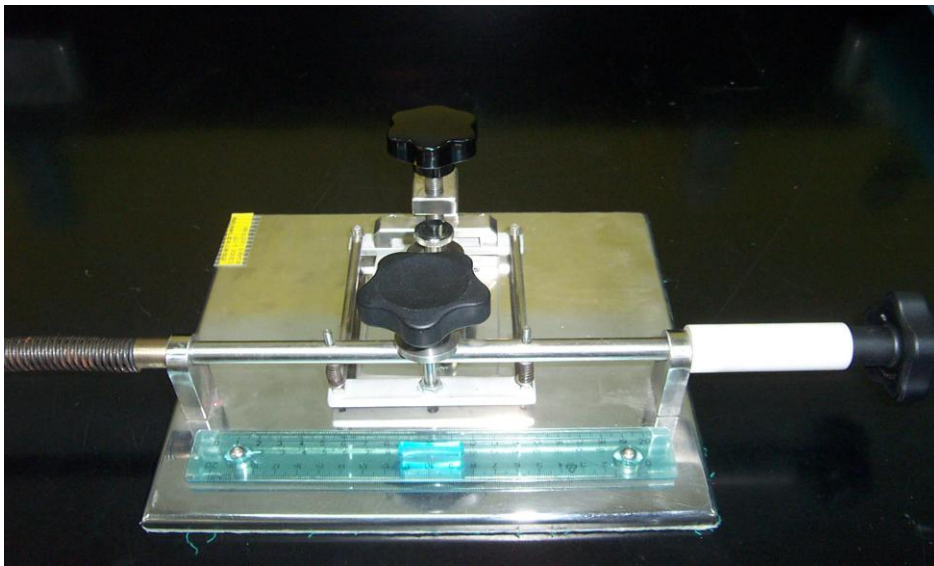


Figure 9 is the device to compare diagonal distortion. A fabric sample is clamped in place, sideways force is applied, and the distance that the fabric deflects is measured.

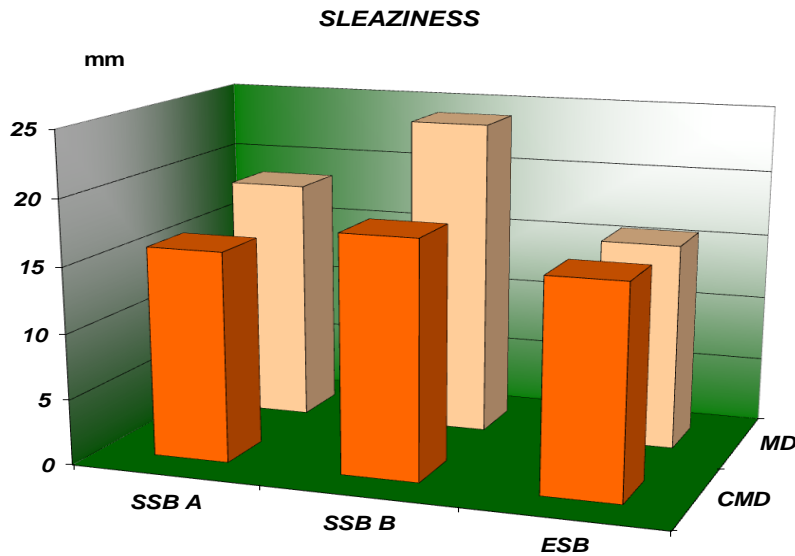


Figure 10 shows the result of comparing two of the most common SSB designs to the ESB. Smaller numbers mean less deflection and higher stability. Sleaziness is diagonal distortion when force is applied to the MD and CMD at 90 degrees, in the plane of the fabric.

CMD Stiffness

As discussed earlier, the amount of CMD stiffness affects the sheet profile on twin wire machines. The ability of the fabric to withstand cross direction deflection, particularly in the pressurized environment of the forming zone, is critical to maintaining a flat sheet profile. Fabrics capable of running at high tensions and without CMD deflection produce consistently better moisture profiles and an inherently reduced need for energy to dry wetter streaks. A flatter profile should result in higher machine speeds or reduced energy consumption. CMD stiffness is measured in the lab by the Taber Stiffness Index.

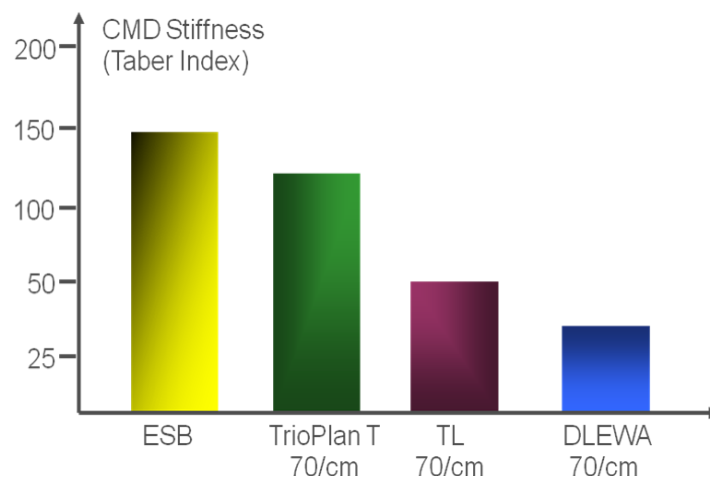


Figure 11 compares stiffness of the ESB to weft bound triple layer (TrioPlanT), warp bound triple layer, and the double layer extra stand (DLEWA) styles, made in comparable yarn size combinations.

Wear resistance and drag load reduction

It is not just the sheet side and center of the ESB style 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, has placed these yarns in a more widely spaced pattern which reduces the contact area and results in lower drag loads. The pattern and spacing of these yarns allow the fabric to “skate” over stationary foil and vacuum units. On multiple applications, drive load reductions of up to 10% have been noted. On typical high speed machines of average width, a 10% reduction in total drive load (the combination of couch and wire turning roll amperage) will result in annual savings of over \$100,000.

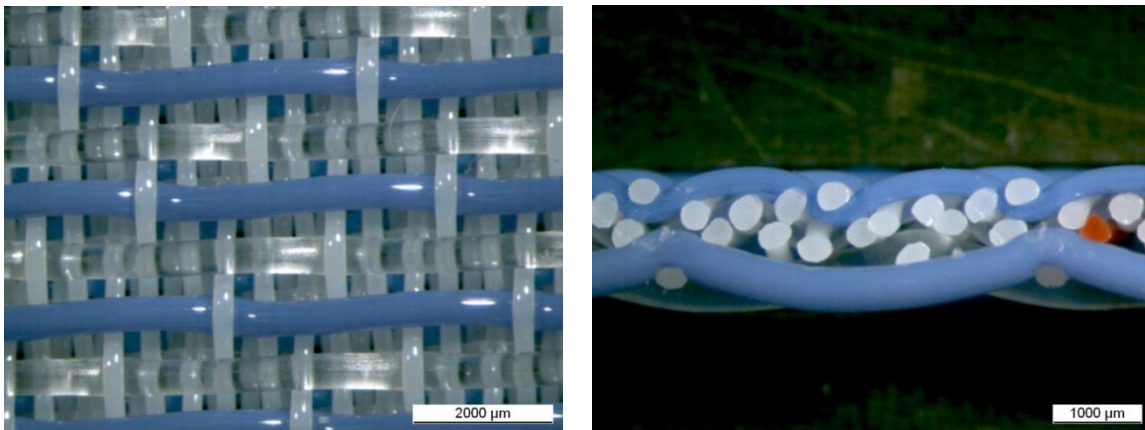


Figure 12 shows the unique machine side interlacing pattern which a) exposes the entire diameter of the roll side yarns to sacrificial wear, and b) reduces overall contact area with stationary objects to reduce sliding friction.

Summary

A new family of forming fabrics has been developed with the over-riding premise that compromises in design attributes need not be accepted as a normal part of the “pluses and minuses” of the design process. Trade-offs that historically are the normal outcome of maximizing a particular desired attribute, no longer need to be tolerated since all desirable properties can be incorporated into one design, whether actually identified as specific needs, or not. These ESB structures additionally incorporate a special interlacing pattern on the machine side that can reduce drag load to the extent that the cost of the fabric can actually be offset in energy savings.