Modern Developments In Forming Fabric Designs And Their Application in the Paper Industry

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ABSTRACT

Based on needs of the paper industry, led by the rapid modernization of the printing machine, automated packaging and increased hygiene demands, significant developments have taken place in the last decade on Forming Fabric design. As per today's demand, a fabric must maximize overall machine efficiency, runnability and profitability, while continuing to keep a sharp focus on sheet quality. This has necessitated the advent of new fabric designs, from earlier Single Layer Fabrics to Multilayer Fabrics leading to today's latest offering of our STL design which belongs to SSB (Shute Support Binder) family. The introduction of SSB design has established its supremacy across most paper grades and machine types. This is a multilayer forming fabric in which binding yarns become a part of the fabric structure linking the top side and bottom side to provide superior sheet support, easy drainability and high abrasion area. Our STL Fabrics are woven on standard 20 and 24 shed weave technology. We supply these fabrics to high speed Fourdrinier machines, Twin wire and Gap formers showing remarkable improvements reported in terms of reduced paper breaks on machine, improved mechanical retention values, cleaner run and an overall improvement in many other operating efficiency parameters.
This paper highlights the major developments that have taken place in the past decade in Forming Fabric designs to meet the paper machine as well as the paper maker's demands.

RECENT DEVELOPMENTS IN FORMING FABRICS AND ITS RELEVANCE

Introduction

In the recent past, Indian Paper Industry has been going through a difficult period. The globalization of Indian economy has brought vibrancy to Indian paper Industry by bringing competition of International players. Added to this, the consumer has now become very much quality and price conscious.

This has led to the mills looking inwards and work continuously in pursuit of upgrading their manufacturing process to achieve quality and productivity improvement, and most of all cost reduction.
In this endeavor of the paper mills towards reducing operational costs and increasing operational efficiency, the selection and use of appropriate design of forming fabrics plays a silent but very vital role.

Even though the cost of machine clothing is below 2% of total manufacturing cost, the loss to a paper mill due to improper selection of a fabric or its usage can be colossal. Forming fabric is the first point of sheet forming. Any mistake here can hardly be erased from the final sheet. The wet end is the heart of paper machine and the forming fabric is the heart of the wet end..

Realizing this importance, it has always been a constant endeavor of forming fabric manufacturers, to understand the needs and requirements of the paper maker adequately, and then translate them in their product design so that their needs and requirements are optimally met. Credit for the very significant success achieved in this endeavor goes to those paper makers who demand the best but treat the forming fabric supplier as his partner. The benefits namely, in fabric life, operational efficiency, machine runnability and quality of paper produced - derived by the paper mill because of the developments in forming fabric in the last two decades, are immense. The best example is first the change from bronze to synthetic fabric, then from single layer to double layer fabric and now from double layer fabric to triple layer fabrics or more commonly known as SSB fabrics.

The design and development of high speed twin wire and gap formers was achievable only after the advent of the modern synthetic forming fabrics.

This paper surveys the recent developments in forming fabrics, superiority of one design over the other and how a paper mill can optimise their product quality, productivity and machine runnability by appropriate selection and usage of a forming fabric.

Forming Fabric Requirements

A forming fabric performs three operations

a. Allows water to drain through its openings
b. Supports and retains the fibers to form a sheet
c. Acts as a conveyor belt to transfer the sheet to the press part.

These are multifaceted requirements. The forming fabric designer has to balance the properties for :- retention, wiremark, sheet release which consists

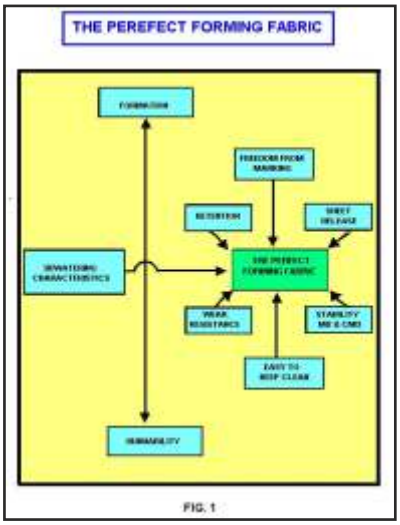

FIG. 1

Wires & Fabriks (S.A.) Ltd.
Industrial Area: Jhotwara, Jaipur
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of pick-up, knock-off and separation properties, stability in MD and CMD, cleanability, wear resistance and the drainage (fig 1).

Some of these demands are contradictory to each other. So a forming fabric design is a compromise between these demands. On one end of the design spectrum we have a very fine mesh fabric which can provide the desired forming surface and fiber support characteristics, but this design lacks stability and fabric wear potential. On the other end of the design spectrum is a very coarse mesh fabric, which imparts long life and stability to the fabric but sacrificing on fiber support aspect. Thus, many a times it is difficult to change one aspect of a forming fabric's performance without affecting one or more of other characteristics of the fabric.

Fabric Designs

Three basic families of forming fabrics available today are:- Single layer, Double Layer, and Triple Layer.

Single Layer

Single Layer fabrics are simplest in construction and the least sophisticated of today's forming fabrics. The most common designs are 4shaft and 5 shaft. (Fig.2 & Fig.3)

The forming surface of a typical four shaft single layer is dominated by warp yarns (machine directional strands). This design is commonly used in manufacture of all varieties of paper grades and also tends to give the least degree of wire mark. However, there are some inherent shortcomings. Between each of the warp yarns, there are long unsupported troughs called "valleys" in the forming surface of the fabric (Fig. 4) . During the drainage process, the fibers tend to deposit into

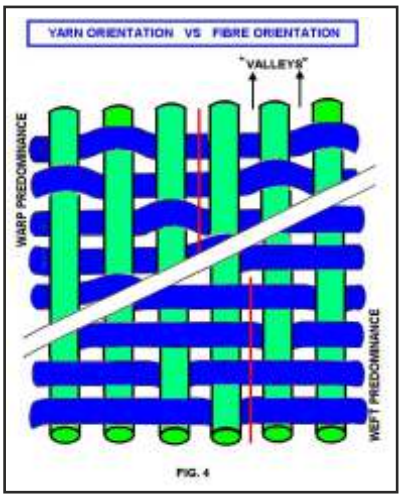


FIG. 4

these valleys and restrict further drainage.

Moreover, single layer fabrics provide the lowest degree of fiber support and retention levels, particularly of fines and fillers. Wear surface of the single layer fabric is dominated by the weft yarns (cross directional strands) to provide maximum wear potential and maintain fabric stability

Many varieties of single layer fabrics are available. While there are subtle differences between each single layer design, all tend to have similar major characteristics.

Double Layer

As machine speeds and widths increased, single layer designs were not dimensionally stable and had the tendency of forming wrinkles especially on the return run. Research efforts towards improving the stability of the fabric led to the development of double layer fabrics.

A double layer fabric has one warp but two weft strands stacked one over the other. The density of warp is generally more than 100% as compared to around 55 to 60% in single layers. This allowed finer fabrics while increasing stability. These fabrics have no projected open area. The drainage path through the fabric is on a diagonal and is not straight through as in a single layer fabric (Fig. 5).

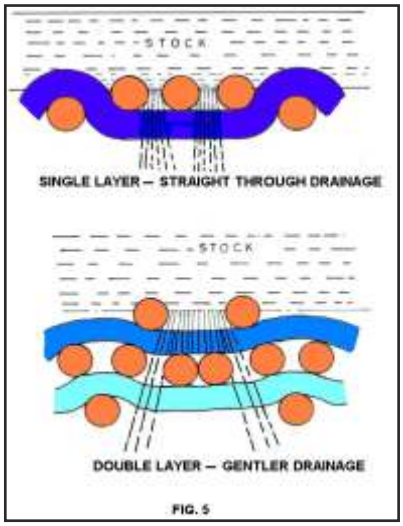


FIG. 5

Double layer fabrics have much more complex construction and provide a greater degree of flexibility in optimising the forming surface without adversely affecting the wear surface. Fig.6 illustrates double layer commonly used in writing and printing grades.

The top rows of CD strand contacts only the forming surface and the bottom row only the wear surface. With this, it was now possible to modify strand diameters and material types to a greater extent to optimise the forming

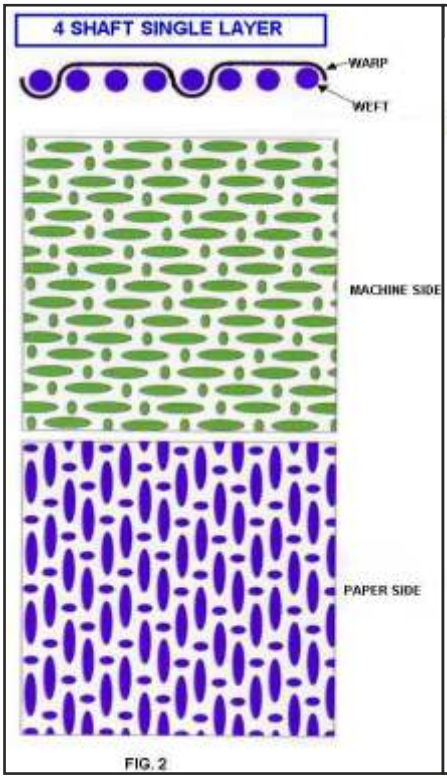


FIG. 2

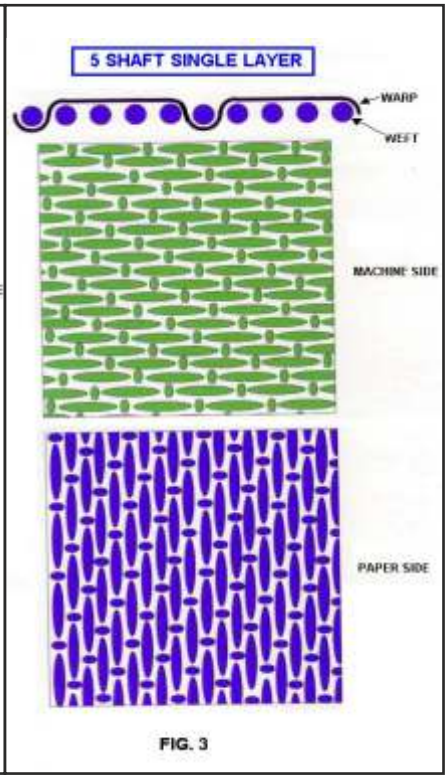


FIG. 3

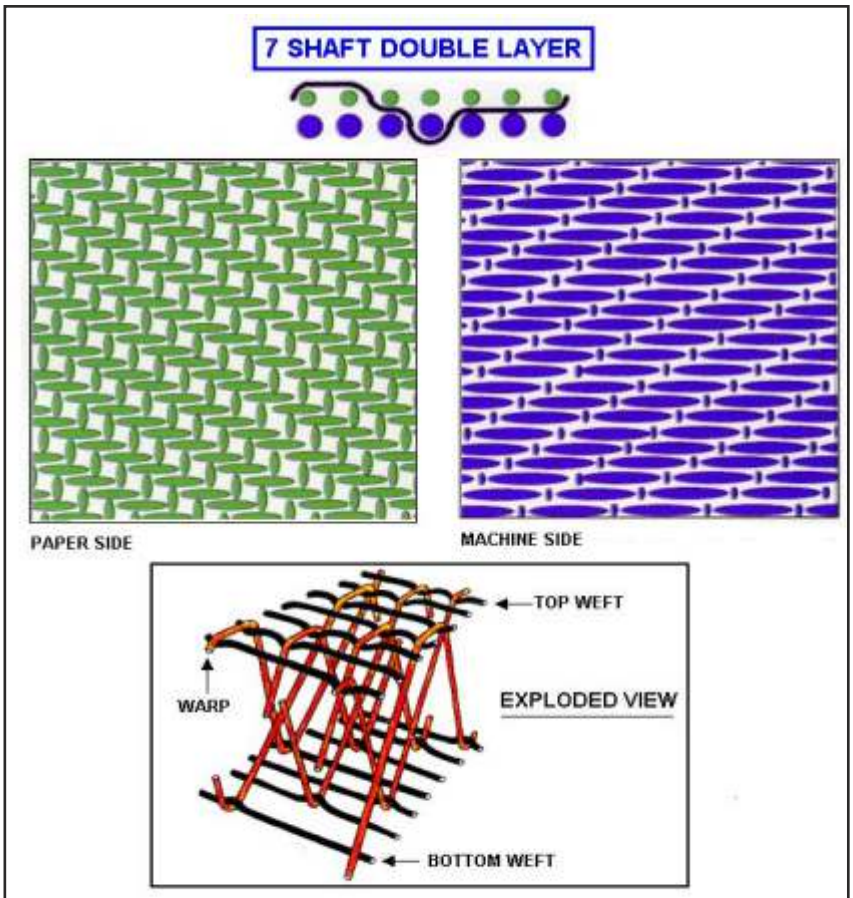


FIG. 6

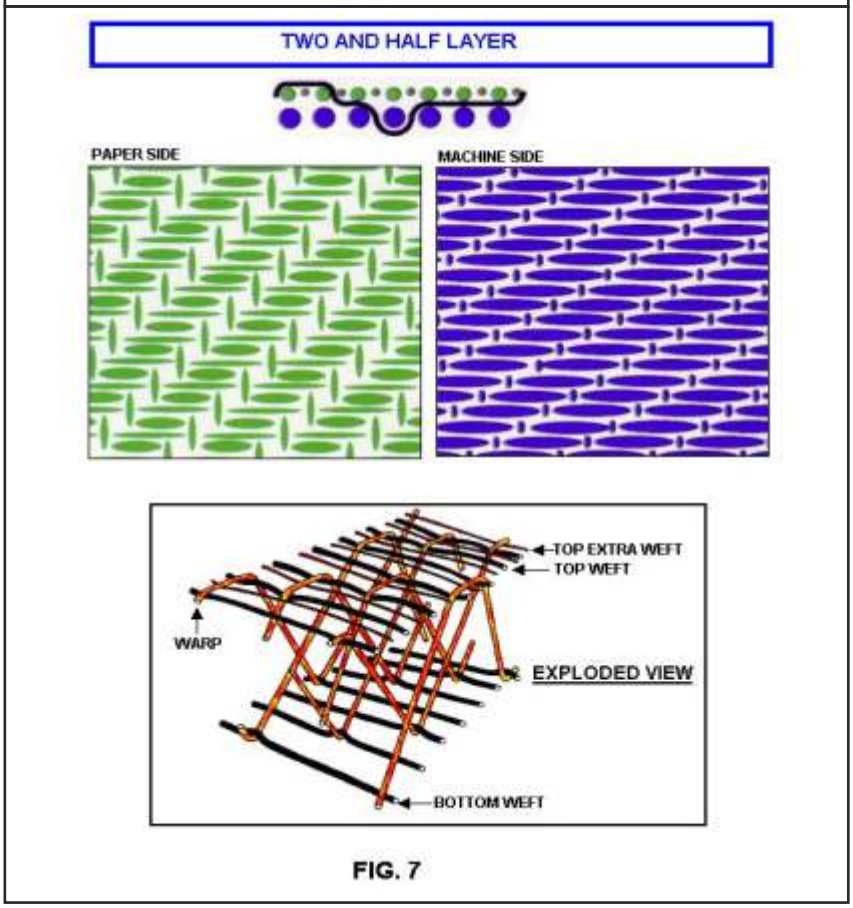


FIG. 7

surface and the wear surface, individually

The forming surface is dominated by both MD and CD strands. The increased length of the MD and CD contact points or knuckles provide a more balanced and effective support system, thereby providing important benefits in term of increased retention level, improved sheet surface and minimised two sidedness. The wear surface of the double layer is dominated by the CD strands that are used as wear elements and the MD strands are allowed to carry out the job of load bearing.

Two And Half Layer

On realizing that the improvement in formation and retention was essentially due to higher fiber support points provided by the double layer design, further research resulted in the now most popular family of two and half layer fabrics i.e. a double layer fabric with extra support weft. These fabrics offer more fiber support because of the construction of the yarn system on the forming side. Two and half layer fabrics have an additional small weft yarn woven in the top layer to reduce the distance that the fiber needs to bridge for support (Fig. 7). With this fabric design it is possible to achieve higher standards of formation required by modern printing technology. With this development, the extra support weft double layer fabrics have become standard for making fine quality paper.

14 And 16 Shed Double Layer

This design is a development with the primary objective of increasing the life of the forming fabric without affecting the paper quality.

It is generally accepted and well known that the abrasion potential of the fabric can be enhanced by increasing the volume of the bottom weft yarn, which comes in contact with the conveying/dewatering elements of the paper machine. However, with the standard double layer and two and half layer, the weaving design does not permit use of very thick bottom weft yarn, because they greatly disturb the stacking of top and bottom weft yarns resulting in poor drainage characteristics of the fabric.

This design (Fig. 8) facilitates to use double the no. of shafts than conventional double layer i.e. from 7 to 14 and or 8 to 16. The unique warp and

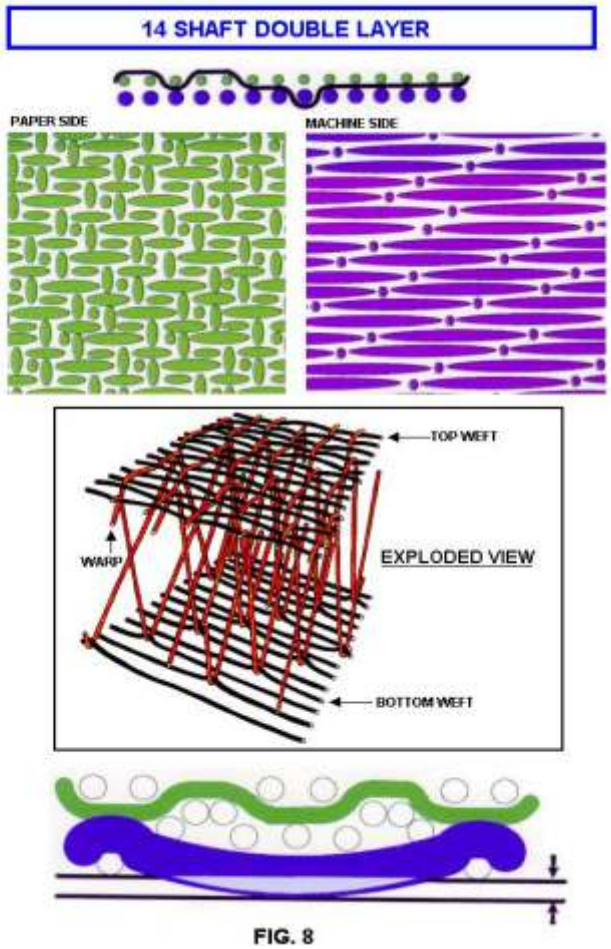


FIG. 8

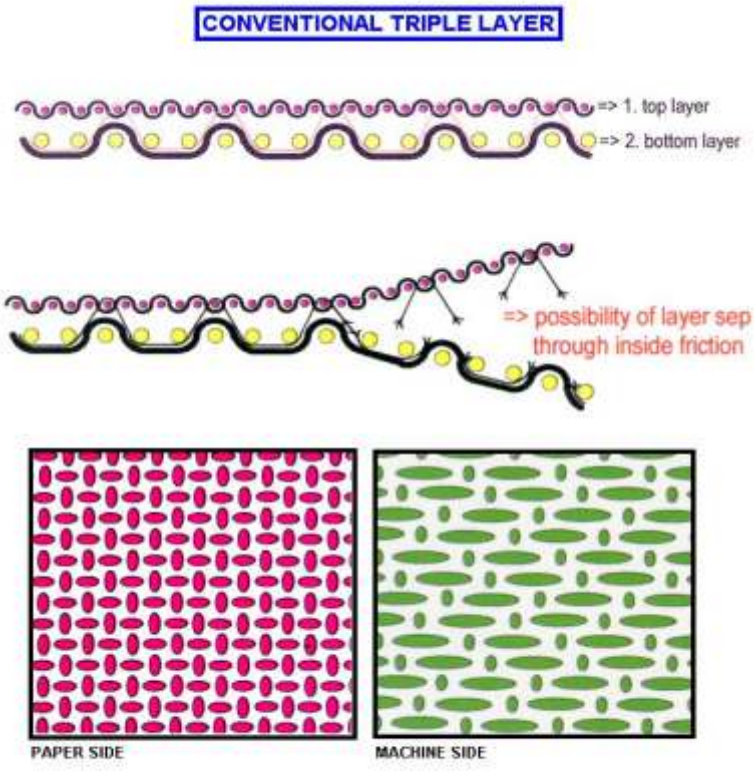


FIG. 9

weft interlacement pattern facilitates the float length of the bottom weft yarn to be increased and simultaneously thicker bottom weft yarn to be used. Added to this, the strong crimping achieved on the bottom yarn results in the warp yarns to get abraded much later i.e. after the thick bottom weft yarns are fully worn out, thereby enhancing the life of the fabric.

Triple Layer

In triple layer design, a fine two shed plain weave structure of small yarns is woven to coincide with an underlying coarse mesh single layer structure. Both the single layer constructions are held together by a binder yarn.(Fig.9). In the first trials the binder yarns were 'additional' CMD yarns. The vast difference in the stress and strain characteristics of the -top and bottom layer constructions resulted in a "relative movement tendency" between the two layers frequently leading to layer separation and stability problems. The second generation of triple layer constructions employed an 'additional' MD binder yarn which to a great extent was able to solve the problems of delaminating and stability. However, the major short coming in these designs was that the fabric thickness exceeded the acceptable standards resulting in performance problems like water carryover, sheet transfer problem in twin wire formers, and tendency towards shadow marking on paper.

The design consists of three layers of weft yarn, which are bound together by one set of warp yarns (Fig.10). The presence of three layers of weft yarn results in the fabric to have extremely high bending stiffness, high level of surface stability, as well as low cross directional contraction. The necessary functional separation of the paper and running sides can only be achieved in a limited manner, since the functional layer border directly on one another. Triple layer fabrics of this design, on the other hand, allow better adaptations of the differing fabric sides to meet the demands required.

In this triple layer design, the paper side is very fine while the running side is more roughly structured. The additional middle weft layer creates a balance between the paper and running sides. The cross directional stability is very high, for this reason, paper produced on machines with these triple layer fabrics maintains a very even

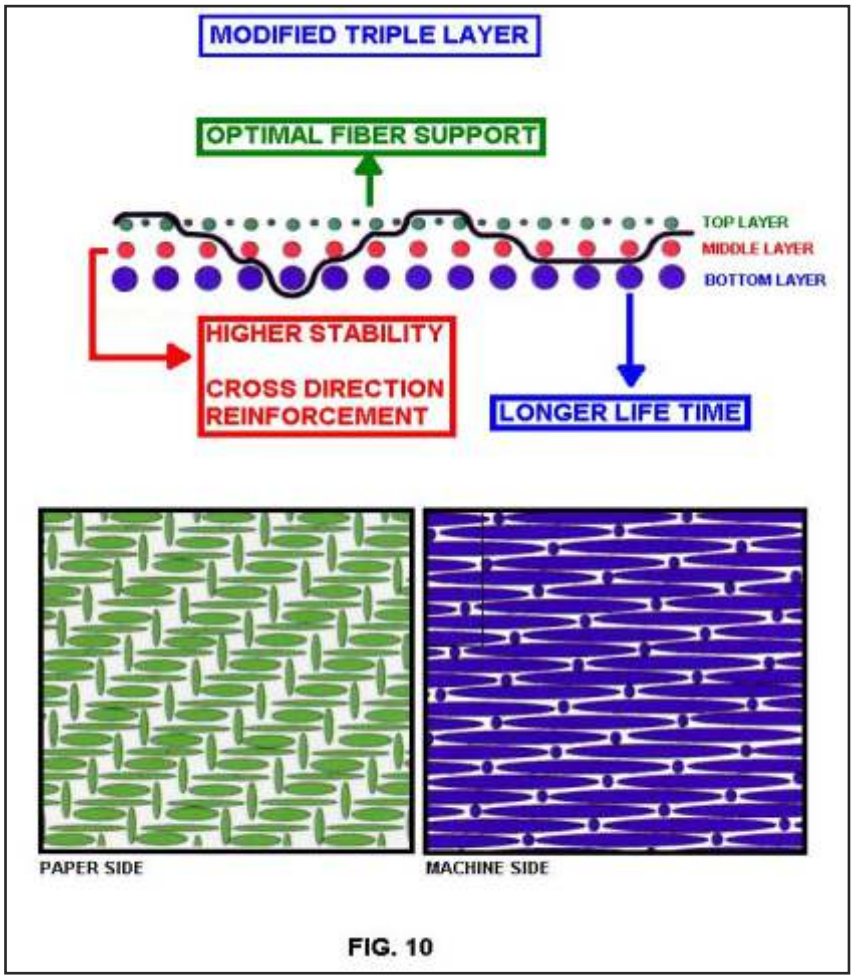


FIG. 10

basis weight profile, even at the end of the fabrics running time.

A New Generation SSB Fabric For High Speed Paper Machines

New Multi-Layer Developments - In the mid-to-late 1990s, forming fabric design turned some dramatic developmental corners. A new generation multi-layer forming fabric, STL structure that would further minimise the compromises inherent in traditional double-layer and triple-layer designs was launched. The problems like water carryover, sheet transfer problem in twin wire formers and tendency towards shadow marking on paper is successfully eliminated in new design STL structure fabric. It was the first ever to truly provide paper quality, mechanical stability, energy efficiency, and runnability, in the same structure. One of the key features of this fabric is its "Shute Support Binder" (SSB) structure. The binding yarn serves two functions it binds all of the yarns together (producing a single homogenous structure), and it maximizes fiber support by spending two-thirds of its time on the surface of the fabric. Simply put, this provides the fabric a plain weave pattern on the paper making surface for optimum sheet quality while providing a rugged machine side surface for CD stability and extended life potential (Fig 11).

Today, this new technology is used for over 70% of the Triple Layer fabrics supplied worldwide, almost equally spread between Fourdriniers, hybrid formers, and gap formers. Paper machine speeds have increased an average of 300 M/min a year during the past five years, and the trend continues. At the same time, fast machines have increasingly moved to using mainly SSB fabrics. SSB fabrics offer several advantages for papermakers.

The most important of these are:

- Higher fibre support index for increased mechanical retention
- Uniform top surface for superior formation
- Unique fabric structure for Higher drainage capacity and cleaner fabric run
- Capacity to increase fabric life through additional options.
- Improved profiles through stable structure, savings in retention aids through high fiber support, good paper structure, clean run of the machine, and longer running lives. This has been achieved through the structure where bottom side machine direction (MD) yarn density is higher than the top side MD yarn density. High CMD yarn count on the bottom side, thin MD yarns on the paper side are used in the fabric without jeopardizing dimensional stability. The crosswise top yarn count can be increased providing optimal fiber support but without closing the paper side of the fabric too much. With the top MD yarn count lower than in standard fabrics, the paper side of the

NEW GENERATION STL FABRIC FOR HIGH SPEED PAPER MACHINES

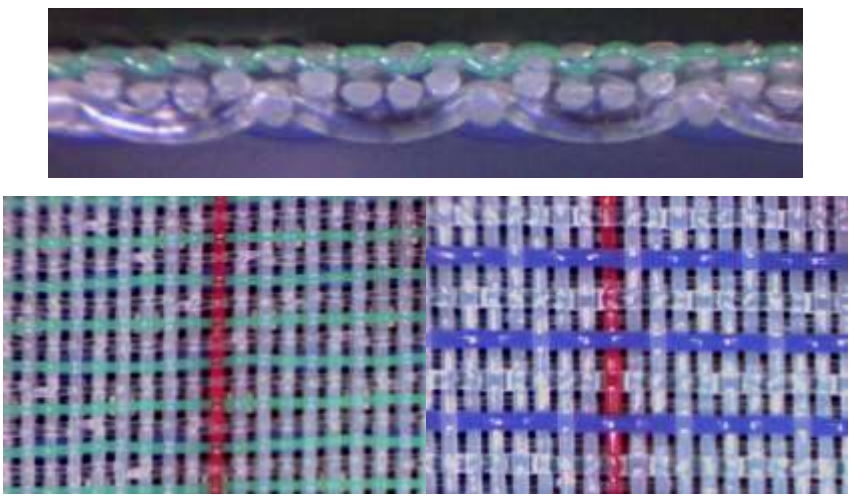


Fig. 11

fabric is not too dense allowing high drainage capacity.

Fabric Structure

In a macro scale i.e. sq.mtr. the fabric has a uniform structure. In micro scale, i.e. sq. mm. it is not. The unit cell varies from 1sq.mm to 50 sq.mm. In case of double layer weaving pattern the unit cells are much larger and more complex. Thus with the unit cells depending on its size and drainage channels, the local retention at that particular point varies.

The critical parameters in a fabric structure, which influences drainage properties are,

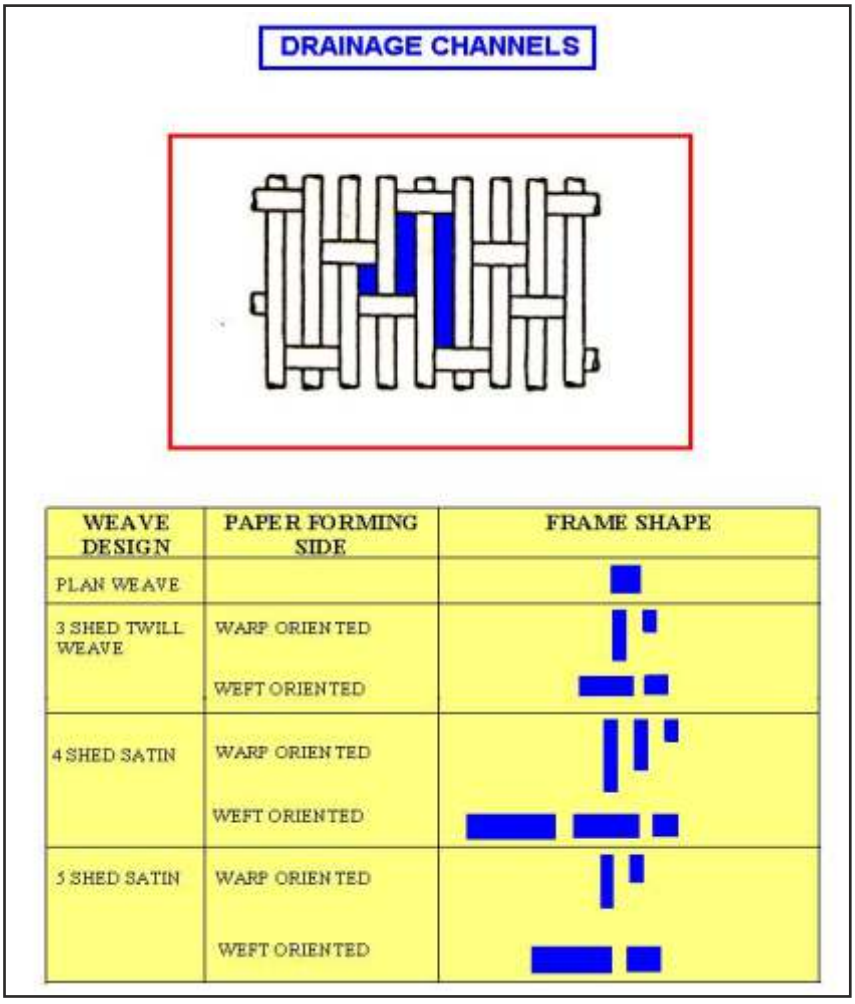
a. Drainage channels
b. Fabric structure bottle neck
c. Fiber support index
d. Drainage index

Drainage Channels

The registered drainage at some point reflects the average drainage over the unit cell. A typical set of unit cells is shown in fig.12. The flow resistance and consequently the drainage speed varies over the unit cell of the structure, according to the "voids and pores distribution". A fairly low average drainage speed thus may well cover parts of the unit cell having almost no drainage and other areas having very strong specific drainage. The fiber and filler retention of the open areas will normally more than offset the good retention in the dense areas. Hence not only the average retention but even the local retention becomes important. Thus to give a good and uniform retention, even in sq.mm scale, the drainage resistance of the fabric should be uniform even within the unit cell area.

Fiber Support Index

In 1978, Dr. Robert Beran setup a two dimensional mathematical model, which gives the probability of a uni dimensional fiber falling on a two dimensional grid created by a forming fabric structure. Dr.Berans's work resulted in a very effective simple equation which could be applied to the parameters of individual forming fabric design and produce one number which is call Fibre Support Index (FSI), calculated as follows:



FSI = 1.69 (a.Nm + 2.b.Nc)

Here 'a' and 'b' are weaving design constants

Nm = Warp count per cm.

Nc = Weft count per cm. (only paper side)

Calculation of FSI is most widely used by forming fabric manufacturers to describe the benefit of their product namely its fiber support power. Higher the value, the fabric is said to have higher fiber support capacity.

Drainage Index

For many years, it has been customary to define the drainage capacity of the forming fabrics by its air permeability (AP) measured in CFM. However, it is very well known that double layer fabrics are being successfully used on number of Fourdrinier machines wherein they often exhibit better drainage and first pass retention than the single layer fabrics. This contradicts the widely accepted view that drainage of a fabric is proportional to its air permeability because double layer fabrics have lower air permeability than single layer fabrics.

This led to the development of a Drainage Index, which takes into consideration the top surface cross directional strand fiber support and air permeability values. Drainage Index is calculated as follows:,

DI = b.Nc.V.10_3

Herein 'b" denotes weaving design constant

Nc = Weft count per cm. (only paper side)

V = CFM of the fabric.

Figure gives standard values of various fabric structural properties of single, double and triple layers. These values clearly confirm how the modern forming fabric SSB designs are far superior with respect to fibre support and drainage characteristics as well as on fabric wear potential.

Practical Application Of Forming Fabric Designs

It is common to find Indian paper mills to produce diverse range of paper grades using different types of furnishes & chemicals on a day to day basis. Added to this, the technology of paper machines in India ranges from old paper machines running at 200

mpm to modern wide width twin wire formers running at over 1000 mpm.

Forming Fabric design selection is very much paper grade and machine condition specific.

The Indian paper segment can be broadly classified into 4 categories as:

- Newsprint
- Writing & Printing
- Industrial Packaging
- Specialty

Each of these segments requires different Forming Fabric designs to meet their unique and specific quality requirements.

Newsprint Sector

In India, Newsprint is predominantly manufactured on high speed, wide width Twin wire formers to have the advantage of economy of scale.

High speed, wide width twin-wire machines require Forming Fabrics of following characteristics:

- High CD stability
- Flat fabric run
- Fast drainage
- Smooth sheet release
- Withstand high torque variations

Many of these high-speed machines are using agricultural residues or recycled de-inked fiber as their major raw material,. Hence the selection and designing of forming fabrics for these machines becomes quite demanding and challenging initially because of short fibers, quick drainage and good retention required. The forming fabric manufacturers were able to meet these requirements successfully with regular interactions with the papermakers.

Initially finer varieties of S/L fabrics were being used. In the recent past, they are being replaced by finer designs of two and half layer fabrics so as to achieve the desired properties of Newsprint paper. The use of extra-weave Double layer design fabrics have greatly benefited Newsprint manufacturers to reduce their clothing cost per unit ton of production.

Triple Layer SSB fabrics are gaining acceptance world wide due to their high Cross Dimensional stability and excellent drainage capacity on high speed, wider width machines. We foresee the wide application of Triple layer SSB design fabrics in Indian Paper Industries.

Writing Printing Sector

Majority of the machines manufacturing this grade are moderate speed Fourdrinier machines. The furnish composition in this segment includes:

- Bleached hard wood pulp
- Bleached bamboo pulp
- Recycled de-inked pulp
- Bleached agricultural residues

The important and critical feature of these papers is the use of wide range of filler levels, 6-22% (sheet ash). Sheet quality requirements are,

- Formation
- Retention
- Low wire mark
- Less two-sidedness

Almost 90% of the machines producing writing and printing grades today use Single Layer, Double Layer or Triple Weft design fabrics

Till 1995 S/L was the most widely used fabric. Major operational problems faced on using single layer fabrics are Bleeding and dimensional stability on high-speed machines.

Fiber bleeding problem is an inherent drawback of S/L fabrics, especially mills using mainly short fibers. The intensity and severity of bleeding differs from machine to machine and fabric to fabric depends on,

- Fabric design and mesh
- Furnish
- Rate of abrasion on m/c
- Fabric running tension
- Cleaning arrangement

Recently a new design S/L fabric has been developed and tried successfully on machines with chronic complaint of bleeding. This S/L fabric is gaining acceptance with customers who do not want to change over to Double layer fabrics due to either machine limitations, want of better cleaning systems or cost.

Extra weft Double Layer fabrics are normally being used regularly by customers who are more quality conscious. The various advantages derived on use of these multilayer fabrics are:

- Very Good FSI (Fiber support index) which enhances retention, formation and sheet release
- Good Drainage : Uniform and gentle drainage, void volume distribution facilitates use of high freeness stock and lower consistency
- Fabric cleanability: MD strand in extra weave design travels from top to bottom side of the fabric and has more open flow channels that facilitates gentler and more uniform drainage and a cleaner running of the fabric.

The modern SSB fabrics offer innumerable advantages specially for the newsprint and writing/printing segment of industry.

As mills gradually switch to alkaline sizing, , the need for much higher retention values and superior drainage properties becomes intense, specially due to higher filler usage in the furnish While $CaCo_3$ is cheap ,it is also highly abrasive in nature.

Our new STL forming fabrics from the SSB family, is most suited for these kind of machines, as it retains fillers and is having a very high Wear index, to take care of increased rate of abrasion as well as offering best surface properties.

Triple layer SSB fabrics are already in use on few machines in India and are running very successfully. Reduced drag load requirement by 10-15%, superior formation due to gentle and very uniform drainage, higher fibre and filler retention, cleaner run, are reported in almost all cases. .

Industrial Packaging Grade

This is an important segment of the paper industry, which has witnessed a very high growth in the last 3 years. This sector uses a wide range of furnishes with waste paper being the maximum.

The condition and upkeep of the machines is normally found to be moderate to poor, as majority players are small scale. Clothing economics i.e. fabric cost v/s tonnage produced is perhaps the most important factor. The main requirements from forming fabrics used here are,

- Good Drainage
- Long Life
- Robust to withstand stringent operating ·conditions
- Stay clean

Predominantly coarser varieties of 5 shaft S/L fabrics are used in this segment.
Due to present market condition and severe price pressures, mills are increasingly using very short fibers and slow draining furnishes. At the same time demand for high quality packaging paper is increasing. Hence many mills in this segment are switching over to double layer and two and half layer designs of forming fabrics to enhance the paper quality in spite of using low quality furnishes.

Multiformer Machines

To meet the increasing demands of higher quality packaging boards, multiformers consisting of 3-4 Fourdrinier tables are being used. Different designs of forming fabrics are generally employed for different layers of the board.
As the top most layer is of very finer grade paper, which is usually coated to have high quality printing surface a finer mesh fabric with high fibre support index is preferred in this application.

As the furnish in the middle and bottom layers consists of mixed quality waste paper, the forming fabrics used here should yield good life, be sticky repellent and run clean.

The paper characteristics like wire mark surface impression or look through are not critical. This permits the use of large strand diameters and coarse mesh fabrics to enhance stability durability and easy cleanability..

The coarser grade SSB triple layer designs have also been tried successfully and are fast gaining acceptance on the multi former machines.

Speciality Paper Grade Segment

This segment consists of machines manufacturing different grade tissue papers and other special application papers like Glassine Paper, Parchment Paper, OTC, Cigarette Tissue, etc of a very low GSM of usually between 18-38.

Tissue Machines:

The machines operate at very high speeds and the fabric length is very short. Long fiber furnish is used with a very high degree of hydration. The basic requirements from the forming fabrics are:

- Good Formation
- Drain fast as the wire is short
- CD stability as it has to run at high speeds
- Stay clean

A very fine quality 5-shaft design S/L fabric (as warp runner) is used to facilitate instant drainage in the forming zone itself. Now fine quality Triple Layer SSB fabrics are widely used for very high speed tissues machines.

Other Special Grade Papers:

In these grades also, long fibers are used along with a combination of high cost performance chemicals to achieve some specific properties of the paper related to the application they are meant for.

As sheet formation, retention and minimal two-sidedness are the pre-requirements of these papers, high FSI fabrics with excellent drainage properties are preferred. Modern triple layer SSB fabrics have proven to meet all these requirements very successfully.

Conclusion

Significant developments have taken place in the last decade on Forming Fabric designs. Today, papermakers expect the Forming Fabrics to last anywhere from two months to six months plus. There are few cases where fabrics have lasted for more than a year. This has greatly reduced machine down time for wire changes.

This extended life of Forming fabrics has been achieved along with ever improving paper qualities like formation, retention, etc. The excellent retention properties achieved on the modern Forming Fabrics have facilitated the papermakers to use higher quantities of secondary fibers and expensive chemicals to produce high quality products.

Forming fabrics face severe and demanding conditions in Indian paper mills due to older paper machines and multiple furnish usage. Thus, there is still a considerable scope of achieving high standards of performance with modern fabric designs, once paper machines are upgraded.

Inspite, of the superiority of multilayer forming fabrics majority of Indian paper mills around 266 customers are and will still continue to use single layer fabrics for quite some time. Hence, there will be continued design and developmental efforts in single layer fabrics to enhance its performance.

Bigger and medium, sized mills will be the major beneficiary of modern forming fabric designs. In these mills use of two and half layer fabrics and triple layer SSB fabrics will significantly increase. More so, will be triple layer SSB fabrics due to the immense advantages and economies it offers to the paper maker. In the last 2 years of its introduction by us, its success has been envious.

With the advent of high speed multi colour offset printing machine, the quality demand for newsprint and publishing papers will increase considerably. For example,. Surface smoothness, bulk, opacity, strength etc are to be far superior to run trouble free on high speed printing machines. Same is the case with packaging paper and boards. Secondly in future the demand is expected to be more and more for coated papers in all grades.

All these factors will put more pressure on papermaker, to meet their customer's requirements at minimum cost. Hence, it is foreseen that the paper maker will demand high quality performance from forming fabrics. The emphasis will be more on long and trouble free running, optimal drainage characteristics, and superior quality of paper produced. The importance of service support from the forming fabric supplier will also increase and quite naturally, local suppliers are best suited for this. With paper maker and forming fabric manufacturers working together as partners, as it was always the case in the past, it is very much possible to achieve the objectives.

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