Developments in Forming Fabric and Its Application to Indian Paper Industry

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ABSTRACT

Long and trouble free running of forming fabrics with optimal drainage characteristics and maintaining all required sheet properties is a common demand of all paper makers. This paper presents the various developments taken place in the last decade in the forming fabrics designs namely Single Layer, Double Layer & Triple Layer. Fabrics structural parameters namely drainage channels, void volume distribution, fibre support index, drainage index which influences the drainage characteristics of forming fabrics is discussed in detail. The present trend in various sectors of Indian Paper Industry with respect to selection and usage of modern forming fabrics designs and the benefits derived thereby, is reported.

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 mill 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. Eventhough 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 or due to its poor performance 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 makers 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

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forming fabric in the last two decade 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. The design and development of high speed twin wire and gap formers was successful 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 forming fabric.

FORMING FABRIC REQUIREMENTS

A forming fabric performs three operations

a) Allows water to drain through its openings

b) It 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 of pick up, knock-off and sepration properties, stability in MD an CMD, cleanability, wear resistance and the drainage (Fig. - 1)

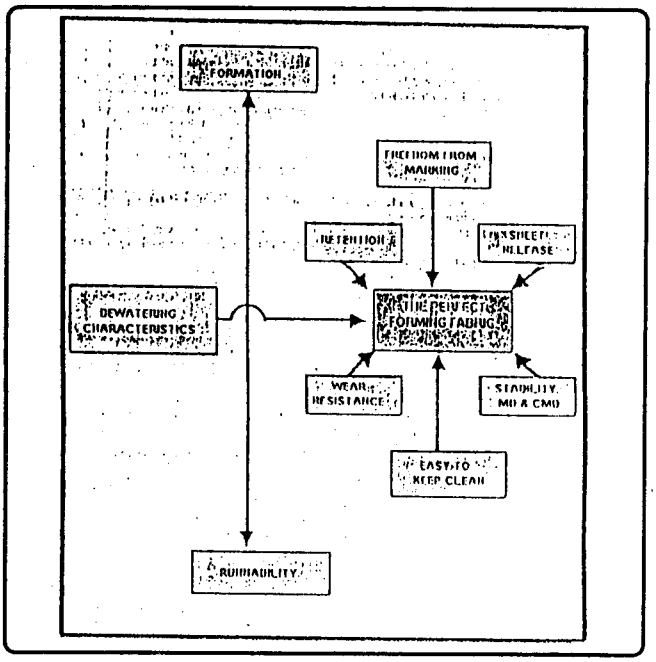


Fig. 1 The Perfect Forming Fabric

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 fabrics 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.

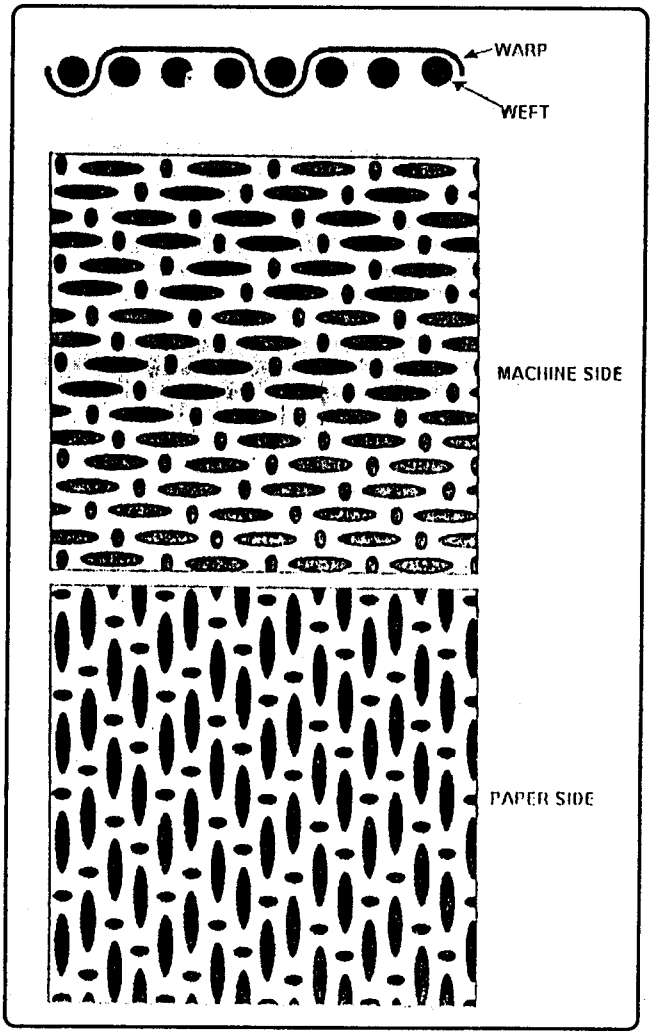


Fig. 2 - 4Shaft Single Layer

SINGLE LAYER

Single Layer fabrics are simplest in construction and the least sophisticated of today's forming fabrics. The most common designs are 4 shaft 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 these valleys and restrict further drainage. Moreover, single layer fabrics provides 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.

A 5shaft design has more internal void volume, meaning more drainage capacity. This design finds major usage in Kraft and Tissue making machines, where large quantities of water to be drained.

Other varieties of single layer fabrics are available. While there are subtle differences between the single layer designs all tend to have the same major characteristics.

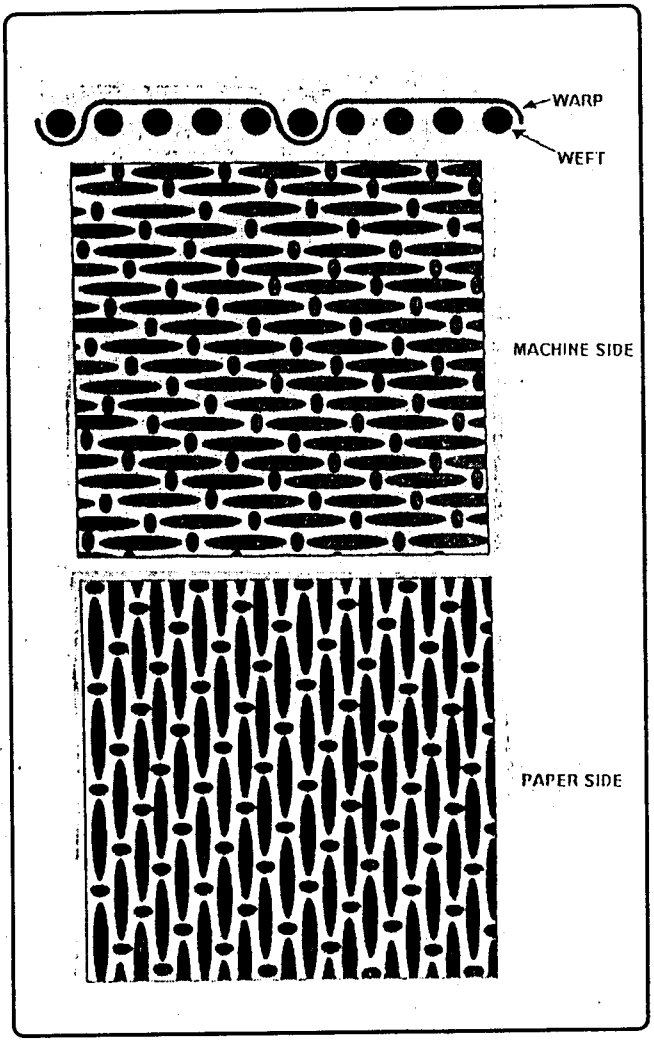


Fig. 3 - 5Shaft Single Layer

DOUBLE LAYER

As machine speeds and widths increased, single layer designs were not dimensionally stable and had the tendency of forming wrinkles specially 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).

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 a "seven shed double layer" commonly used in writing and printing grades. The top row of CD strands 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 surface and the wear surface.

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 to increase retention level, improved sheet surface and minimised two sidedness. The wear surface of the seven shed 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.

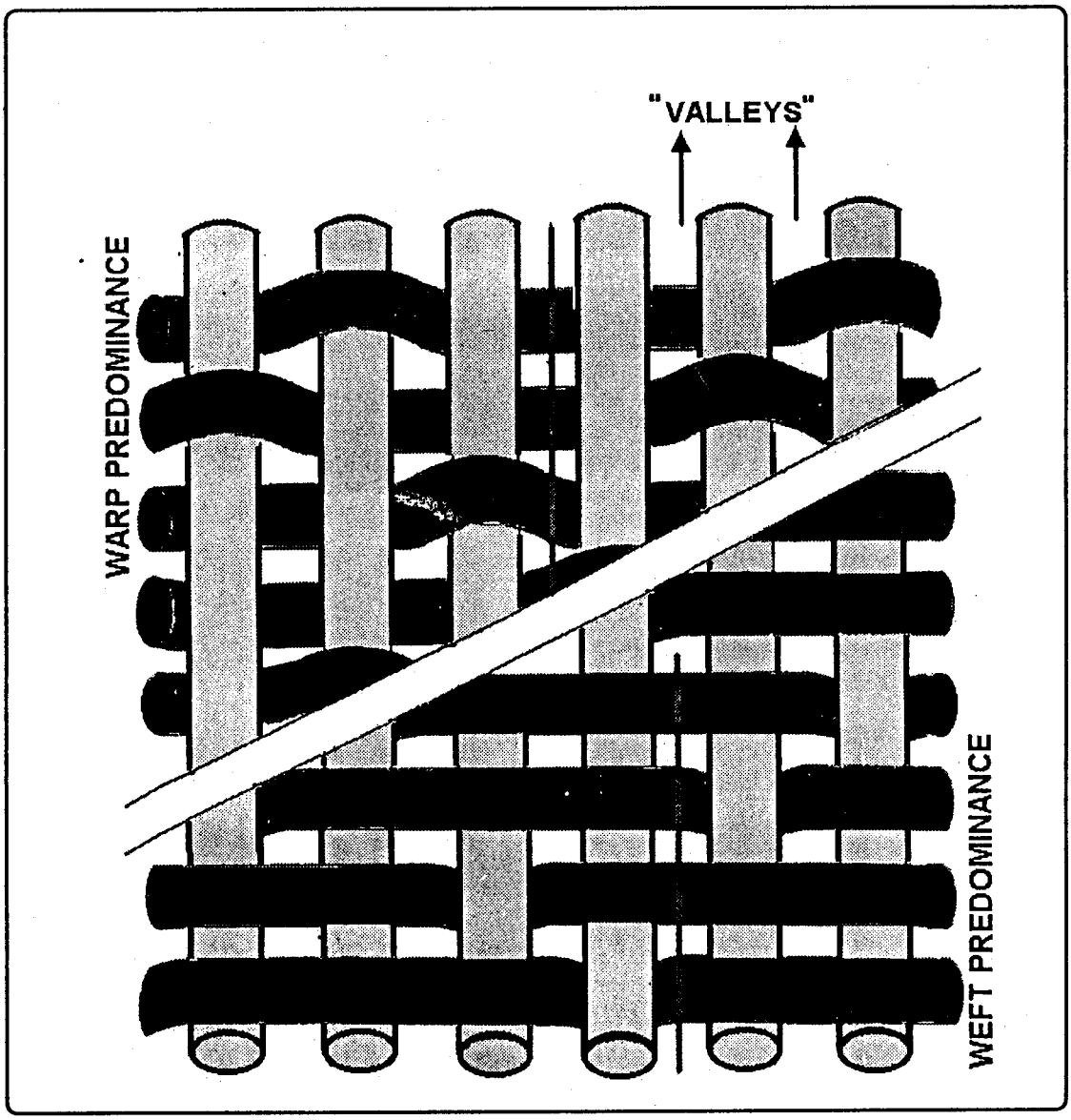


Fig. 4 Yarn Orientation vs Fibre Orientation.

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 shute. 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 CD 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 support shute double layer fabrics have become standard for making fine quality paper.

14 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 dewatering elements of the

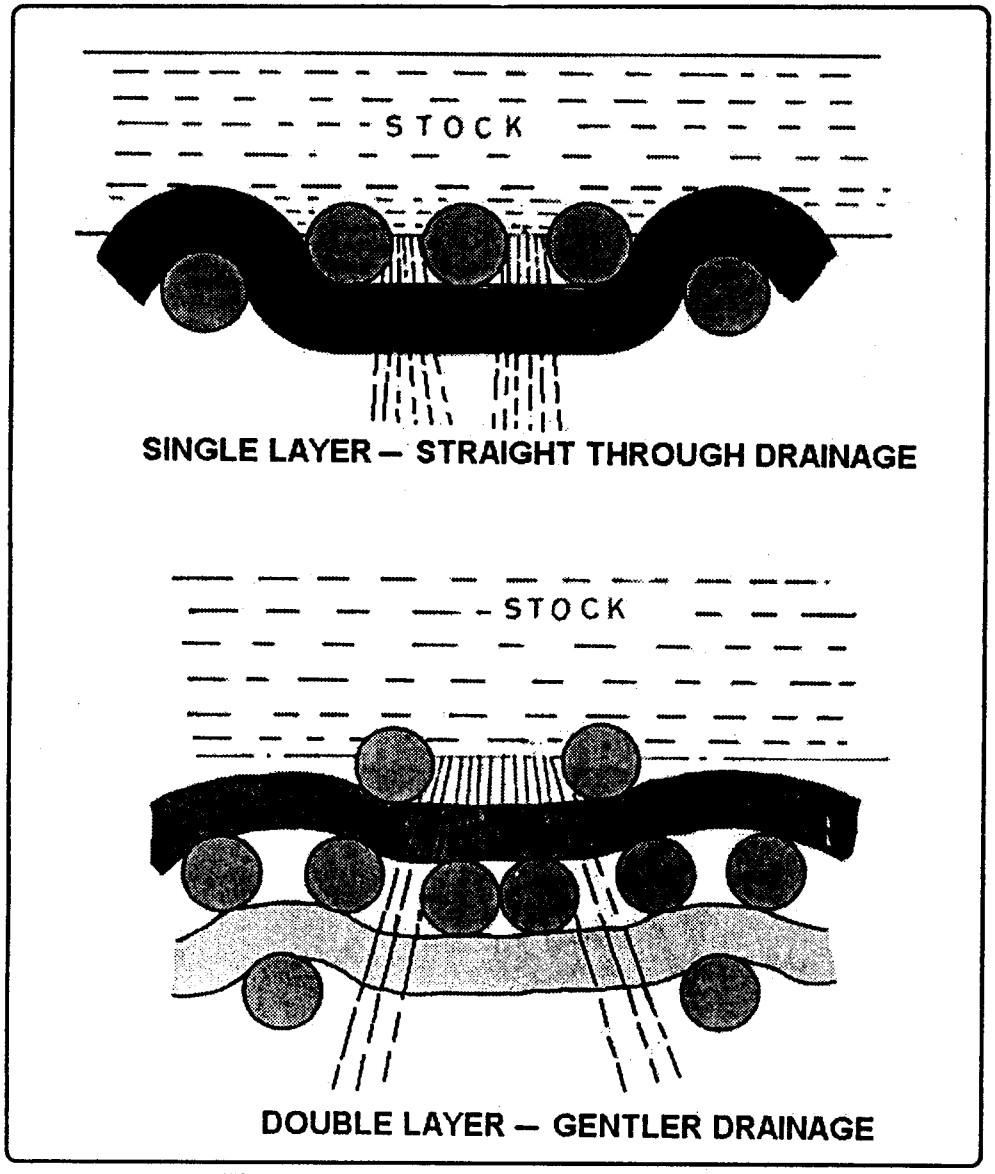


Fig. 5 Double Layer - Gentler Drainage

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 14 shed design (Fig. 8) facilitates to use double the no. of shafts than conventional double layer i.e. from 7 to 14. The unique warp and 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 CMD yarns. The vast difference in the stress and strain characteristics of the two different single layer constructions resulted in a "relative movement tendency" between the two layers frequently leading to layer separation and stability problems.

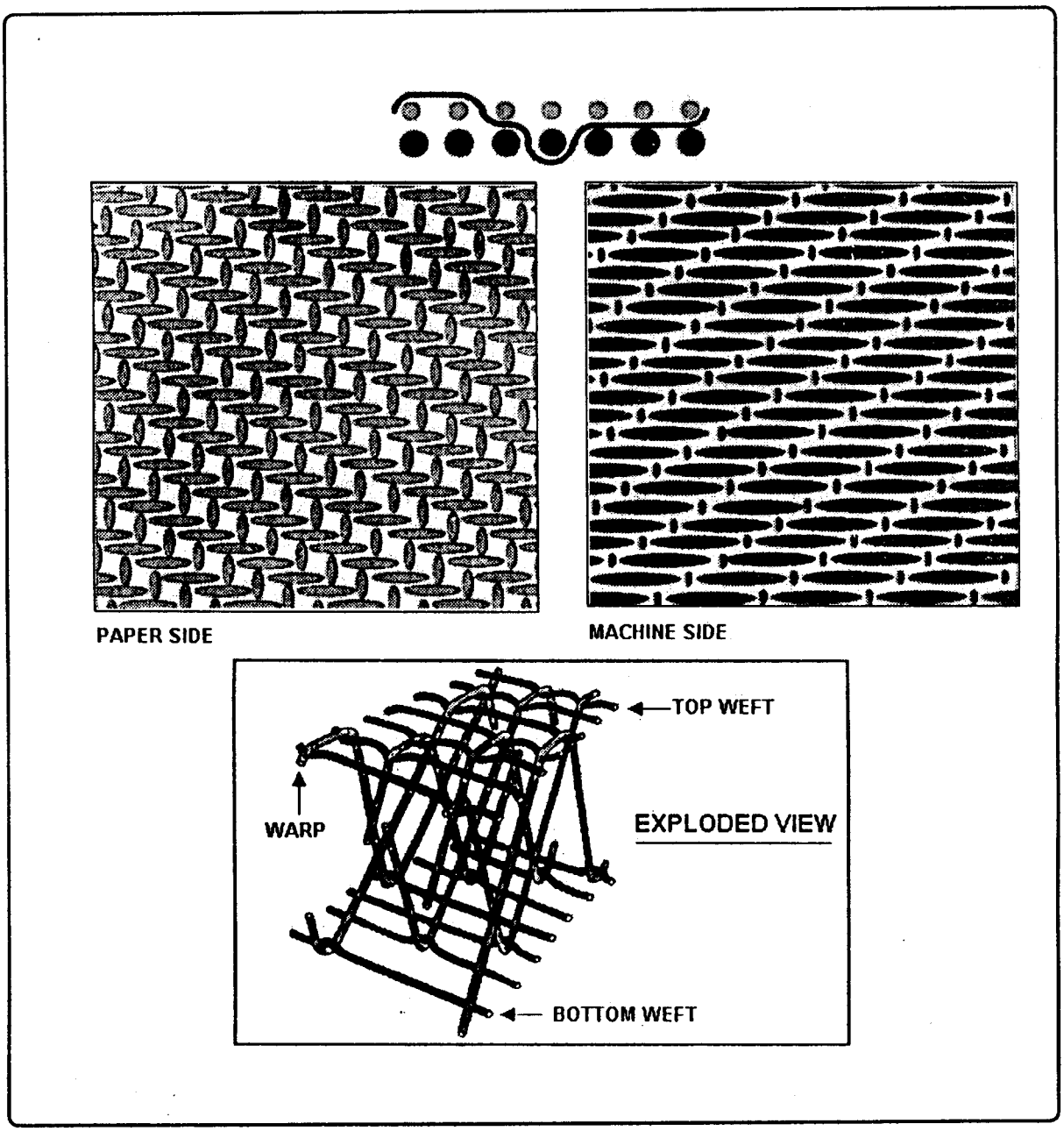


Fig. 6 7 Shaft Double layer

The second generation of triple layer constructions employed MD binder yarns and have to a great extent solved the problems of delaminating and stability. However, the major short coming in these designs is the fabric thickness exceeding the acceptable standards resulting in performance problems like water carryover, sheet transfer problem in twin wire formers, and tendency towards shadow marking on paper.

These problems resulting due to high fabric thickness is successfully eliminated in new design of triple layer wherein the binder yarns are eliminated and thereby fabric caliper could be reduced to magnitude of double layer designs.

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 result in the fabric to have extremely high bending stiffness that is 4 to 8 times higher than with conventional double layer fabrics. The three weft layers built up provides a basic high level of surface

stability and bending stiffness, as well as low cross directional contraction. These fabrics contract only to a minimum, even under peak loads, and no any longitudinal waves in the fabric return occurs.

In addition to this advantage, these fabrics demonstrate a variety of other innovative details. In double layer fabrics compromises are often necessary to meet various conflicting requirements, since the desire for a finely structured paper side contradicts the other need to high running time. 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 because of its three-weft layer built up.

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, In addition, the middle weft experiences no abrasion at all during the

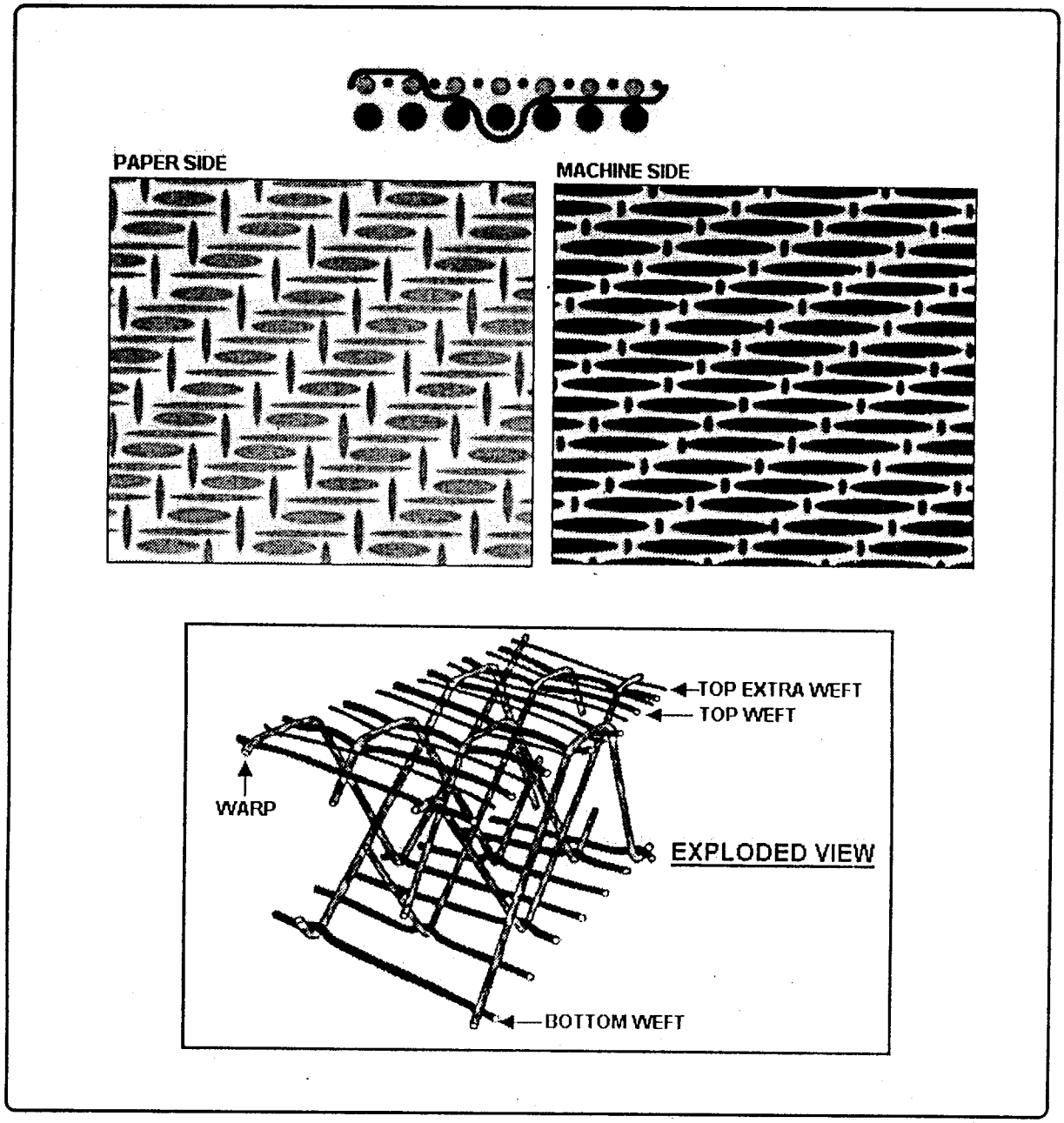


Fig. 7 Two And Half Layer

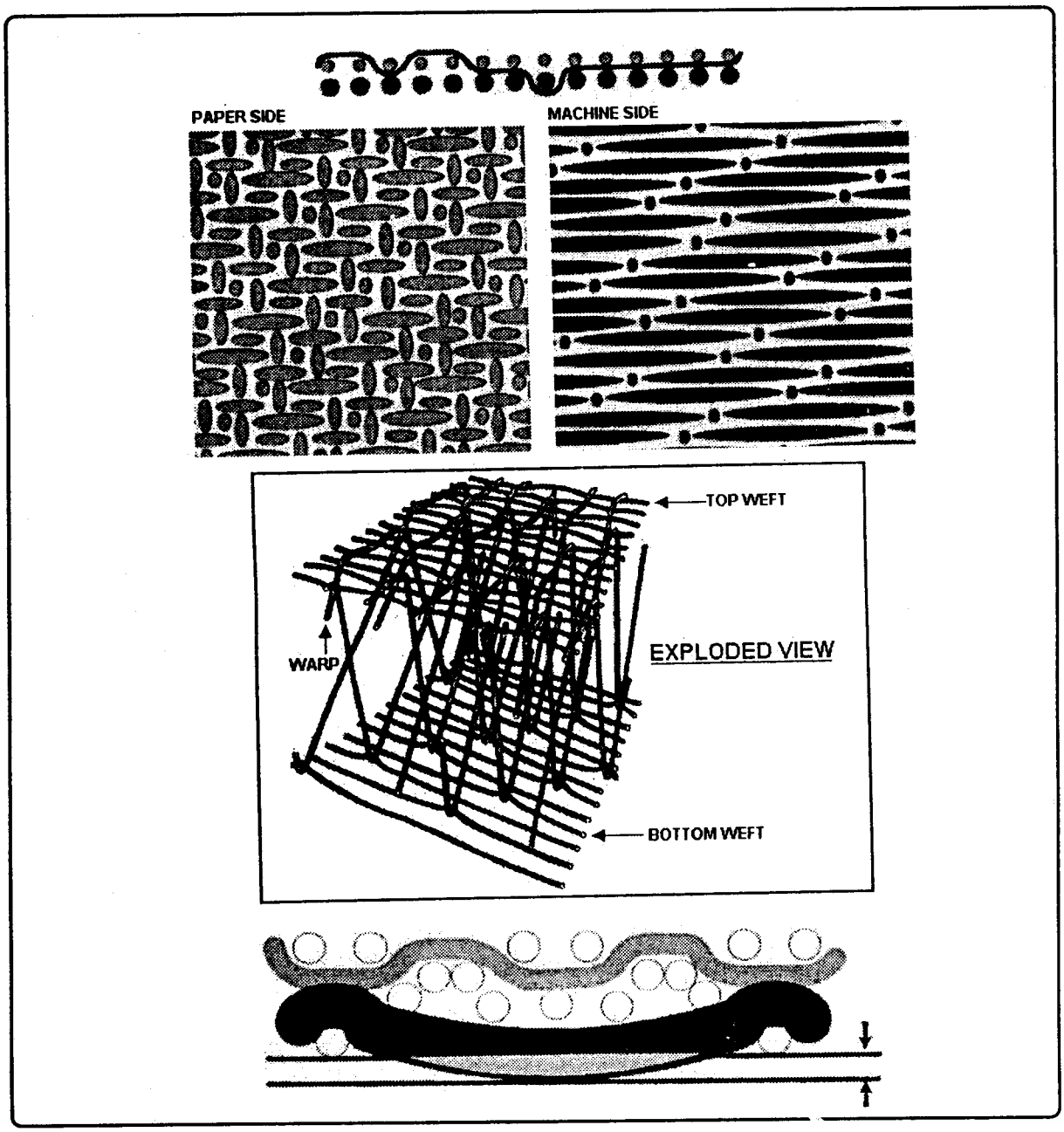


Fig. 8 14 Shaft Double Layer

entire fabric lifetime. This means that despite normal abrasive wear on the running side, the crossdimensional stability is hardly reduced. For this reason, paper produced on machines with these triple layer fabrics maintains a very even basis weight profile, even at the end of the fabrics running time.

Practical trials of this triple layer fabrics in various mill have shown the following advantages.

1. very low cross directional contraction even on high speed machines
2. optimum drainage
3. superior surface stability
4. high bending stiffness
5. low power consumption

FABRIC STRUCTURE

In macro scale i.e. sq. mtr., the wire is 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 complex 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. 11. 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 be more than offset the good retention of the dense areas. Hence not only the average retention but even the local retention will be more 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.

FABRIC STRUCTURE BOTTLE NECK

The critical factor influencing retention is the

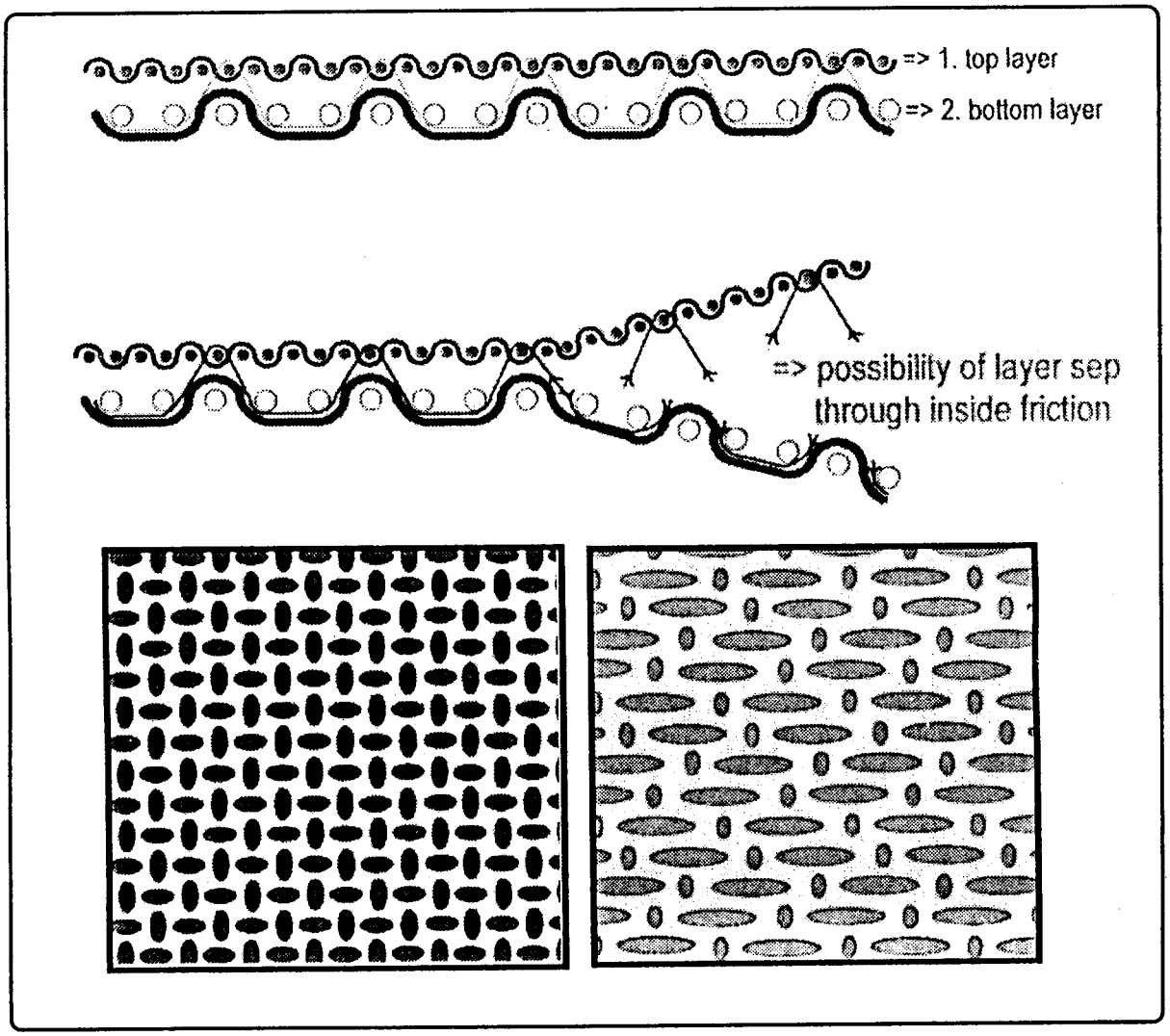


Fig. 9 Conventional Triple Layer

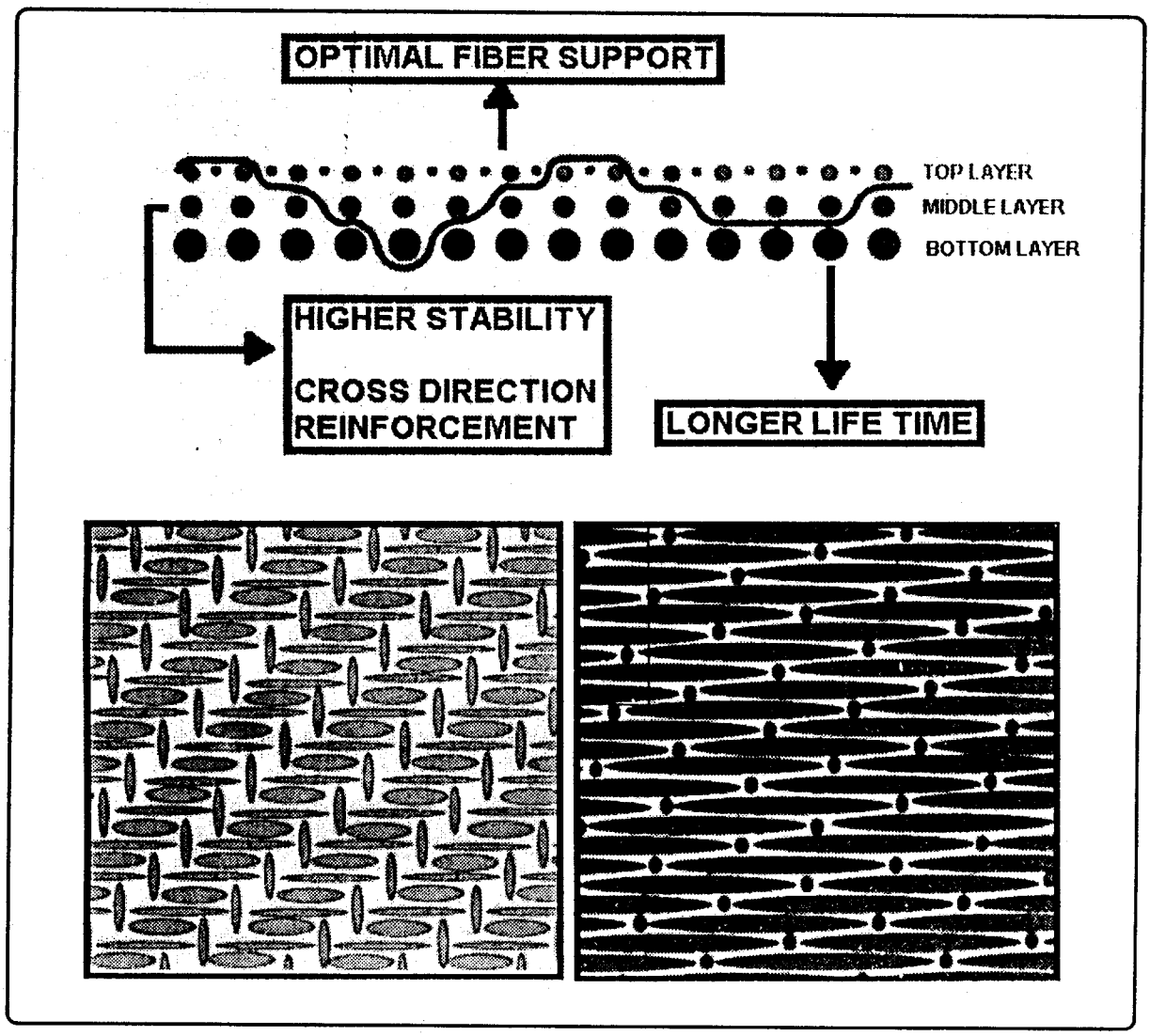


Fig. 10 Modified Triple Layer

drainage speed. The resistance of water flow through the fabric is strongly influenced by the densest layer of the wire or "Bottle neck". To ensure best retention under verying running condition, the bottleneck layer should be positioned in the upper half of the fabric.

In order that the drainage speed be slowed down as soon as possible after the drainage started, the bottle neck layer should be positioned in the upperhaft of the fabric, as the bottle neck operates as such only when the draining water has filled the wire donw to this layer. Simultaneously, the bottleneck layer should be positioned sufficiently deep that the web does not penetrate deep into it, harming further drainage. Fig. 12 shows the void volume distribution of a typical single layer fabric.

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 FSI.

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

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 fibre support power. Higher the value, the fabric is said to have higher fibre 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 fabric are being successfully used on number of fourdrinier machine wherein they often exhibit better drainage and first pass retention than the single layer fabrics. this contradicts the sidely 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.

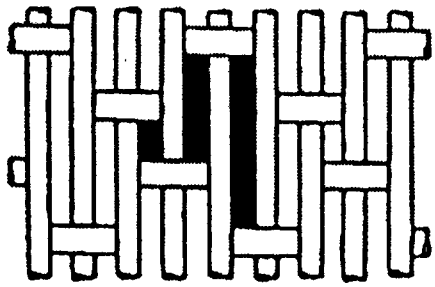
This led to development of Drainage Index, which takes into consideration of the top surface cross directional strand fiber support and air permeability values. Thus, DI = b.Nc. V. 10 _3

Herein 'b' denotes weaving design constant

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

V = CFM of the fabric.

Fig. 13 gives standard values of various fabric structural properties of single, double and triple layer. These values clearly confirms how the modern forming



WEAVE DESIGN	PAPER FORMING SIDE	FRAME SHAPE
PLAN WEAVE		
3 SHED TWILL WEAVE	WARP ORIENTED WEFT ORIENTED	
4 SHED SATIN	WARP ORIENTED WEFT ORIENTED	
5 SHED SATIN	WARP ORIENTED WEFT ORIENTED	

Fig. 11 Drainage Channels

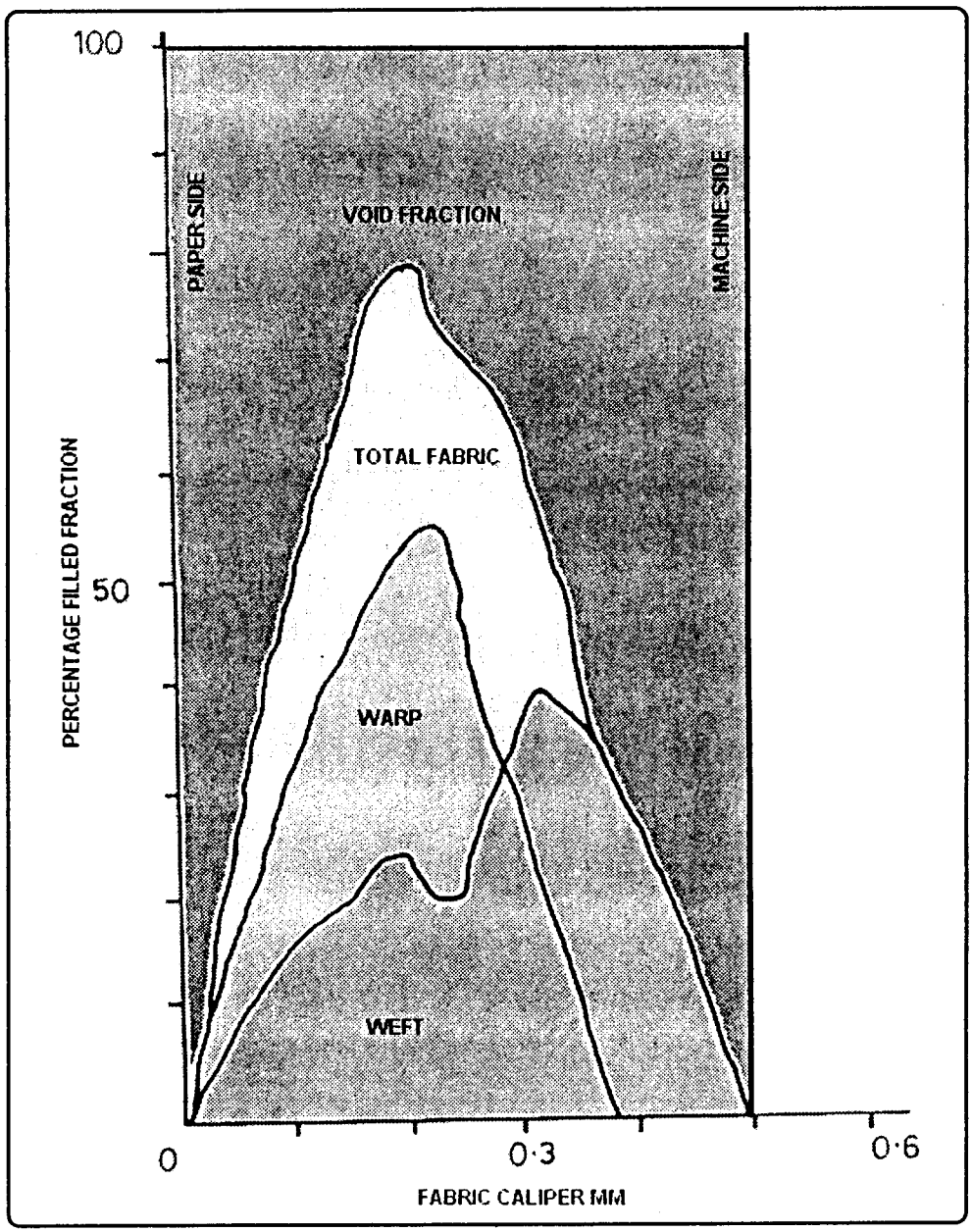


Fig. 12 Void Volume Distribution - Single Layer

fabric designs are far superior with respect to drainage characteristics as well as on fabric wear potential.

PRACTICAL APPLICATION OF FORMING FABRIC DESIGNS

It is very 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 100 mpm to modern wide width twin wire formers running at 800 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 Sector
- Writing & Printing Sector
- Industrial Packaging Sector

PARAMETERS	SINGLE LAYER	DOUBLE LAYER	TWO & HALF LAYER	14 SHAFT DOUBLE LAYER	TRIPLE
SUPPORT POINTS /CM^2	258	377	472	472	494
FSI	78	97	136	136	142
DI	13.1	14.4	28.2	27.9	27.4
ABRASION FACTORS	1.53	1.07	0.90	1.57	1.47
POROSITY CM^3 / M^2	330	386	410	490	552

COMARISION OF FABRIC STRUCTURAL PARAMETERS

Fig. 13

- Specialty Sector

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 scale of economy.

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

Majorities of these high-speed machines are using agricultural residues as their major raw material, with some mills also using recycled de-inked fiber. Hence the selection and designing of forming fabrics for these machines was very much 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 extra-weave Double layer design fabrics have greatly benefited Newsprint manufacturers to reduce their clothing cost per unit of production.

Triple Layer 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 application of Triple layer design fabrics in Indian Newsprint sector also very shortly.

WRITING PRINTING SECTOR

Majority of the machines manufacturing this grade is 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

Metal wires were being used predominantly in segment till 1980's. As metal wires were rigid (stiff), accident/damage prone, wire changes were frequent resulting into increased machine downtime, higher cost of operation and reduced efficiency. Hence the metal wires were gradually replaced by more efficient and economical synthetic forming fabrics.

Almost 95% of the machines producing writing and printing grades have swithced over to synthetic forming fabrics of different weave and designs,

- Single Layer- 4 Shaft and 5 Shaft
- Double Layer - Standard Design of 7 shed and 14 shed .
- Extra weft design of 7 shed and 14 shed.
- Triple layer 14 shed- extra weft.

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 large, quantity of short fibers. The intensity and severity of bleeding differs from machine to machine and fabric to fabric depending 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 on machines with chronic complaint of bleeding. The result from the performance is very encouraging and satisfying. This S/L fabric is gaining acceptance with customers who do not want to change over to Double layer design due to machine conditions, want of better cleaning systems and cost.

Extra strand design Double Layer fabrics are also being used regularly by the clients who are very much 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 gentle and uniform drainage and clean running of the fabric.

The usage of Multilayer design fabrics is on the increase and on an estimate 20% of the machines manufacturing this grade of paper have already switched over to this design.

Many Indian paper mills are expected to gradually switch over to alkaline sizing, which allows the use of calcium carbonate as filler. $CaCO_3$ is cheap but at the same time is highly abrasive in nature. Triple layer design forming fabric is the 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. Added to it Triple layer offers the very best surface properties to the paper.

Triple layer fabrics used on few machines in India on trial basis have been very successful. It is reported that, drag load requirement has reduced by 10-15%, superior formation due to gentle and very uniform drainage, filler retention has increased greatly and marginal increase in fiber retention (As already) Extra weave design fabrics are giving a high fiber retention).

We foresee increased use of finer quality of two and half layer fabrics and Triple layer fabrics in this sector.

INDUSTRIAL PACKAGING GRADE

This is an important segment of the paper industry, which has witnessed a very high growth potential in last 3 years. this sector has majority of the machines, which use wide range of furnishes with

waste paper being the maximum.

This grade represents high production demand with paper / board quality requirements being mostly mechanical.

The condition and upkeep of the machines is moderate to poor, as majority players are small scales. Clothing economics - fabric cost vs tonnage needs to be very low.

The main requirements from forming fabrics are,

- Drain well
- Run longer
- 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 there is an increasing demand of high quality packaging material. 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, multiformer consisting of 3-4 Fourdrinier tables are being installed. Different designs of forming fabrics are generally employed for different layers. The top most layer is of very finer grade paper, which is usually coated to have high quality printing surface. Hence a finer mesh extra strand double layer fabric 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 triple layer design have also been tried successfully and are gaining acceptance from 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 8-38.

TISSUE MACHINES

The machines operate at very high speeds and te 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 high speeds
- Stay clean

On majority of the machines a very fine quality 5-shaft design S/L fabric (as warp runner) is used to facilitate instant drainage in the forming zone itself.

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, very fine quality 2.5 layer is the most suitable design. Few paper mills have also tried triple layer fabrics and significant improvement in formation, retention and drainage characteristics was observed.

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 facilitiated the papermakers to use more quantity of secondary fibers and costly chemicals (which do not drain through) to produce high quality products.

Forming fabrics face severe and demanding conditions in Indian paper mills due to older paper machines. 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 are and will still continue to use single layer fabrics. 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 fabrics will significantly increase. More so, will be triple layer fabrics due to its tremendous success of limited trials carried out in the last two years.

With the advent to 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 papermakers, to meet their customers 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. With paper maker and forming fabric manufacturers working together as a partners, as it was always the case in the past, it is very much possible to achieve the objectives.

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