# Designing of Forming Fabric Considering Paper Making Aspects

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**ABSTRACT**

Forming Fabric design, properties and application have tremendous effects on paper properties & paper making process. Proper fabric can increase productivity, decrease Paper Machine downtime and increase bottom line. Therefore, it is crucial that the Fabric Manufacturer develops the right fabric & the Paper Maker knows a good deal about Forming Fabric. Forming Fabric design requires careful attention and a high level of engineering. Different paper grades require different forming fabric design. When selecting a fabric design for a specific application, various paper and paper machine parameters need to be considered.
There are many problems the paper makers face out of which four basic areas are -

1) Fabric Elongation / Stretch
2) Low Retention / Formation / Drainage
3) Low life of Fabric or Fabric Wear.
4) High drag load.

In this paper we will focus on these problems affecting life & performance of forming fabric and their solutions. Spacial emphasis will be given on less discussed but important areas of some forming fabric properties which a paper maker should know to get optimum & trouble free performance of forming fabric.

### Introduction:

Forming Fabric design, properties and application have tremendous effects on paper properties & paper making process. Proper fabric can increase productivity, decrease Paper Machine downtime and increase bottom line. Therefore, it is crucial that the Fabric Manufacturer develops the right fabric & the Paper Maker knows a good deal about Forming Fabric. Though the cost of machine clothing is only two cents for a dollar's worth of paper sold, the loss to a paper mill due to its poor performance or its usage is tremendous. As the heart of a paper machine is the wet end and the heart of the wet end is the forming fabric, any mistake here can hardly be erased from the final sheet.

So, it is important that the forming fabric manufacturers understand the needs and requirements of paper makers adequately and then translate them in their product design. It is also important that the paper maker knows the basic characteristics & properties of forming fabric and help forming fabric manufacturers to develop the right fabric for them by providing the information of paper and paper machine which are required to tailor made the fabric for each machine and each paper grade.
In this paper, we will focus on following less discussed but important area of forming fabric

1. Selection criteria of forming fabric.
2. Requirements of forming fabric.
3. Forming fabric properties.
4. Operating problems of forming fabric.

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### Selection criteria of forming fabric:

Forming Fabric design requires careful attention and a high level of engineering. Different paper grades require different forming fabric design. When selecting a fabric design for a specific application, the following paper and paper machine parameters need to be considered-

1) Paper Properties
   - Grade (tissue, writing & printing,newsprint, kraft, spaciality paper etc.)
   - Type of furnish and recycled fiber content
   - Paper weight (GSM)
   - Wire marking considerations
   - Two sidedness
   - Printability
   - Formation Type
   - Retention of Fibers & Fillers
   - Off Couch moisture (Dryness achieved after Wire part)

2) Paper Machine parameters
   - Machine Type (Fourdrinier, Hybrid M/C, Gap Former, Duo former)
   - Machine Speed
   - Operating Tension
   - Wire Size (Length & Width, Minimum & Maximum Length)
   - Type of Pick up
   - Paper Machine elements (Rolls, Foils, Vacuum elements)
   - Running Load & Tripping Load

3) Other Factors
   - Running time of Fabric
   - Reason for Fabric removal
   - History of previous fabric (if not new M/C)

### Requirements of forming fabric:

The term “forming” comes from formation of paper sheet. Water and wood fiber mixture (slurry) is pumped into rotating forming fabric. Typical consistency of slurry at the head box exit is 0.5% fiber (along with fillers and chemicals) and 99.5% water. Water is filtered through the forming fabric and fibers are retained on the top surface, thus the sheet is formed as shown in fig 1.There are three types of hydrodynamic processes during formation drainage, oriented shear and turbulence. Oriented shear is the result of the difference between fabric speed

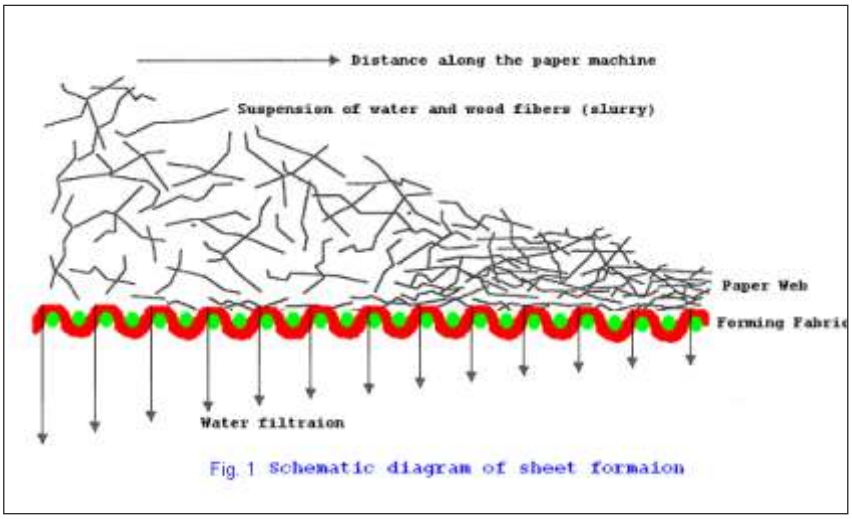


Fig. 1 Schematic diagram of sheet formaion

and head box exit speed. At the end of the forming section, sheet, which has a consistency of approximately 20% fiber and 80% water, is transferred from forming fabric to press section by open draw or suction pickup.

So, forming fabric performs basic three operations

a) Allows water to drain through its openings.
b) Supports and retains fibers to form a sheet.
c) Transports the sheet to the press section and thus acts as a conveyor belt.Clothing" Oct' 2009.

Apart from these basic requirements of forming fabric, other multifaceted requirements of forming fabric are

| | |
|---|---|
| 1 | Mechanical stability |
| 2 | Low power requirement |
| 3 | Long life |
| 4 | Optimal drainage |
| 5 | Good retention of fibers and fillers |
| 6 | Wire marking considerations |
| 7 | Less two sidedness |
| 8 | Printability |
| 9 | Good sheet release |
| 10 | Clean ability |
| 11 | Less elongation |
| 12 | Good cross direction stability |
| 13 | Adequate seam strength |
| 14 | No edge curl. |

These complex and often contradictory to each other requirements of forming fabric make its application an extremely challenging one, but it is possible only due to its unique properties.

## Forming fabric properties:

### Raw Material Properties:

Today almost all the forming fabrics are made with high molecular weight and high modulus monofilament Polyester yarn as machine direction yarn (MD yarn) and for cross direction yarn (CD yarn) alternate Polyester and Nylon are used. For better wear resistance, alternating Nylon yarns are used in single layer fabric and in bottom layer of multilayer fabric.

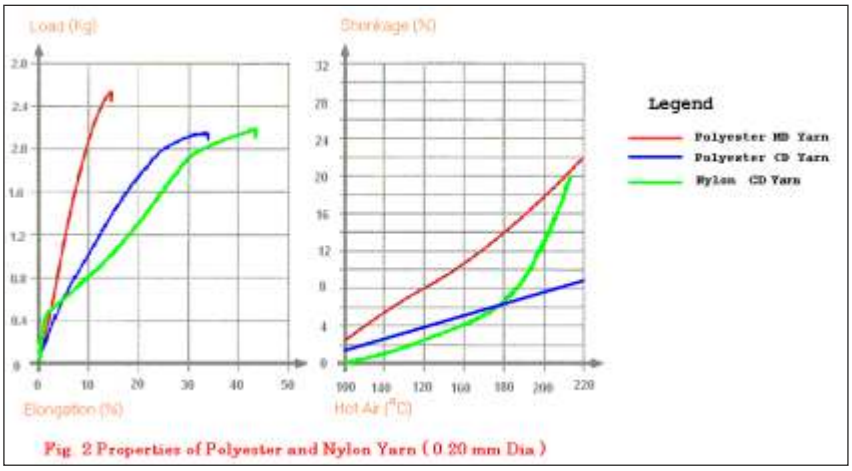


Fig. 2 Properties of Polyester and Nylon Yarn ( 0.20 mm Dia )

Physical properties of a typical MD & CD Polyester Yarn and CD Nylon yarn is given in Table 1 and the corresponding graph is shown in Fig-2

Fig. 2 shows that Polyester MD and CD yarns have different strength, elongation and shrinkage properties. MD yarn has considerable high modulus and low elongation to withstand operating tension of paper machine. Whereas CD yarn has low modulus than MD yarn to form better crimp which will ultimately help in better seam joint, better burial, better wire marking etc.

In comparison to polyester, Nylon has low modulus and high elongation and hence less stable than polyester, but for its excellent wear resistance property (as shown in Fig. 3) it is being used in alternate CD yarn in single layer and

**Properties of Yarn: Table 1**

| | Polyester (PET) | | Nylon (PA 6) |
|---|---|---|---|
| Diameter | MD Yarn 0.20MM | CD Yarn 0.20MM | CD Yarn 0.20MM |
| Breaking Strength Kg | 2.6 | 2.1 | 2.1 |
| Elongation At Break % | 12 | 35 | 45 |
| Shrinkage % at 180°C | 14 | 6 | 6 |

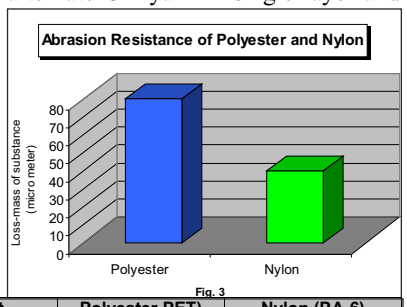


Fig. 3

| Particulars | Unit | Polyester PET) | Nylon (PA-6) |
|---|---|---|---|
| Density | G/cm$^3$ | 1.39 | 1.11 |
| Relative wet tensile strength | % | 100 | 85 |
| Moisture absorption (at 20$^0$ C and 65% rel. hum.) | % | 0.3 | 4.0 |
| Melting temperature | $^0$C | 257 | 215 |
| Dry heat resistance (long term) | Bis $^0$C | 150 | 95 |
| Aging resistance | | Excellent | Good |
| Fastness to light | | Good | Good |
| Weather resistance | | Good | Good |
| Rot- resistance | | Excellent | Good |
| Acid –resistance | | Good | Limited |
| Alkali –Resistance | | Limited | Good |
| Resistance to organic solvents | | Good | Good |

machine side of multi layer.
Other physical properties of polyester and nylon are given in Table - 2

## Physical Properties of Fabric:

Some physical properties of forming fabrics are crucial to its successful performance on paper machine. These are

## MD and CD count:

MD and CD count is the number of MD and CD yarns per cm of fabric. These numbers are generally used to distinguish forming fabrics and they affect other fabric properties also. Higher number of MD and CD count usually means finer fabric. Following is a typical example of two type of fabrics -one is a finer fabric suitable for writing/printing and the other one coarser fabric suitable for Kraft shown in Table - 3

**Table 3**

| Paper Grade | Design | MD/CD Diam (mm) | MD/CD Count/cm | Caliper mm | Burial MM |
|---|---|---|---|---|---|
| Writing/printing | Single layer | 0.21/0.30 | 28/22 | 0.59 | 0.164 |
| | Double Layer | 0.17/0.20,0.27 | 61/41 | 0.735 | 0.09 |
| Kraft | Single layer | 0.25/0.40 | 22/17 | 0.75 | 0.20 |
| | Double Layer | 0.27/0.30,0.45 | 37/28 | 1.30 | 0.28 |

## Fabric Caliper:

Fabric caliper measures the thickness of the fabric. This measurement provides a baseline for determining the degree of wear once on a paper machine. Multilayer fabrics have higher caliper than single layer fabric by virtue of two layers. Incase of high speed gap former machines low caliper is usually preferred especially in multi layer fabrics since it reduces the water carry-back and increases the drainage. Example of typical single and multiplayer fabrics are shown in Table 3.

## Burial:

Burial, also called Bottom monoplanity, is used to characterize the paper making wear potential. Burial is used in calculating fabric wear. Fig. 4 shows a schematic diagram of Burial.Example of typical burial of some fabrics are shown in Table 3.

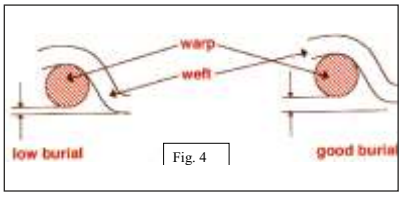


Fig. 4

In double layer, life is considered over when 85% of machine side weft is worn out provided, warp is worn out less than 55%.

## Air permeability:

The air permeability is a relative measure of drainage capability of a fabric. In actual practice drainage on a paper machine is also governed by certain other fabric properties. Air permeability is the measurement of air flow through the fabric at a pressure difference of 0.5 inch of water. It is measured as the air volume (cubic feet) passing through a unit area (square feet) of fabric per minute (CFM). Often it is understood that fabric having higher CFM will lead to higher drainage, but it is not always true. For drainage other properties of fabric like Drainage Index, Void Volume, design etc is more important. However CFM can be used to compare different fabric with same design. Example of Air Permeability of different fabric is shown in Table 4.

**Modulus**:

Modulus measures the fabric's ability to resist machine direction load. With the increasing speeds of paper machines, tension on fabric has increased significantly. In order to prevent excess stretching of fabric beyond take up limit of the machine under high tension, fabrics should have enough resistance to stretching in the machine direction. In practice Modulus is expressed in terms of load per linear unit length across the fabric width (PLI or Kg/cm). Example of modulus is given in Table 4.

**Fiber Support index:**

Fiber support index (FSI) is a statistical model, developed by Dr.Robert Beran in 1978, to calculate the fiber support potential of various forming fabrics. With the increased use of recycled fibers, that are generally shorter, fiber support capability of forming fabrics has become more important.The FSI is calculated as follows-

$$FSI = 2/3[a.Nm + 2.b.Nc]$$

Where,

a & b = support factor for MD & CD yarn respectively

Nm & Nc = MD & CD count per inch respectively.

Increasing the FSI is beneficial in -

Reducing wire marking, increasing retention, improving sheet release, reducing fiber carry and improve fabric clean ability. Higher support points by virtue of higher FSI leads to better formation. Example of FSI of some forming fabric is given in Table 5

## Drainage Index:

Drainage Index is a tool to provide a comparison of the drainage properties of different forming fabrics. Drainage index is given by the following formula

$$DI = (b.Nc.Ap)/1000$$

Where,

b = Support factor for CD yarn

Nc = Number of CD yarn per inch

Ap = CFM of the fabric

Example of Drainage Index is shown in Table 5.

## Wear Index:

Wear Index is used to compare fabric wear potential. While assessing wear potential of a fabric following fabric parameters are taken into account
1. Bottom CD Yarn Dia 2. Burial 3. MD & CD count 4. Weave pattern 5. Caliper
Example of Wear Index is given in Table 5.

**Table 4**

| Paper Grade | Design | MD/CD Diam (mm) | MD/CD Count/cm | Air Permeability (CFM ) | Modulus |
|---|---|---|---|---|---|
| Writing/printing | Single layer | 0.21/0.30 | 28/22 | 530 | 1050 |
| | Double Layer | 0.17/0.20,0.27 | 61/41 | 390 | 1250 |
| Kraft | Single layer | 0.25/0.40 | 22/17 | 540 | 1100 |
| | Double Layer | 0.27/0.30,0.45 | 37/28 | 480 | 1900 |

**Table 5**

| Paper Grade | Design | MD/CD Diam (mm) | MD/CD Count/cm | FSI | DI | Wear Index |
|---|---|---|---|---|---|---|
| Writing/printing | Double Layer | 0.17/0.20,0.27 | 61/41 | 82 | 12.69 | 19.52 |
| | 2.5 Layer | 0.17/0.20,0.13,0.27 | 61/51 | 119 | 28 | 16.82 |
| | SSB | 0.13,0.21/0.14,0.26 | 29/35 | 169 | 29 | 28 |

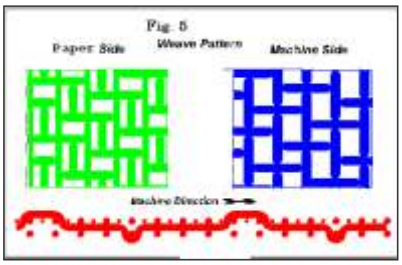
## Hole Size:

Forming fabric top surface construction plays a vital role in fiber support and drainage. The size of each hole or orifice gives a fair idea of fiber supporting and drainage characteristics of forming fabric. Example of hole size is given in Table 6.

**Table 6**

| Paper Grade | Design | MD/CD Diam (mm) | MD/CD Count/cm | Hole Size |
|---|---|---|---|---|
| Writing/printing | Double Layer | 0.17/0.20,0.27 | 61/41 | 0.776 x 0.322 |
| | 2.5 Layer | 0.17/0.20,0.13,0.27 | 61/51 | 0.458 x 0.322 |
| | SSB | 0.13,0.21/0.14,0.26 | 29/35 | 0.146 x 0.215 |

**Fig. 5 illustrates the hole size and shape of a fabric -**




## Operating problems of forming fabric:

Some of the most common problems affecting life & performance of forming fabrics are mentioned here under -

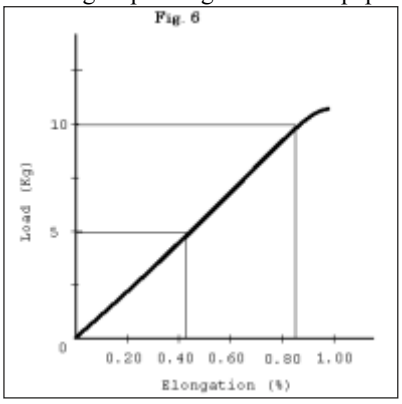
a) Fabric Elongation / Stretch
b) Low Retention / Formation / Drainage
c) Low life of Fabric or Fabric Wear.
h) High Drag Load

Now let us discuss these problems one by one.

## Fabric Elongation or Stretch:

With high operating tension on paper machine the forming fabric elongates to a certain extent. This elongation should be within stretch limit of the machine. Hence to design the correct running length of a forming fabric following parameters of Paper Machine is important

a) Minimum Length of Fabric




b) Maximum Length of Fabric or the Stretch limit of Machine.

c) Operating Tension of Fabric.

Following Load-Elongation curve (Fig. 6 ) of Fabric shows, with increase in MD load the fabric elongates to a certain extent. Hence to determine correct running length of fabric operating tension is utmost important.

Though it is a well known fact that Fabric with good Modulus plays an important role in solving the elongation problem but experience has shown that often lack of information on correct Minimum / Maximum Length & Operating Tension plays a vital role also.

So, giving correct Minimum / Maximum Length & Operating Tension to Fabric Manufacturer is very important to get good life and performance of fabric.

## a) Retention / Formation / Drainage

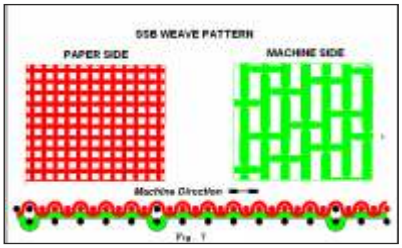
Fabric top surface topography plays an important role in paper making. Hole size & shape of fabric determines fiber bridging between the yarns and fiber orientation. Drainage path of forming fabric is very important. It determines the orientation of fibers in the sheet which in turn affects physical properties of sheet.

Fabric top surface and the fiber length fraction of the furnish play a vital role here. The area of each drainage hole is useful; especially the MD length of the drainage hole is related to the fiber length used to form the sheet of paper. This becomes more important as in case of recycled furnish, majority of fiber length is in shorter side.

Fiber length analysis of various grades of furnish from soft wood to recycled furnish reveals that a significant portion of fibers exiting from the headbox is below 0.40 mm.

For this application, the fabric will be designed such a way that the top surface will have orifice size of below 0.40 mm. This hole size will give good support to the fiber and will reduce or prevent sheet sealing and allow good drainage, which will ultimately give good paper quality.

Following diagram (Fig. 7 ) of fabric illustrates the above requirements of forming fabric




Though retention, formation and drainage depend on some other factors of paper machine e.g. furnish used, vacuum applied, angle of foils and table configuration etc. and some other properties of forming fabric e.g. Drainage Index, Fiber Support Index, Air Permeability of fabric etc. but experience has shown that matching the drainage hole size of top surface along with fiber length of the slurry is the most vital aspects to be considered to get good paper quality.

Hence, to design a good fabric with optimum retention of fibers & fillers, good formation and drainage, the fiber length plays an important role.

## b) Running time

The main causes of fabric wear are slippage, high vacuum, abrasive roll surface, flat box cover material, fillers in slurry etc. Fabric design and its wear resistance property of machine side CD yarn also play an important role.

The Wear Index of fabric is a useful tool to provide a comparison of wear potential of different forming fabric.

The amount of life remaining in a fabric can be ascertained by measuring the caliper of the fabric and comparing the value with that of the original caliper of the fabric. Machine side wear is the most common phenomenon for which most of the fabrics are removed from the machine either due to machine direction cuts in single layer or cross direction burst in case of multiplayer. To avoid unplanned wire change, suppliers are normally providing the safe caliper to decide the planned wire

change. Calculation of Safe Caliper is given below-
Safe Caliper = Original Caliper (MS CD Dia x 0.85)

For Example taking data from Table 3 for double layer fabric
Original Caliper = 0.735 mm
MS CD Dia = 0.27 mm
Hence, Safe Caliper = 0.735 ( 0.27 x 0.85 ) = 0.505 mm

### d) Drag load

Fabric running tension cannot be recommended without first determining the total fabric load, because different machines making many varied weights and products have different "Drag load".

$$\frac{\text{Volts x Amp. (or watts) x 49 (constant)}}{\text{Wire speed x fabric width in mm}} = \text{kg/cm. Drag load}$$

EXAMPLE
Couch Amps = 300
Volts = 400
Wirespeed = 320
Fabricwidth = 4500 mm.

$$\frac{300 \times 400 \times 49}{320 \times 4500} = 4.08 \text{ kg/cm. Drag load}$$

The majority of small slow machines would run with a drag load of approx.2.5/3.0 kg with a fabric tension approx. 3.0/4.0 kg/cm. Drag load while longer & faster m/c. would run with fabric tension of 5.5/6.0 kg with Drag load approx. 5/5.5 kg/cm.
Normally majority of drag load of a fourdrinier unit is caused by suction boxes/vacuum augmented area, any flaws in this area will certainly lead to low life and higher energy consumption.

### Conclusion :

With increasing paper machine speed and more use of recycled fiber, designing a forming fabric is becoming challenging day by day. Here comes a systematic and scientific approach to determine forming fabric design to suit various machines and paper grades is the need of the hour. Equally important is the importance of various paper machine parameters in selecting the correct design of forming fabric. Bridging the two technology together (paper & textile technology) is the right way to obtain the ultimate objective of trouble free running of paper machine and at the same time producing paper quality of international standard.

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