Stock Preparation

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Introduction

Stock preparation, as is generally understood, includes those parts of the paper manufacturing process where the pulp fibres are subjected to physical and chemical treatment to make them suitable for forming a special paper on a paper machine. In an integrated mill, as we have in India, this would chronologically include the following steps:

(1) Receiving the fiber suspension from the pulp mill.
(2) Thickening and pulp storage.
(3) Beating.
(4) Blending of non-fibrous additives.
(5) Stock storage.
(6) Broke utilisation (blending and metering).
(7) Final refining and supply to paper machine.

The two major functions normally associated with stock preparation are:

(a) Fibrillation and hydration of the fibres.
(b) Cutting or control of fiber length.

Both these functions are controlled during the process of beating and subsequent refining. All the developments in efficient stock preparation machinery or practices are, therefore, intended to do these two jobs in the most efficient manner possible.

Beating, as part of the stock preparation, may be defined as expansion of mechanical work on the fibre to develop fibrillation and cutting.

Refining is carrying the process further to improve formation and to adapt the fibers better for forming on the paper machine.

Fibrillation as one of the objectives of beating and refining is achieved by subjecting the fibers to such mechanical action which tends to fray its ends. Fibrillation assists in developing the strength characteristics of the resulting paper.

Hydration is simply to carry a point further and develop or increase the area of the fibre exposed to ambient conditions. Hydration is also referred to as the wetting of the stock or fibres or increasing the susceptibility of the fibres to the absorption of water. The collective role of fibrillation and hydration is well recognised as the greatest factor involved in developing the strength and optimum sheet conditions desired in the final sheet of paper.

Cutting, as the name indicates, is simply regulating the fibre length. It imparts to the resultant sheet of paper properties that cannot readily be achieved by the combined action of fibrillation and hydration. Cutting has the greatest influence on bursting strength development and closeness of formation of the sheet.

Structure of Cellulose Fibre

Before discussing the subject any further it would be most opportune to review the popular conception of the cellulose fibre and then explain as to what happens to this fibre during the process of beating and refining.

Studies have established that the cellulose molecule is made up of somewhere between 200 and 1500 glucose anhydride units grouped in a long chain molecule. It has been further suggested that fibrils—small groups of glucose anhydride—help to form the cellulose fibre by wrapping themselves around a core, called lumen, which is roughly similar to a straw. The whole structure is then covered by a very tough water-resistant layer known as Cambium Layer. The fibre has fundamentally a crystalline structure of the cellulose molecule. Figure 1 shows a schematic of the cellulose fibre based on the above conception.

Theory of Beating

With the above conception of the cellulose fibre make-up in mind it is now possible to describe as to what happens to the fibre during the process of beating and refining.

There are several theories concerning this phase. The most popular theory states that during beating the cambium layer is broken up exposing fibrils which are receptive to water. Water is also drawn into the voids between the inner fibrils. With the progress of beating more and more fibrils are exposed resulting in increased inner surface exposed to ambient conditions. The fibrils at time break off entirely causing gradual shrinkage in the cellulose fibre. The net result of

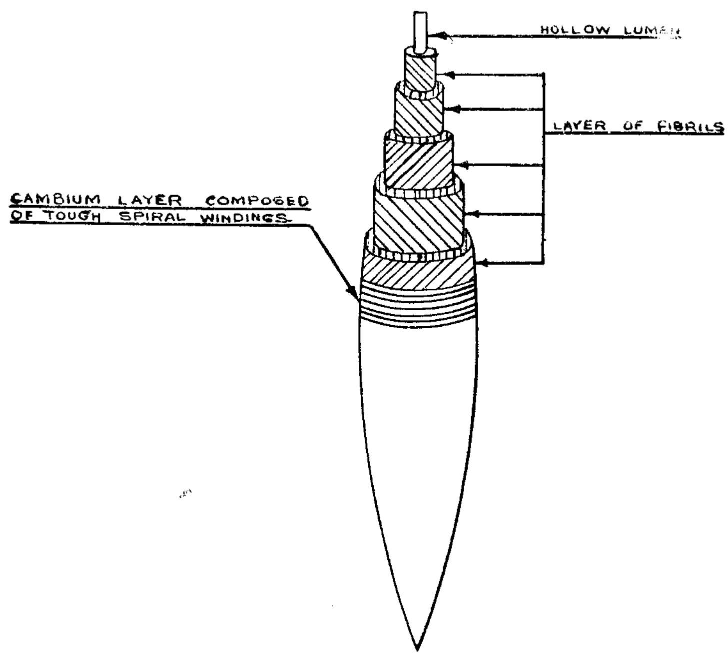


FIG-1 SCHEMATIC OF CELLULOSE FIBER

all these developments is that the beaten fibre is able to retain more water by virtue of its increased surface area. This is called fibrillation.

Now if the process of fibrillation is carried further the fibre becomes more resistant to drainage on the paper machine wire as the new surface exposed offer increased friction to the flow of water across them. This stage is known as hydration. It is of considerable importance because it plays a major part in the formatian of the sheet on the long wire and in determining the physical properties of the paper so produced.

Transverse cutting or shortening of the fibre also results from beating. It is desirable so far as improvement in bursting strength and close formation are concerned. But if carried too far it appreciably destroys the inherent strength of the fibre itself by making it shorter. Folding endurance is also decreased appreciably.

Having discussed the effects of beating on the fibre, the next logical step is to examine how they determine the properties of resultant paper.

(i) The primary result is the increased strength development through fibrillation and hydration.

(ii) The density of the sheet is increased because beating makes fibre shorter and more compact.

(iii) The porosity, softness and absorbency are consequently decreased.

(iv) The formation of the sheet is improved.

(v) The shrinkage of the sheet during drying is increased.

Figure 2 shows how these changes in sheet characteristics are brought about with increased degree of beating.

With these thoughts in mind the following assumptions can be made :

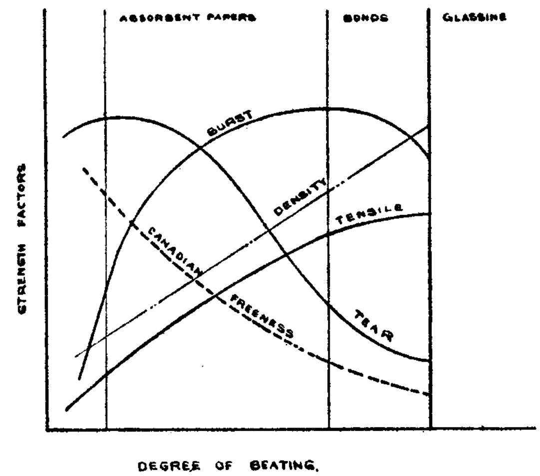


FIG-2 BEATING EFFECTS ON PHYSICAL PROPERTIES OF PULP

(a) For sheets which require a high tearing strength, fairly high bursting strength—the factors of fibrillation and hydration are the most important items to be considered.

(b) For sheets which require high bursting strength development, very low tear strength development—the cutting action is desired.

(c) For sheets which require high tearing strength, high bursting strength, high folding endurance and good density—the stock preparation system should be very well balanced to get proper combination of fibrillation, hydration and cutting.

The correct application of these three foregoing principles should ensure the best sheet characteristics of the desired paper with minimum horse power applied to the beating and refining machinery.

However, other variables such as furnish being used, consistency, the type and quality of sheet desired, rate of production, machine speed, etc. are no less important and must be correctly analysed to obtain proper proportion of each of the 3 factors mentioned above.

Selection of Fibres (furnish)

The selection of fibres and their proportions to each other must take into consideration the end use of the paper or board to be made.

For example, paper currency notes have to withstand an awful lot of folding and creasing without cracking, tearing or damage to the printed matter. Hence one has to select a kind of fibre that will withstand the hard usage to which such paper is subjected.

To withstand folding and creasing the fibre must be long and flexible and should possess the inherent strength which may be developed in stock preparation room. The longer and more flexible the unit fibre used the more often it can be folded over and over itself without cracking and breaking.

To have better idea of the subject let us now survey the fibres commonly used for paper making. There are three major fibre families most widely available for the purpose.

(i) The seed hair family which includes cotton, linen and hemp fibres.

(ii) The wood family which includes conifers such as spruce, pine and fir and hard woods such as poplar, birch, etc.

(iii) The straw family which includes straw, bagasse, grass, bamboo, etc.

The chart below shows the length and diameter of some of the commonly used fibres belonging to the above groups:

Fibre	Av. Length(mm)	Av. Dia.(m)
1. Linen	20-30	15-25
2. Cotton	10-40	19-38
3. Spruce	1.6-2.7	39
4. Hard woods	0.7-1.6	20-40
5. Bamboo	3-4	14
6. Bagasse	1.7	20
7. Straw	1.5	14-24

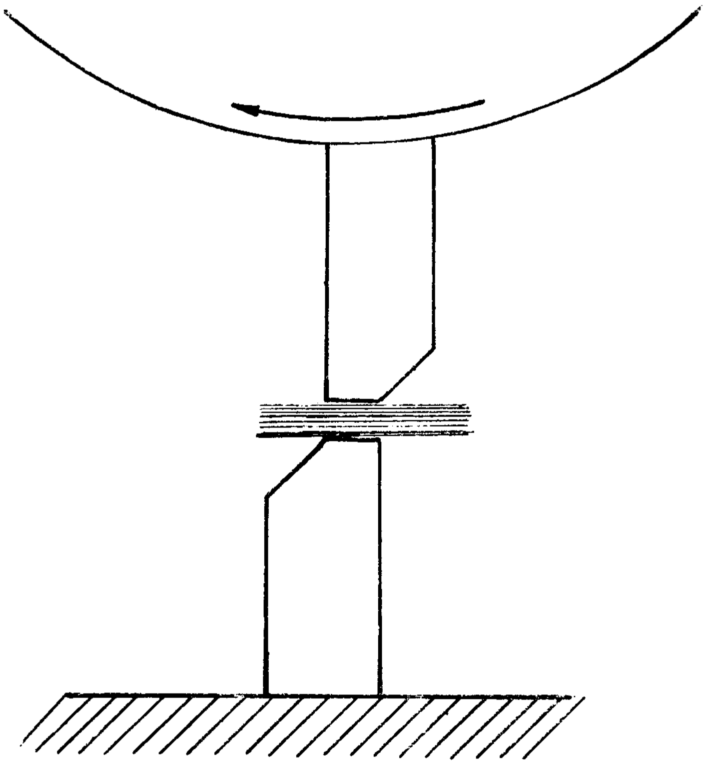
Now coming back to the selection of fibre for currency paper we find that the most suitable fibre falls in the seed hair family group. Hence commonly used combination is cotton with linen.

Again take the other end of the string. Newsprint, the utility of which is of very short duration—it is read and then thrown away—requires fibres which need not be very strong. It should be rather cheap. Hence the most commonly used combination is mechanical wood pulp along with chemical pulp from 2nd and 3rd groups in suitable proportion. Modern trend is to use mechanical wood pulp to the extent of 85 to 90% to reduce the cost of production.

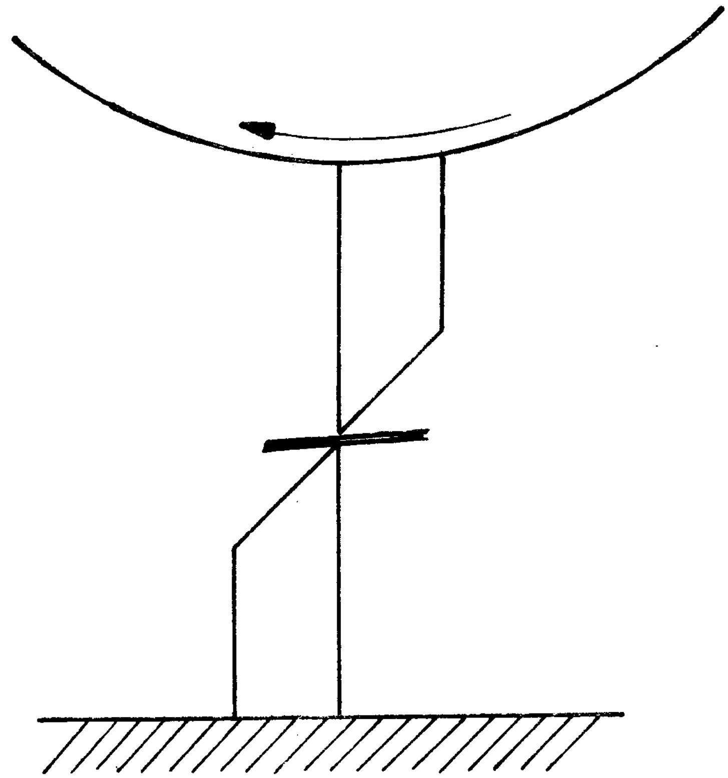
Effect of Thickness of Blades

Thickness and setting of the beater or refiner blades are the greatest factor in controlling the fibrillation, hydration and cutting of the fibres. To illustrate the point three different cases are considered here :—

Case 1.



Case 2.



1. *Blunt Blades separated:*

It is clear from the diagram that when the fibre passes between the blades its surface is principally affected, i.e., the fibre is "frayed" or split along its length. This operation is known as "fibrillation". The paper made under these conditions will have considerable strength specially tensile, folding and tearing.

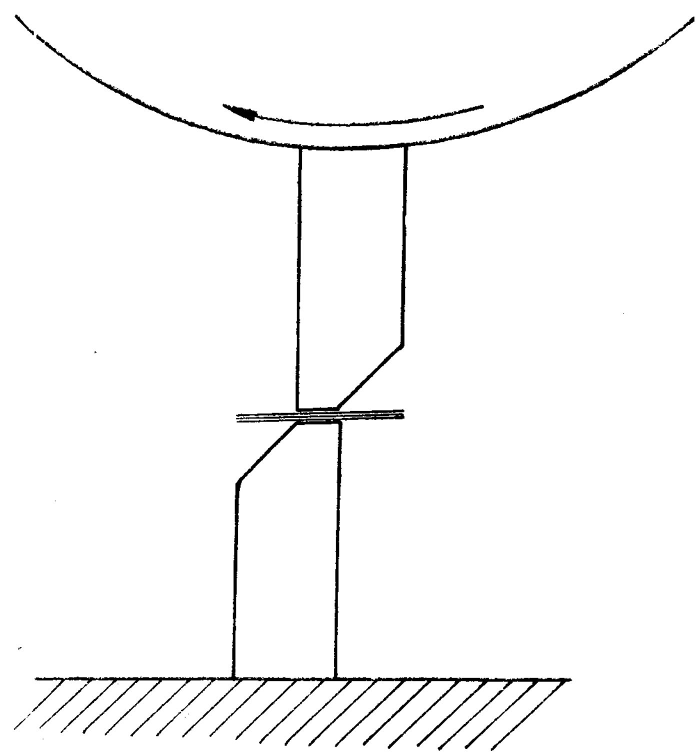
2. *Sharp Blades close together:*

In this case there will be more of cutting and relatively very little fibrillation. The paper made under this condition has relatively little strength because the fibres have fewer fibrille to hold them together. On the other hand, because of the open structure of the fibres, the paper has bulk, opacity and absorbency.

3. *Blunt Blades close together:*

In this case neither fibrillation nor cutting will predominate, but the fibre will

Case 3.



undergo a change in state which is termed as hydration. In this case paper produced is very dense, hard and transparent. They have a short tear, but are relatively rigid and have a high bursting strength.

Bearing in mind the various results obtained by beating, as they just have been described in general terms, it is necessary next to consider the ways by which such results are obtained. This may be done, first, with reference to the practical operation of beaters in paper mills and, secondly, with reference to the theories of beating.

Beater Operation

For example, take the case of mixed furnish for this is the simplest case. After the beater has been furnished and roll action started, nothing is added or taken away ; no change can be made in the speed of the roll ; no change can be made in the form, hardness or number of bars in roll or bed plates. The only manner in which the beater-man can influence the quality of the final paper is by his manipulating the roll up or down, including not only his positioning of the roll but also the length of time of treatment at any given roll adjustment. At this very point to make the concept clear, regard the beating process just similar to the support of a journal in a bearing. The beating surface, i.e., bed plate and beater roll of beater, core and plug of a refiner being analogous to the journal and bearing, and the material being beaten analogous to the lubricating oil. Just as a heavy oil can support a greater pressure than a light one before the oil filler breaks and the metal to metal contact occurs, so a harder pulp can support a greater roll pressure than a soft one. Hence a harder pulp if beaten to the same state as that of a soften one, the former will require a longer time and probably more of lowering of beater roll.

Effects of Roll Setting on Paper Characteristics

One engaged in paper making so often hears the words fine, free, long and wet (slow) . The beater-man is supposed to master the technique of controlling these factors so that the paper with desired characteristics may be produced on the machine.

(i) *Free and fine stuff :*

When the roll is set low to give violent and drastic punishment to the stuff it will result in the greater physical change in the fibres. If this setting is maintained for a comparatively short time the resulting stuff will be free and produce comparatively well formed paper. However, the paper will be soft, weak in tensile and bursting strength, easy to tear, possessing low wearing endurance and, unless specially sized, absorbent. It will not take high finish on calendering.

(ii) *Wet stuff :*

Under the same conditions if the roll is set lightly and the setting is maintained comparatively for a longer period the resulting stuff will be slow or wet. The resulting paper will, though cloudy, be hard and strong with high wearing endurance and less absorbent. It will readily take high calender finish.

In either case if the roll setting is maintained for a long enough period the resulting stuff would be slow or wet, but the two actions will not produce the same kind of paper. In case (i) the stuff will be fine and at the same time wet also. In the second case the stuff will be wet but long. Technically we can say that in the first case cutting has predominated and in the second case hydration. A free stuff is indicated by the fact that water leaves the mat freely when run on the paper machine. In case of wet stuff, on the other hand, water leaves the mat slowly or only with difficulty.

The mill practice for beating is to set roll lightly at first and then gradually lowering it at intervals during the run. The control of setting and length of time, however, still remains with the beater-man.

Consistency

It is usually meant the per cent weight of bone dry fibre in any combination of fibre and water. It plays a very important part and has direct control on the end properties of stuff. The pulp beater at lower consistency under the same condition of beating is comparatively more free than a pulp beater at higher consistency with the development of refiners its importance has all the more increased. Because of intimate bar-to-bar contact in refiners, the consistency of pulp exerts a great influence on the characteristics of the stuff passed through refiners. If cutting is important stock density is maintained at three per cent. If maximum hydration is desired, the stock is at six to eight per cent consistency.

Beating and Refining Equipments

The Chinese, original makers of paper, used to do the job by hitting the fibres with rods or crushing them in crude stamping mills. However, with the coming of machine age in the middle of eighteenth century beater was developed in Holland which is fundamentally the Hollander type beater in use today. This continued to be the only successful beating device for next 100 years.

But with the advancement of paper technology and introduction of high speed machines Hollander beater could no more serve the purpose because of the following disadvantages :

1. Extremely high power consumption. The large roll is used to move the stuff around the beater.
2. They have low beating capacity, useful work is being done while the pulp is between roll and bed plate. Also it requires a great deal of time to load.
3. They are bulky and require much space. For example large flywheels are required to reduce motor speeds of 1,600-2,000 revolutions per minute down to 80 or 100 revolutions per minute for the roll.
4. Due to poor circulation of stuff (called channelling) the stock is not uniformly developed. The stock near the mid-feather will pass under the roll more frequently than that on the outside.
5. Because it works on batch operation, the quality of the stuff from batch to batch is not likely to be uniform.

Hence around 1850 conical and disc refiners were conceived. However, proper metal bearings and precission machining were not obtainable and hence disc refiner was then shelved. The conical type, however, was developed, introduced into the pulp and paper field and advanced to present day design by technological study of results and effects.

The Jordan refiner is a typical example of conical refiner. It is essentially a solid conical plug within a conical shell. The plug rotates at 300 to 550 revolutions per minute. Peripherial speed is 2,300 to 4,500 feet per minute, for a 30″ diameter (large end) plug. The stock enters the smaller end, passing between the plug and the shell and then discharging at the large end. On the working surfaces of both plug and shell, bars are placed parallel to the longitudinal axis. The plug shaft runs in bearings, the one at the larger end being a thrust bearing. This bearing is connected to a handwheel which positions the plug horizontally controlling plug and shell clearance. There are more bars at the larger end to equalise wear and maintain fit between plug and shell. The stock generally goes through the Jordan at a consistency of 3-3.5%. The modern trend is moving toward higher speeds and higher consistency.

The disc refiners, which have recently come into wide use, are a radical departure from the conical refiners and somewhat resemble an attrition mill. In place of shell and plug, two vertical discs are used, either or both of which may be rotating. Stock enters through a hollow arch and passes vertically between the discs to the periphery by centrifugal force, and then discharged. Each disc is fitted with removal plates containing a variety of working surfaces. The clearance between discs can be accurately controlled due to the massive construction and fine adjustments available. Disc refiners are versatile in that new plates can be installed quickly to change refining qualities. The three main factors affecting refining are clearance between discs, the speed of the discs and type of working surface.

Refiners have gained popularity over beaters because:

- (i) They are versatile.
- (ii) They are accurate.
- (iii) They have high capacity and minimum space demand.
- (iv) They are easy to control.
- (v) They are comparatively inexpensive.
- (vi) They permit continuous operation.
- (vii) They are reasonable in power demand.

Now having studied the different types of stock preparation equipments available the next logical step is their selection for a particular job. The choice of particular equipment is made keeping in view the type of paper or board to be produced and the type of pulp to be used and the rate of production.

In spite of distinct advantages of refiners over the beaters every type of paper cannot be suitably made by the use of the former. In the production of Glassine (grease proof) paper, tracing paper and kraft papers, where hydration is more important, the use of beater is still preferred. In fact many mills manufacturing kraft and sack paper have modified their process by using the beaters in continuous operation and thus avoiding the disadvantages associated with the batch operation of beaters. They claim that results of their modified system are better than those achieved by use of refiners.

Again the type of pulp used has a vital say in the selection of equipment. A short fibred furnish does not need use of beaters since the necessary characteristics can be developed by the use of refiners. Rag pulp on the other hand, develops better characteristics in beaters.

The rate of production of paper is another important factor in selection of stock preparation equipment. High rate of production definitely requires use of refiners. In such case it is advisable to use at least two types of refiners (few with thick bars and other with thin bars) in series to have better control of hydration and cutting.

Broke Utilisation

Broke utilisation is perhaps the biggest control problem in stock preparation. Broke is nothing but unsalable paper. It is good pulp and must be re-used.

Nowadays nearly every machine is equipped at least with one pulper which is actually meant to consume the machine house broke or the broke of the same shade from finishing house. The shift from the pulper is normally pumped to dumping chest. As the pulping is batch system and the shade of the broke is not exactly the same as that of the fresh pulp, so there is likelihood of variation of shade and in the standard degree of freeness of the pulp supplied to the machine. To avoid this difficulty it is advisable to keep one chest extra and from there to regulate the addition at a constant rate to avoid the change in shade and freeness.

Conclusion.

The stock preparation is an additive process and not substractive one. The basic rule in stock preparation is to do a quality job.