Designing of Refiner System in a Paper Mill

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The term "refining" in pulp and paper industry can be classified under the following heads :

i) Separation of individual fibres

ii) Treatment of the

Separated fibres < Primary / Secondary

In the former case, the fibre bundles are usually presented to the refiner as Raw chips (for mechanical pulps), partially cooked chips (for semi-chemical or chemical mechanical pulps and completely cooked chips (for chemical pulps). Even though this preliminary refining can be done at any consistency it is usually done at two consistency ranges.

viz. 30-32% or 2.5—3.5%

In the latter case i.e. development of fibres already separated (may or may not be by the above method) the fibres varying in lengths from 1-2 mm (hard-woods), 3.5 mm (soft woods) and 12-33 mm (in case of raw cotton) are presented to the refiner in the form of a slurry in the consistency range of about 3%. The limiting factor is the ability of centrifugal pumps to handle the stock at higher consistencies.

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This paper was presented out zonal meeting of Ippta, on Pulp & Paper Mill Engineering held at Calcutta of July 6 & 7, 1974.

The discussions are limited to the second type of refining-treatment of individual fibres and is often referred to as "Beating."

'Beating' in the broadest sense covers the physical treatment given to the fibres to render them suitable for paper-making. Raw or unbeaten stock as it comes from the pulp mill is non-uniform, porous, low in strength, and is unsuitable for formation into a sheet of paper. By properly refining this stock, it is made suitable for conversion into different types of paper-ranging from Blotting paper at one extreme to the Glassine paper at the other extreme. To understand this physical phenomenon it is first necessary to understand the construction of a typical paper making fibre.

A magnified figure of a cellulose fibre and its construction are shown in figure 1.

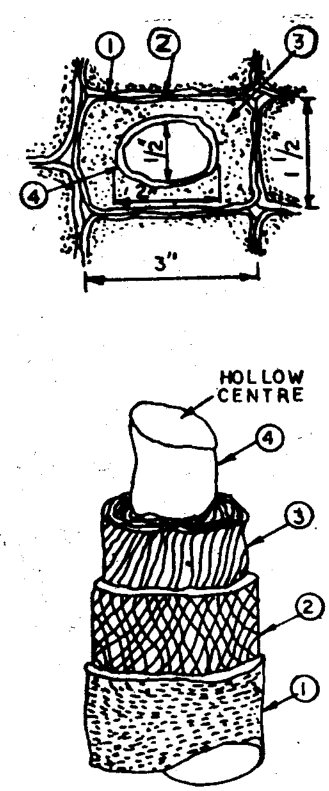


FIGURE-1

PAPERMAKING FIBRE MAGNIFIED 2500 TIMES

1. **Primary Wall (Magnified Thickness 1/32")**

2. **Secondary Wall (Magnified Thickness 1/16")**

3. **Middle Wall (Magnified Thickness 1/2")**

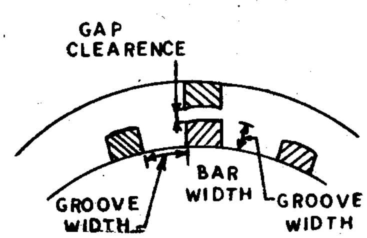
4. **Inner Wall (Magnified Thickness 1/32")**

The possible effects of refining with a Beater, Jordan and a Disc refiner on the fiber and the desired effects are shown in figures 5 and 6,

The Basic Action

For a system designer an understanding of the different elements in a refiner and the basic action involved in the process is necessary.

The different elements involved in the refining action are shown in figure 2. The stator and the



The Different Refining Elements Figure 2

rotor are represented by the letters S and R respectively. The grooves 'G' allow the pulp slurry to pass through the refiner and maintain a constant supply of fiber at the edges of the bars 'B'. As the rotating bar approaches the stationary one the fiber is trapped between them. It then passes over the stationary one dragging the fibers and squeezing them. After the rotating bar passes over the stationary one the fibers are released and they are back into the slurry. This is the basic action involved in all low consistency refining. This is shown in figure 3.

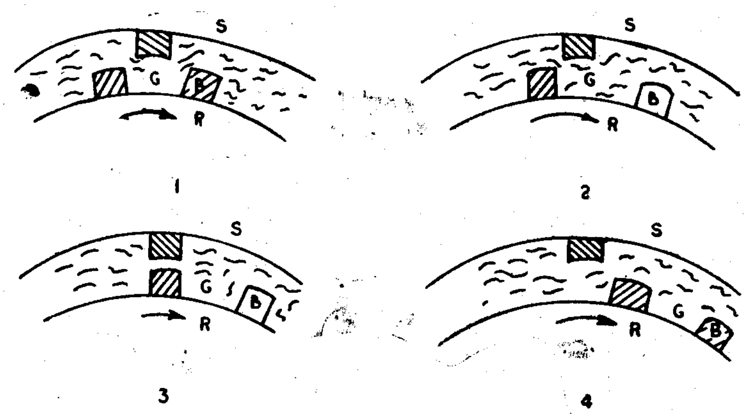


Figure 3—Basic Action of Refining

Thus beating has a destructive mechanical action on the fibers and the process transforms the long, smooth and stiff fibers into shorter, fibrillated and more flexible fibers. Its effect on the individual fibers can be broadly classified into

Internal Fibrillation

External Fibrillation

Fibre rupture

The effects on the fibers and how they influence the wet and dry sheet properties are represented in figure 4. The effect of beating on the various sheet properties for a Bleached spruce sulphite pulp beaten in a Laboratory PFI Mill are shown in figure 4.

Effect of Variables

A. Design Variables

Figure 2 shows the different refining elements. The possible variations amongst these are,

i) Bar width

ii) Number of Bars

iii) Bar Material

iv) Groove width

v) Groove Depth

vi) Refiner speed

B. Operatiug Variable

i) Consistency of the pulp slurry

ii) Pressure or intensity at which the fiber is treated

iii) Temperature of refining

iv) pH

C. Others

The other factors influencing the effect of beating are Cooking Process and Bleaching

Of these, different bar and groove widths produce different types of refining action and various combinations of bar width, number of bars and clearance between them give to basic actions *viz.* Hydration and cutting

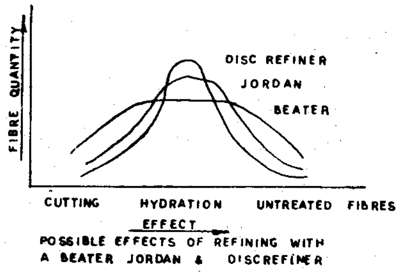


Figure-5

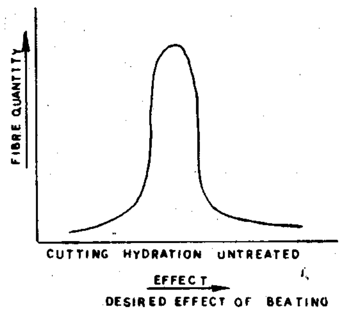


Figure-6

Variations in the groove depth have little effect on the flow rate that can be passed through the refiner.

To get the desired action however requires application of the correct intensity or load. The relative peripheral speed of the rotor to the stator establishes how many times a fiber is trapped between the bars in one pass through the refiner. Generally higher speeds and/or higher intensities give a brushing action thus resulting in increased hydration.

Between the moving and stationery edges the fibres are subject either to many gentle impacts in which case the fiber length is substantially retained and fibrillation results; or to a few relatively severe impacts, in which case fibre cutting predominates. These two factors *i.e.* relative severity and number of impacts per fiber are shown to be functions of certain refiner design and operating parameters as shown below :

$$S = \left[\frac{(HPa - HPn)\,At}{D\,(RPM)\,LfLsC}\right] K_2$$

$$N = \left[\frac{LrLs(RPM)C}{XR}\right] K_1$$

Where,

S : relative severity of impacts

N : relative number of impacts

Influence Beating On

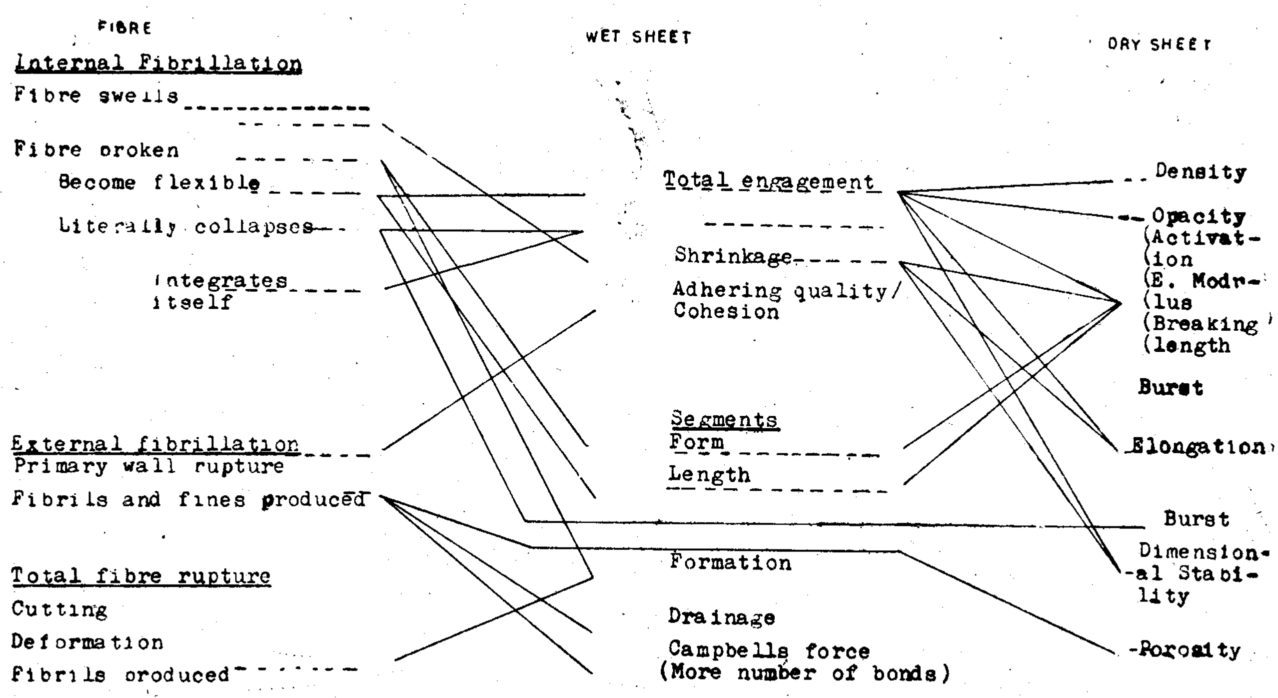


Figure-4. Influence Of Beating On The Fibre, Wet & Dry Sheets.

HPa—applied HP

HPn : no load HP

(HPa—HPn) —net H. P. available for refining

At—total area of refining zone

Lr—Total length of rotor edges

Ls—Total length of stator edges

D—Effective diameter

R.P.M.—Rotor RPM

C—Stock consistency

X—Average bar contact length

R—Throughput rate

K_1K_2—Appropriate constants

During beating the fiber is also exposed to the action of the stresses by the water in which it is suspended. Thus the consistency at the time of refining has an influence on the effect.

With increasing temperature the beating rate is retarded and development in strength is rather slow.

The increasing acidity has a decreasing effect on the tensile and bursting strengths. It increases the freeness and bulk. Lower pH increases the frictional resistance and there will be a high consumption of power. By refining the pulp in the alkaline pH range superior strength properties are developed. Swelling is maximum in the pH ranges 5-6 and 8-9 and minimum in the range 7.0–7.5.

The effect of cooking process on beating is mainly due to the variations in the amount of retention and the method of distribution of the residual lignin. Lignin does not swell and moreover its presence inhibits the swelling of hemicelluloses also.

In sulphite pulping where the hemi-celluloses are largely dissolved and molecules are shortened and the lignin is present in the outermost layer, development of strength properties is much less as compared to the sulphate pulping where in the residual lignin is more uniformly distributed. They beat slowly but develop greater strength.

Similarly in the case of NSSC pulp also the hemi-cellulose are prevented from swelling by the high lignin content, where as the pulp cooked by Mitcherlich sulphite cook where the cooking is slow and gentle, swells freely due to higher hemicellulose and lower lignin contents.

The effect of ordinary bleaching on beating is also due to the removal of lignin which helps more swelling of the fiber and develop greater strength. The influence of the different variables on Hydration and cutting are shown in Tables 1 and 2.

Table 1

Variable	For Hydration	Cutting
1. Bar width	6–10 mm	3–5 mm
2. Number of bars	More	Less
3. Material*	Soft	Hard
4. Speed	High	Low
5. Pressure/Intensity (Load/Cutting)	Medium	High
6. Consistency	5—10	3

* Where the increase in °SR desired is above 40 to 45 Basalt Lava filled refiners are preferred. These are also becoming popular on hardwood fibers. Bronze is used for making certain grades of grease proof paper.

Table 2

Varying the Wetting Cutting Balance			Principal Bar Materials
Factor	**Increase Wetting**	**Increase Cutting**	**Desired. Toughness. Edge Retention qualities Erosion Corrosion Resistance**
Bar Clearance	Large	Small	In approximate order of increasing hardness.
Bar Area*	Large	Small	Phosphor Bronze
Bar Speed*	High	Low	Lava
Stock cons.	High	Low	Cast Iron
Applied HP	Low soft	High Hard	Carbon Steel Type 4140
Bar Material	Porous	Dense	Stainless Steel Type 431
*At the same applied power			Jones super stainless (Precipitation Hardened)

Ultimately how the different strength properties are developed with beating is shown in figure 7. The developments can again be classified into two groups viz. useful and non-useful as shown in Table 3.

Table–3.
Influence of the effect on the fibre sheet properties.

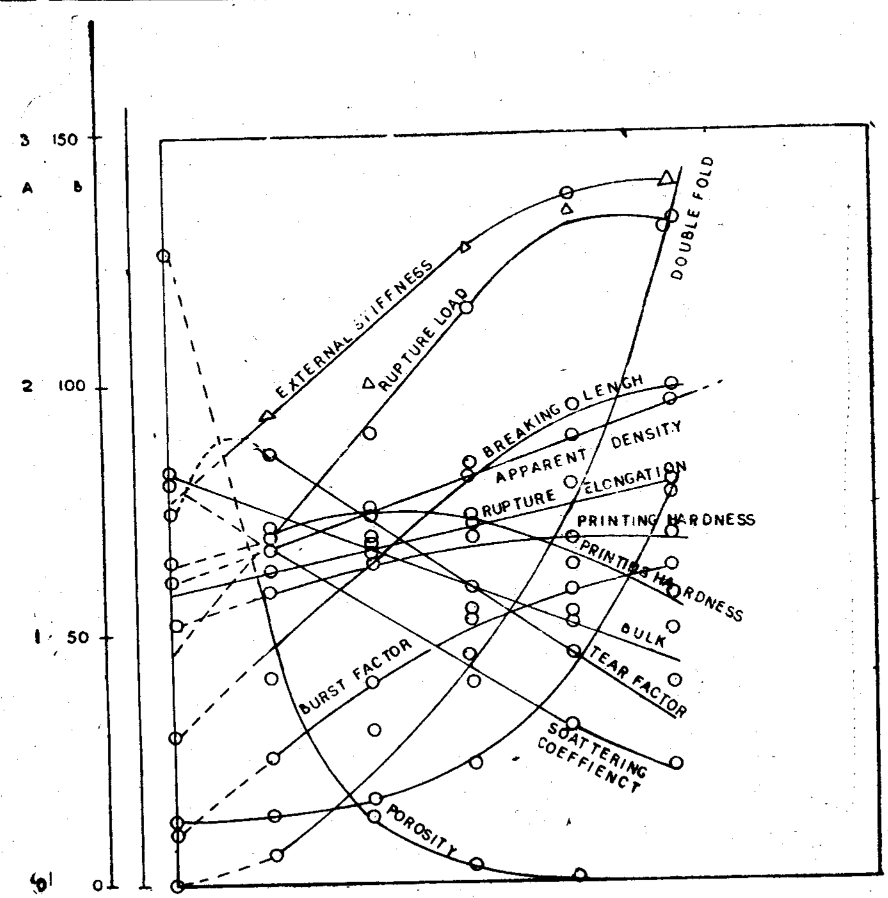
Cause	Effects: Useful	Effects: Non-Useful
Hydration	Tensile strength	Increasing
	folding strength	Drainage
	stiffness	Resistance
Cutting	Formation	Increasing Density Decreasing Opacity Decreasing Tear

II. Refiner Types

For a designer to determine the type of refiner to be used a knowledge of the different equipment available and an understanding of their working is essential. Within the limited time available, it is only possible to give some typical applications of these units and a brief remark on these refining equipments.

The different types of refiner available are enumerated below :

1. Beaters
2. Conical Refiners < Jordans < Small Angle; High Speed Refiners < Steep/wide angle
3. Stock makers 4. Disc Refiner
5. Deflakers, supratons and Dispersall



EFFECT OF BEATING ON THE VARIOUS PROPERTIES OF PAPER
(BLEACHED SPRUCE SULPHITE PULP)

Figure—7

1. **Beaters**

In the past these have been indispensible equipment for this purpose. Due to the long time required for attaining the desired pulp characteristics the energy consumption is quite high and is in the order of 50 HPDT. These operate at low peripheral speed of 1000-2000 fpm. Their maintenance and labour requirements are said to be high. As the recent trend is away from the beaters, these are installed only for very special applications primarily for fibers difficult to beat, and which need a lot of wetting e.g. Rag. hemp, jute etc. In fact best rag papers are said to be made in beaters.

2. **Conical Refiners**

(a) **Jordans** : Jordan is the oldest representative of the conical type of refiners. It has an angle of 10-20° and operates at peripheral speed of 2000-3000 fpm (measured at the large plug circumference). Power requirement compared to the beaters is less. Jordans are known for their severe fiber treatment resulting in much cutting. The total stock preparation energy with Jordans in the system is in the range of 30-50 HPDT. Generally these are used in front of the paper machine for brushing out and controlling the length of the fibers. Usually for length control these are fitted with narrow bars.

(b) **High speed small angle refiners** : These are primarily designed to fibrillate the fibers with minimum fiber cutting. This is by virtue of the consistency at which the fibers are treated i.e. usually above 4.5%. The peripheral speed (measured at the larger end) ranges from 5000-6000 fpm. The higher the speed and the consistency, the less tendency there is to cut the fibers. Favouring of wetting at high speeds for a given motor power is partly due to the higher no load power thus allowing less power for fiber treatment.

Another advantage with the high speed refiners is that greater clearances at higher speeds do not affect the rate of beating compared to the same at lower speed and hence higher pressures can be maintained. Higher speeds are also better suited for weak purpose.

(c) **High speed wide angle refiners** : The wide angle conical refiners are an improvement over the previous ones. They have an angle of 120°. These are specifically designed to provide a 'fiber brushing' action, with minimum fibre cutting. These are manufactured in a range of sizes upto 42" dia (measured at larger rotor circumference) and operated at peripheral speeds of even 600 fpm. Even higer speeds, about 15-50m/sec (5000-6000 fpm) are used for smaller units, connected motor horsepower is upto 500 H P.

Some of the specific advantages of these type of refiners are :

1. The no load power requirement is less. That means for the same power input more power will be used for fiber treatment as compared to the small angle refiner. Therefore thoroughput of treated stock is quite high.
2. Being some what an intermediate between the disc refiner and Jordans wide angle conical refiners can be used for most of the furnishes.
3. It is also possible to connect variable speed motors to this type of refiners. This with different types of fittings offers great flexibility for the designer.

   A comparison between the Jordans and High Speed conical refiners is given in Table 4.

(d) **Recent development**

It is worthwile mentioning here a new development in the Conical refiner. The equipment is called a "rebeater" and the advantage of a high consistency refining is made use of. Slits are provided in the stator through which part of the suspension passes. This is collected and by reintroducing is mixed with the incoming stock so that its consistency is increased. The quality of the refined pulp is much superior to that of conventional conical refiner pulp. Tensile strength is higher and the fibre distribution better.

3. **Stock Makers**

This is again a modification of

the conical refiner, with provision for recirculation of the stock, if necessary within the refiner itself. As different from the other types of conical refiners stock is introduced at the centre of the plug at the smaller end. It passes through the inside to the larger end and is again forced to the smaller end against the centrifugal force, again passing between the bars and cone for the second time. The refined stock can by means of a valve arrangement, either be recirculated or passed out. Refining space is completely filled. It produces a well hydrated stock and can be used for papers ranging from soft tissues to glassine, it offers a wide variation with Jordans in series or parallel.

Table 4
Comparision of Jordans and Refiners

	Refiner	Jordan
H.P.	Low 400 H.P.	High 400 H.P.
Speed	High 5400–6000 FPM large end	Low 2000–3000 FPM large end
Intimacy	Fiber Diameter 0.002" Clearance	Bar to Bar 0.0001" Metal to Metal
Bar Width	Wider Bars 1/2"–3/4" Large Contact Area	Narrow Bar ¼" Small Contact Area
Material	Stainless Steel, Work Hardens Rounds Off Leading Edge.	Phosphor Bronze, Heat Treated Normal Wear Pattern.
Consistency	High 5–6% Heavy Mat	Low 3–3½% No Mat
Effect	Hydration	Cutting, Fibre Length Reduced
System	Continuous or Batch	
	What They Do	
Freeness	↑ Contributory No Sharp drop	Control, Rapid Drop
Mullen	↑ Some Rise	Good Improvement
Tensile	↑ Contributory	Follow Mullen
Tear	Max. Development	Normally Decreases
Shrinkage	High	↑ Low
Flit	(Fiber Length Little Reduction Index)	Control
Formation	Negative	Control
Porosity	↑ Contributory	Under Control Machine Tender
Smoothness ↑		
Printability	Negative	↑
Cockle	Due to Hydration	

4. Disc Refiner

Recently accelerated interest has been shown in the disc refiner which is experiencing rapid acceptance and growth in the Industry.

Basically the design consists of a rotating disc with grooves/bars on either sides positioned between two stationery discs with grooves on the inner side. The stock is admitted through a hole in the centre of one disc, it passes outward between the discs and is discharged at the periphery. The direction of pulp travel and the relationship Bars to pulp path are shown in figure 8.

There are different types of disc refiners. They are :

1. Single rotation type —has one stationery and one rotating disc.
2. Double rotation type —has two rotating discs.
3. Double disc type —has two stationery discs and one double sided rotating disc.

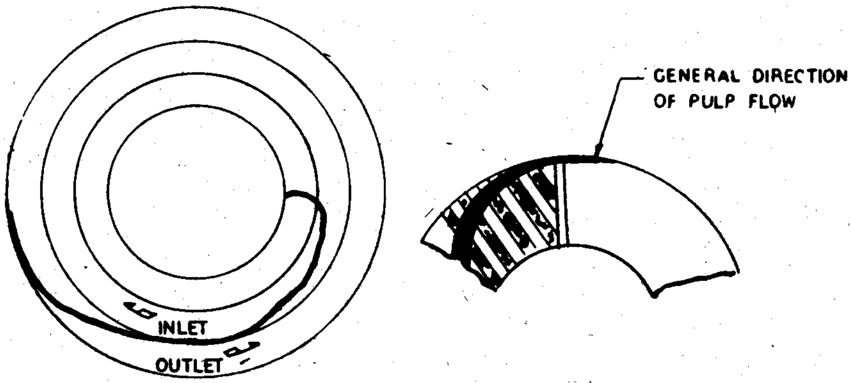


Fig.—8

The refiners were being used to a considerable extent for making bag and wrapping papers, kraft boards and similar grades, now with a variety of patterns of bar configurations available, are used for most of the grades of papers. Some of its specific advantages are :

a) Greater power economy:— A disc refiner requires 20-25% less power than the conical refiners for the same freeness of stock.

b) Discs are available with a variety of patterns of bar configurations.

c) Easy changing of discs to meet any change in the beating conditions required.

d) Can be used with a wide margin of stock consistencies and can be made to do either fibrillation or cutting or a combination of both.

But disc refiners are still expensive per unit of power and the cost is really prohibitive in small units. Moreover the wrong type of filling and faulty conifiguration may lead to enormous wastage of power.

These refiners are available in sizes upto 3000 HP and capacities ranging from 100-500 tpd, depending on the degree of refining sought. A counter rotating disc refiner with each disc driven by a separate motor is also available for handling stock in the consistency range of 30–40%.

A comparison between conical and Disc refiners is given in Table 5. Possible effects of refining with a Beater, conical refiner and a disc refiner on the fibers and the effects desired are shown in figures 5 & 6.

Some New Developments

An "in line fiber refining" process has been developed which uses the application of ultrasonic energy or New shear forces to fiber treatment. Application of shear forces for fiber refining was tried by forcing the fibers under high pressure through narrow slits with a clearance of a few fiber diameters (maximum pressure used was 2,000 psi). Both the methods are in experimental stages.

Treatment of Secondary Fibres :

5. (Deflakers and Supratons)

For treating the Secondary fibers (such as broke) and separating the flakes or fiber bundles deflakers and supratons are the known equipments

These are not designed to increase the Schopper Riegler of the stock. In this type of machines hydrodynamic pressure waves are produced at high frequencies

Table 5

Refiner Comparison

	Maximum Horse Power	Circulating Horse Power	Efficiency %
Conical	200	100	50
	300	150	50
	500	200	60
	800	310	61
Disk	250	75	70
	400	120	70
	800	210	74

and the stock is subjected to turbulent agitation with alternative compression and expansion. There is no actual attribution by metallic or other elemental contacts.

In construction, a rotor fitted with vanes in two stages spins at about 3000 rpm. The frequency of pulsation is multiplied depending on the number of vanes. They work adjacent to similar vanes in the stator. The clearance between them is very small. The clearance can however be adjusted during stoppages. These are usually placed after hydrapulpers.

Now Beloits have introduced another equipment known as "Dispersall" specifically for deflaking. The equipment is designed for higher speeds, with special filling and built in junk-trap. The stainless steel bars in the plug and shell are specially hardened for long wear in severe service conditions. Thus the equipment will be better suited for treatment of even inferior grades of waste papers which-carry along with them abrassing foreign materials such as sand etc

These are also used in regular stock preparation systems to ensure complete separation of pulper processed stocks into individual fibers before refining. They preserve fibre length and leave the fibers soft and absorbent. Therefore for this reason they are suitable for preparation of paper stock such as "cellulose wadding" and for disintegration of wet strengthened and glassine papers which are exceptionally difficult to break up. Power requirement of these equipments is quite comparable with beaters and refiners.

III. Design of the Refining System

With the above background let us now see how a refining system can be designed suitable for a particular mill.

Basic Information Required

Before the designer commences his work it is essential that he possesses certain basic informations such as :

a) Whether the system to be designed is for new mill or for the expansion of an existing mill.
b) Furnish composition and the type/types of raw materials to be used.
c) Production programme–This should include final product, substance, tonnage, details of furnish, colour etc.
d) Any possibility of increasing the capacity at a later stage.
e) Any special additional informations necessary or precautions to be taken.

With the above informations in hand he has to decide the type of refiner to be installed, to size and design the system to be followed i.e. whether batch or continuous or both.

Refiner Type

There are quite a number of parameters that determine the type of refiner. The different types of refining equipments available, some typical applications, merits and demerits have been discussed earlier. For all these equipments there are different fillings w. r. t. the material, configuration and speed. The ultimate choice is based on

i) the final product and the strength characteristics desired
ii) The furnish to be treated, its fiber length
iii) the initial freeness of stock
iv) final stock freeness before entering the machine.

The choice is made mainly taking into consideration the following factors :

a) economics–installed cost and operational cost
b) ease of maintenance, availability of spares etc.
c) local conditions
d) familiarity of the equipment, interchangeability of spares etc. in case of expanding the existing unit.

Sizing or dimensioning of the refiner :

The total horse power and the number of refiners required are determined taking into consideration

i) tonnage required from the system
ii) type of furnish and
iii) whether the different furnishes are to be treated separately or together

The first point to decide is the horsepower required per day/

tonne for the type of furnish and paper to be made. This has to be done based on some previous experience on similar type of pulp. While working out for expansions generally figures are available from the mill already making similar paper using the same furnish. Where such information are not available for certain raw materials usually the raw materials are tested in pilot plants to determine the power required. It must be borne in mind that a weak short fiber will absorb less power than a strong long fiber. Also the power requirement will vary depending upon the type of refiner to be used. The power requirement is generally expressed with the following dimensions. Energy, time taken, output (weight) and degree of desired freeness to be achieved i. e. KW or H. P /HR/ 100 kg/° SR rise in freeness or in HPDays/Tonne. For certain grades of paper some figures are given in Tables 6 and 7.

TABLE 6

Paper	KWH/100 kg/°SR	KWH/100 Kg.
Kraft	0.8	
Glassine	0.7–1.2	
Condenser tissues	4.0–5.0	
High class rag Bank Note	2.0	80
Cigarette tissue	4.0	300
Medium class rag and wood filter papers.	2.0	40
Rag blotting	**	10

* Resulting °SR is 85 and if this type of refining is considered further power required will be 10–20 KWH/100kg/°SR due to lower efficiencies.

** For Blotting papers, it can not be taken as having a genuine rise in °SR. Therefore, only the power required per hour/100 kg is given.

TABLE 7

Grade	Power Typical HPdays Per Ton
Tissue	8
Book and Bond	15
Kraft Bag	12
Kraft BD PRI	6
Kraft BD SEC	12
Twisting	20
Condenser	60
Glassine	40

The next major point to consider is the ratio of beating refiners for fibrillating to brushing refiners for smoothing out and controlling the length of the fibers in front of the machine. This mainly depends on the type of paper to be made and how much cutting of the fibers is required. It is always better to allow for certain variations in this ratio especially where different qualities of papers are made on the same machine.

From the informations available from the equipment manufacturers the number of units required to be installed can now be decided.

It is always economical and advisable to instal the maximum horsepower a refiner is capable of absorbing. A check should be made on the throughput of the refiners. This is necessary in order to determine whether the units should be installed for parallel or for series operation. Moreover in the ordinary conical type of the refiners as there is no development of pressure due to the conflicting pumping actions of the input pumps and the rotating plug some fibers slip along the groove without being subjected to the high pressure areas along the bars thus missing the treatment in a single pass. This is known as the Refining capacity of a refiner.

Consideration must be given while designing to include at least an additional extra unit for each type of refiner to be installed. Of course this is bound to affect the decision to choose the most suitable size for the system especially so in a new installation.

Treatment of different furnishes

Even though different furnishes will be treated separately for fibrillation purposes, the final brushing and fiber length adjustment has to be done in the same refiner since the stock going forward to the Head Box would be well mixed. It is better to decide the horsepower reqiurement on the basis of strong fiber as it will absorb a higher power than the weak short fiber. The same refiner can be installed with a higher horsepower for strong fibers than for a short weak fiber.

The system to be followed

For fast higher output machines making just one or two qualities continuous system can easily be adopted. Where a beater is used for treating the fiber in special cases and in case of machines making a wide range of qualities with small orders on each a batch system is preferred. For this the following basic requirements are to be met with :

1. As, for reasons mentioned earlier some fibers will always receive less treatment than others, in order to ensure uniform fiber treatment each fiber should be passed through the active refining area a number of times.
2. Again, where a unit would be passing too much stock and if it is to be used at its optimum throughput a recycling system has to be adopted for giving the fibers the necessary repeated treatment.
3. The furnish changes are not too many and involves no complications.
4. Proper metering methods are provided. The design of a refining system will not be complete without proper piping arrangements, since proper pipe line connections with necessary bypass lines, valves etc. help a smooth operation and prevent downtime. There are three basic types of refiner set ups.

A. Series

B. Parallel

C. A combination of the above two.

Generally series connection is used where higher power consumption is required for smaller flow rates. In this system valves are necessary in between two refiners in order to reduce any excess pressure developed in the previous refiner.

Constant inlet pressure and consisteney are two parameters of a good refiner installation. A pressure control with recirculation and a consistency controller in the pump outlet are advisable.

It is always advisable to get the piping arrangements approved by the refiner manufactures.

The following two examples illustrate how the various remarks made above are applied.

Example 1

The system was designed for a new mill to make writing and printing grades of paper.

Raw Material

(i) 100% Bamboo Kraft

or

(ii) 70% Bamboo kraft and 30% Mixed Hardwood out of this 10% broke reuse. About 10–20% filler will be used.

Final Product	Writing and Printing Papers
Finished Paper	150Tonnes/day
Number of streets	—Two Machines of 75 TPD Capacity each
Equivalent pulp requirement	130–120 Tonnes/day
Special instruction	In special cases addition of broke and fillers will have to be restricted to a maximum of 10%.

The basic decision to be made in this case was whether or not it is worth refining the fibers separately. In view of the fact that most of the characteristics of bamboo pulp remain in between soft wood and hardwood pulps and the total tonnage to be handled is relatively small two separate refining lines may not be justified.

Refiner Type

Based on the information available on various types of refiners a choice had to be made between the disc and conical refiners. From the data available it appears that the disc refiner has better power economy provided a suitable size of the unit is available. They are very expensive in the initial cost. Moreover when the design was made these were still fairly new in our country and the discs are to be replaced in 3/4 months and involves regular import problems. Therefore for reasons of economics, ease of maintenance, because of familiarity and regular import problems conical refiners were chosen. As to the choice between a small angle and a wide angle either unit would do the job well.

Filling Material

To counteract the grit and sand usually found in bamboo pulp stainless steel or similar abrassive resisting materials werechosen for the filling.

Bar Wid.hs

For fibrillating purposes 8 mm wide bars and for brushing and fiber length adjustment before machine head box 4–6 mm wide bars were chosen.

Refi ıer Speed

The refiners for fibrillating should rotate at about 1000 rpm and the one for brushing and fiber length adjustment at a slightly lower rpm around 700 rpm.

Checking the throughput

Assuming two machines maximum throughput for each machine will be 150/2 × 1/24 × 1000 = 3128 kg/hr.

Reflner with a throughput capacity of about 3200 kg/hr will be sufficient. Though the capacity required for the refiners for fibrillation will be less (because of the addition of broke and fillers at the latter stage) the same throughput capacity was taken for all, for design purpose.

Number of Unit required

This as already suggested has to be based on the H.P. required per day tonne for the furnish used and paper to be made.

Based on the experience and some figures available the power requirement was taken as

† KwH/100 kg/°SR rise for bamboo pulp.

Assuming a maximum total °SR rise of 35 (from an initial freeness of 15 to a final freeness of 50), the total horsepower required for refining 140 tonnes pulp when no filler is added :

$$\frac{140{,}000}{100} \times \frac{(50-15)}{24}$$

$=2042$ KW$=2736$ H. P.

For each machine 1363 H.P.

7 refiners of 200 H. P. each plus one unit as a stand by are required.

Proportioning of beating refiners to brushing refiners

For splitting the required horsepower into fibrillating and brushing and fibre length adjustment usually for ordinary grades 15–25% of the total horsepower is recommended for the latter. Taking 20% for our purpose about 274 HP is required for brushing and fiber length adjustment and 1094 HP for fibrillating. Since stock required to be fibrillated is actually less (by an amount equal to the quantity of broke and fillers) 5 units capable of taking 200 HP each are to be installed for fibrillating and 2 units each capable of absorbing 200 HP for brushing and fibre length adjustment purpose. Two standby units of similar type one for each set are also reeommended.

For treatment of broke and deflaking :

One deflaker of sufficient capacity is required for installation after the broke pulper.

Example 2

The following is another example where the refiner capacity was to be increased under balancing scheme in a paper mill making cultural grades of paper.

Basis

Additional refiners were to be installed to handle 60 tonnes per day pulp of 100% sulphate Bamboo pulp or mixed bamboo and wood pulp of ratio 70 : 30.

The initial freeness was about 15° SR and final freeness required was about 50° SR. To have a single pass refining

Finished Paper/year	45,0C0T
Working days/year	330
Finished paper/day	140 T
Equivalent pulp requirement/day	120 T
Pulp requirement for each machine/day	60 T

In this case the problem was very simple since most of the data were available from the existing stock preparation section. With the existing arrangement there were 11 nos. refiners with 6 mm broad refining ribs for beating and one no. refiner with 3.5 mm broad refining rib for brushing for No. 1 Machine, and 9 nos refiners with 6 mm broad refining ribs and 2 nos. refiners with 3.5 mm broad refining ribs for beating and one no. refiner with 3.5 mm broad refining rib for brushing for No. II machine.

It was observed that the power normally absorbed by a refiner with 6 mm broad refining ribs was about 60–70 HP and that by refiners with 3.5 mm broad refining ribs was about 50–55 H.P.

For Bamboo pulp the average power consnmption in the already existing refiners was 0.95—1 KWH/100 kg pulp/°SR

(i) Dimensioning of the Refiner

Total KWH requirement for 60 TPD pulp for beating from 15° SR to 50° SR

$$\frac{60000}{100}(50-15)=21{,}000\text{KWH}$$

$$=\frac{21{,}000}{24}=875\text{ KW}$$

Power absorbed by each refiner with 6.0 mm broad ribs 70HP

i. e. 70 x 0.746 KW=52.22

Say 52.2 KWH

Power absorbed by the refiner with 3.5 mm broad ribs 55 HP

i. e. 55 × 0.746=41.03

Say 41 KWH

Total power absorbed by refiners on machine I.

52.2 × 11 + 41 = 615.2 KW

Say 615 KWH

Total power absorbed by refiners on machine II.

52.2 × 9 + 41 × 3=592.8 KWH

Say 593 KWH

Total power of Refiners to be installed for expansion

No. I Machine : 875—615

= 260 KWH

No.II Machine : 875—593

= 282 KWH

Characteristics of the refiners to be installed were :

Bars Stainless steel/Mn.Steel

Thickness 8mm

Pump through capacity : 3250 kg/hr at 4% consistency Refining capacity 500–600 kg/hr

Speed at large end periphery 1020 m/min.

Maximum load 100 kpm (kilo pound meter)

Recommended motor : 120 kw 980 RPM

* Number of Refiners to be installed :

Machine I

$$=\frac{260}{120}=2.1$$

= 3 Refiners

Machine II

$$\frac{282}{120}=2.35$$

= 3 Refiners.

Note:

As there was no previous experience with these refiners it was desired to have a more conservative figure of 1.2 KWH/100Kg/°SR. Incidentally this made provision for this also.

ii) **Pump through capacity required :**

140 Tonnes/day

70 Tonnes/day for each machine

$$\frac{70}{24}\times 1000\text{ kg/hr}$$

2920 kg/hr.

Pump through capacity of New Refiners was 3250 kg/hr which was quite sufficient. 20% of which is $\frac{1350}{5}$ = 276 HP

2 New refiners when installed for brushing had a total h. p. of 350

i. e. $\frac{350}{1380}$ = 25%

(iii) Proportion of Beating Refiners to Brushing Refiners

In the existing system original machinery suppliers had recommended 15% of the total horse power for brushing :

Total Horsepower for Refining including that of the three new refiners.

Machine I

10 Nos.	80 HP.	10x80=800
2 Nos.	65 HP.	2x65=130
		935H.P.

H.P. of new Refiners 3x175 525 HP

1455 HP

However it was desired to have 20—25% of the total H.P. for brushing taking 20% :

$$\frac{1455}{5}=291\text{H.P.}$$

Two new refiners when installed for brushing had 2×175=350H.P. which worked out to $\frac{350\times 100}{1455}$ =24%

Machine II

Total H. P. installed :

8 Nos. 80 HP	8×80	640 HP
2 Nos. 75 HP	2×75	150 HP
1 Nos. 65 HP	1×65	65 HP
		855 HP

Three New Refiners 3×175 525 HP

1380

Acknowledgement

The writer gratefully acknowleges the help rendered by M/s Sprout Waldron and Mr. Smythe of Beloit Walmsley for the bulletins and pamphlets and to the Management of NIDC for permission to publish this paper.

Reference

Private Communications :

(a) Lecture notes by Prof. Giertz at Technical University of Norway.

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(c) "Jones Brief" from Beloit jones.