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DESIGN AND ANALYSIS OF DISC REFINER

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Abstract:

Refining or beating of chemical pulps is the mechanical treatment and modification of fibres so that they can be formed into paper or board of the desired properties. It is one of the most important unit operations when preparing papermaking fibres for high-quality papers or paperboards.

For which various instrument were used of which first beater commonly called as Hollander beater in which various problems are occurred. But various refiners have now replaced beaters and the term "refining" is widely used. In fact, both terms are synonymously used, but here the term "refining" is used to describe the work accomplished with refiners on the fibres.

The mostly used is disc refiner, the common advantage is lees labour, area and more efficiency is achieved. In general disc refiner produced in the industry uses 30-40 HP motor to produce 7 tonnes per day but in our project we introduce concept of using 5 HP motor to produce 6 tonnes per day.

In general the cost is high for manufacturing beater and industry produced disc refiner, we even reduced the cost of the refiner too.

INTRODUCTION:

Refining is a fundamental operation in the manufacture of paper considering its importance on the final paper properties. It is the only operation that modifies pulp fibre morphology, shaping the paper with the desired optical, physical and printing properties. At the present time, with paper machines running at 2000 m/min, it is of greatest importance that refining should be a fully known and controlled process, so as not to adversely affect machine productivity or exceed planned output costs. Refining can be described as an operation which, through transmission of mechanical energy from the refining plant, irreversibly changes the structural morphology of pulp fibres.

This is done by passing an aqueous suspension of fibres through the gap between two slotted surfaces, one of which is stationary (stator) and the other moving at high velocity (rotor), with a minimum distance between them, so that energy of friction is transmitted providing the necessary rubbing to refine the fibre. Despite various experimental publications, very few have attempted to understand the physical nature of refining.

Disc refiner involves a concept of plate clash.it occurs when the gap between refiner plates is reduced to zero. The resulting metal to metal contact causes large forces between the bars on these plates, accelerating wear and disrupting operation. Plate clash in disc refiners continues to detract from the efficiency of mills, reducing plate life and affecting production.Inorder to avoid the plate clash we kept at the optimal distance between them

OBJECTIVES:

- Endurance
- Safety and Ergonomics
- Market availability
- Cost of the components
- Standardization and
- Maneuverability
- Safe engineering
- Producability
- Service factor
- Maintanance free
- Workability
- Seviceability

REFINING PROCESS

Refining and stock preparation are some of the most critical phases, prior to actual paper making. The whole paper making potential of the raw

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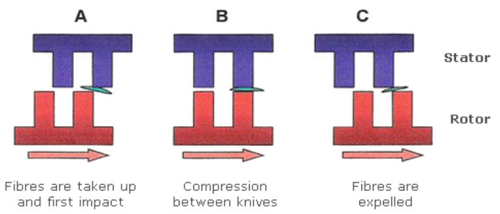
materials should be taken into use with minimum amount of energy consumed

The refining stage in stock preparation plays an important role in developing the properties of stock for paper production. Appropriate fibre treatment in the refiner greatly affects the run ability of the paper machine and quality of the end product. On the Figure was presented mechanical treatment of fibres inside disc refiner.

OBJECTIVES OF REFINING

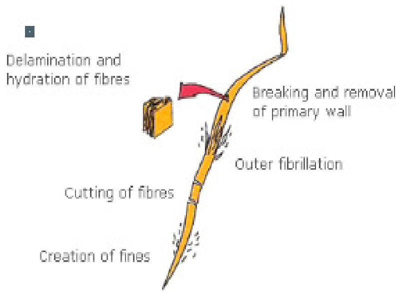
- Improvement in physical and strength properties of the paper
- Control in drainage of the pulp
- Improvement in the formation degree of the paper



REFINING

Effects ofRefining:

During refining, the primary and secondary walls of the fibre break and are partially removed. The penetration of the water to the inside is therefore possible, causing swelling. It also permits the release of internal fibrils which separate and produce a formation of finer micro fibrils on the surface of the fibre.



EFFECTS OF REFINING

Owing to all these effects, the fibre becomes more flexible and softer, at the same time increasing its surface and specific volume. All these effects can be grouped into three:

Hydration:

This occurs when, owing to beating or agitation of the fibres in the refiner, the water penetrates between the fibrils producing a hydration effect in the fibre. This is due to the fact that the water and the cellulose combine via a chemical reaction.

Fibrillation:

This is the releasing and separation of fibrils produced by the partial rupture of the walls during the rubbing of the refiner knifes and fibres against one another.

Trimming:

This is the effect caused by the action of the blades on the fibres, producing breakage (cuts) and therefore decreasing its length.

Properties Affected By Refining:

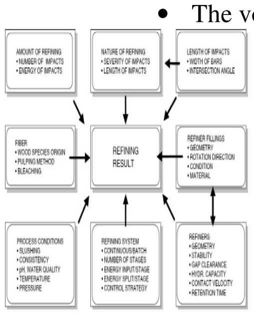
The operation of refining influences differently the technical and mechanical properties of the manufactured paper, increasing some and reducing others.

Properties Which Increases

- Apparent density(g/m^3)
- The traction index(Nm/g)
- Transparency
- Lengthening (%)
- Internal cohesion(scott)

Properties Which Decreases

- Porosity
- Opacity
- The drain ability of pulp
- The volume index



REFINING RESULT

Forces Created During The Refining:

There are many forces created during the refiner. Although energy being an easier and a more

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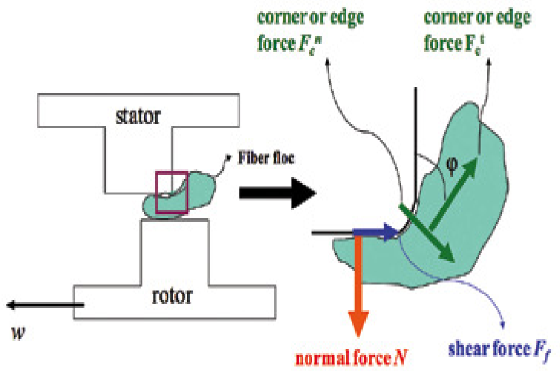
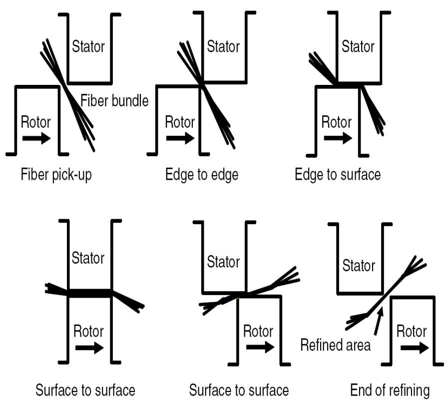
common variable to handle in the paper mills, force is the prime variable in low consistency refining. It is largely accepted that are three the forces acting in refining: normal force, shear force and corner or edge force, which are shown in the following diagram.



FORCES ON REFININ

Principles of Refining:

The most commonly used refining or beating method is to treat fibres in the presence of water with metallic bars. The plates or fillings are grooved so that the bars that treat fibres and the grooves between bars allow fibre transportation through the refining machine. Figure demonstrates all refining stages. At first, fibre flocs are collected on the leading edges of the bars. During this fibre pick-up stage, the consistency is typically 3%–5% (sometimes, in special applications, 2%–6%) and the fibre flocs comprise mainly water.

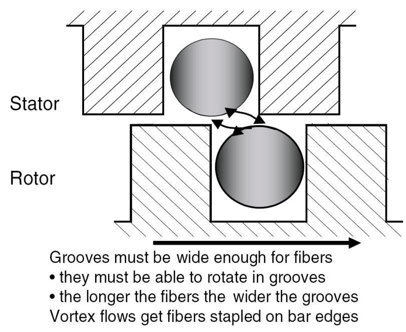


MOVEMENT OF STATOR AND ROTOR

When the leading edge of the rotor bar approaches the leading edge of the stator bar, the fibre floc is compressed and receives a strong hit. As a result, most of the water is compressed out of the floc. Simultaneously, short fibres with low flocculation ability are probably peeled off (escape the floc together with water) and flow into the grooves between the bars. Only those fibres remaining in the floc are compressed between two metallic bar edges and receive refining

After this, both leading edges slide along the fibre floc and press it against the flat bar surface. In low-consistency refining, the average gap clearance is 100 µm. It corresponds to the thickness of 2–5 swollen fibres or 10–20 collapsed fibres. Most refining is performed during this edge-to-surface stage when bar edges give mechanical treatment and friction between fibres gives fibre-to-fibre treatment inside the floc. This stage continues until the leading edges reach the tailing edges of the opposite bars. After the edge-to-surface stage, the fibre bundle (floc) is still pressed between the flat bar surfaces until the tailing edge of the rotor bar has passed the tailing edge of the stator bar. The above described refining stages exert one refining impact on the fibre bundle, and the length of the refining impact depends on the width and intersecting angle of bars.

When the rotor bars move across the stator bars, there are quite strong vortex flows in the grooves between bars, and this phenomenon gets fibres stapled on bar edges during the fibre pick-up stage as shown in diag. If grooves are too narrow, fibres or fibre flocs cannot rotate in the groove and do not get stapled on bar edges, and those fibres staying in the grooves pass the refiner without receiving any refining impacts.



GROOVES MOVEMENT ON FIBRES

The refining results to a great extent depends on the stapling of fibres on the bar edges and on the behaviour of the fibres in the floc during refining impacts. Long fibred softwood pulps easily get stapled on the bar edges and builds strong flocs that do not easily break in refining. Decreased gap clearance hastens refining degree change and increases fibre cutting. On the contrary, it is more difficult to get short-fibred hardwood pulps stapled on the bar edges, and they build weak flocs that easily break in refining. Decreased gap clearance means slower refining, and bars easily establish contact.

Stages of Refining:

The refining process consists of two stages. In the first, wood chips are reduced to individual wood fibre and in the second, the properties of the individual wood fibre are developed so as to be suitable for paper making. These processes are achieved by the cyclic forces which are applied to wood chips trapped between opposing bars on the refiner plates

The first stage of refining occurs in the breaker bar and coarse bar sections of the refiner plate and the second stage occurs in the coarse and fine bars. The design of the bar and groove pattern on the plates, therefore is an important factor affecting the type of refining action that the pulp experiences. There is no clear definition of when the first stage ends and second stage begins. It is therefore, a process of wood chips getting reduced to pulp in continuous fashion.

During the second stage of refining, after the wood chips have been broken down into individual fibres, the loose fibres group together to form 'flocs' of fibres. These flocs are constantly being broken apart and reformed as impact forces are experienced and fibre development proceeds.

Refining System:

The selection of the refining system starts from the end products, available pulps, and planned capacity range. End product and pulp blend establish requirements for desired refining results for each pulp in the blend. Thereafter, refining consistency, bar pattern of fillings/plates to give required nature for the refining, net energy requirement, and number of recommended refining stages (number of refiners in series) will be determined. After this the size, rotation speed, and power of refiners is selected to meet capacity, net energy, and refining intensity requirements for various end products. Because the refining behaviour of pulps depends on so many factors, the dimensioning of the refining system must be based on the known pulps. If pulps are not well known, they must be analyzed. Wood species, fibre length, fibre coarseness, bleaching method, brightness, viscosity, and laboratory beating results are good indicators. Sometimes, refining trials with mill scale machinery are required.

Control of Disc Refiner:

The refiner is controlled by adjusting the gap between rotor and stator fillings. The signal for automatic or manual control may come from the main motor load, the amount of the refining energy, the temperature rise of the stock, the drainage characteristics of the stock, the vacuum from a flat box or couch roll, or from the air permeability of the paper web. Manual power control, either by turning gap control device by hand or by pushing a button that activates a gap control device, is the simplest way to adjust the refiner load. The advantage of this simple method is that flow or consistency variations automatically change the refiner load to the correct direction, although not accurately in proportion. If the gap clearance is kept constant, decreased flow or consistency decreases the thickness of fibre flocs between bars thus also decreasing the refiner load.

The simplest automatic control is power control, which keeps the refiner motor load on the set value. In case flow and consistency variations occur, the net refining energy varies directly with the stock mass flow variations. This type of refiner control can be more harmful than beneficial. The most common control system maintains net energy (net kWh/bdmt) by controlling fibre consistency before refining and fibre flow prior to blending chest. Consistency and flow determine fibre mass flow expressed as bdmt/hour. When that is multiplied by net kWh/bdmt, the result is the required net kW for the refiner. Total refiner load is then obtained so that no load power in kW is added to the net power in kW. The basic set value is the net kWh/bdmt and that must be determined onsite, case-by-case, so that required fibre development is obtained. After setting the net kWh/bdmt figure, the control system automatically follows flow and consistency values and controls refiner load so that correct net energy is obtained. Sometimes freeness, temperature rise, couch vacuum, or air permeability of the paper is used to determine refiner control. In those cases, the control operation is such that the measurements are converted to a new set value for specific refining energy control. The accuracy of any control system depends on the accuracy of the performed signal measurement. It is important to avoid too quick refiner load changes. For example, when using the freeness signal, the

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average value of the five most recent measurements is better to use for control because individual measurements can vary too much. Depending on the type of refiner and on the capacity variations, there might be a circulating line after the last refiner back to pump suction. The purpose of this circulation line is to ensure sufficient fibre flow through the refiner in all conditions.

Effect of Consistency:

Consistency should not be considered as an independent variable because the bar pattern of fillings/plates has an effect on it. In general, coarser pattern with wider grooves requires higher consistency than finer pattern with narrower grooves. Typically, consistency in low-consistency refining is approximately 3.0%–5.0%; 3.5%–4.5% when refining softwood, 4.5%–5.0% when refining hardwood, and 3.0%–3.5% in trimming refining. Lower than 3.0% consistency when refining long softwood fibres strongly increases cutting tendency. Short hardwood fibres behave on the contrary because decreased refining consistency increases fibre floc breakage and more fibres are peeled off from the bar edges into the grooves and avoid refining action.

Basically bar pattern should be suitable for the fibre, but sometimes bar pattern is not most suitable because pulps vary. If the fillings cannot be changed, the only possibility is to adjust the consistency to suit. An increased refining consistency with any fibres means slower vortex flow in grooves and increases fibre flocculation tendency, therefore requiring a coarser pattern than lower refining consistency.

Effect of Refining or Beating Degree:

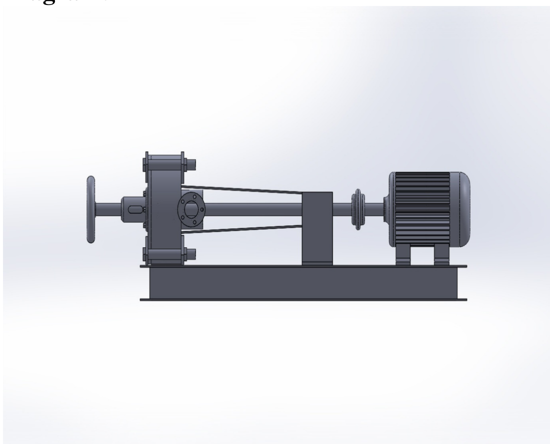
Another important factor is the beating degree of pulp when entering the refiner. Beating degree can be measured in many ways. The most commonly used measurements are freeness (CSF) and Schopper-Riegler (^{0}SR).

In refining, freeness decreases and Schopper-Riegler increases. As the refining reduces the refining resistance of the fibres, the refining intensity must be reduced in the prolonged refining.

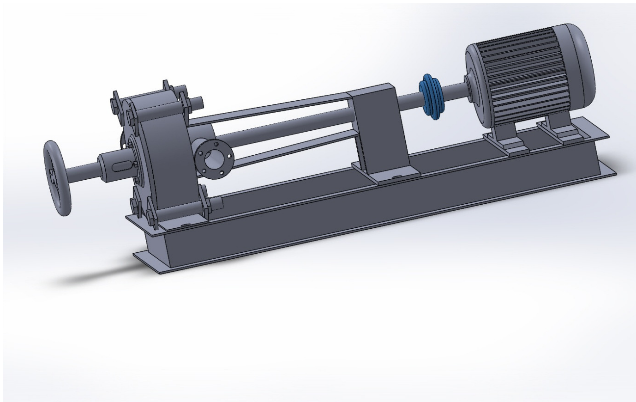
Main Parts of the Disc Refiner:

- Blade (Disc)
- Motor
- Shaft
- Bearing
- Coupling
- Housing
- Frame/Base
- Hand Wheel
- Spring

Diagram:



SIDE VIEW OF DISC REFINER



ISOMETRIC VIEW OF DISC REFINER

COMPUTATIONAL FLUID DYNAMIC ANALYSIS

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows.

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We have conducted three different types of analysis of the plate which we designed. They are

- Velocity magnitude
- Pressure distribution
- Pressure distribution(gap)

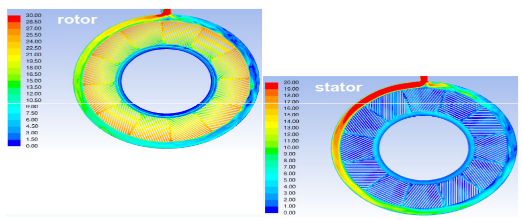
For which initial conditions which were taken are

- Geometry and mesh - GAMBIT
- Mesh: 6 / 24 mln cells
- FLUENT 6.3 / 13

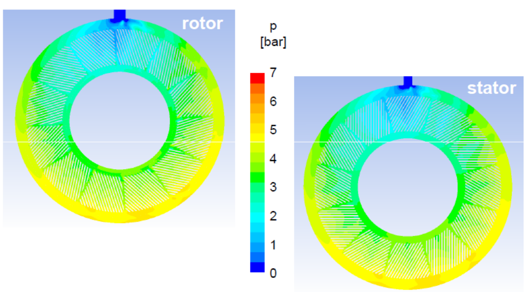
The pulp which we taken for the flow has following conditions

- Soft wood pulp
- 4% consistency
- 1400 µm fiber length
- 26 µm diameter of fiber
- pulp suspension treated as a single-phase continuum (N-S, continuity)
- flow character assumed to be laminar (confirmed by simulation results)
- pulp modelled as either Newtonian fluid
- fiber-fiber and fiber-wall interactions are neglected - main goal was to analyze the LC refining hydraulics

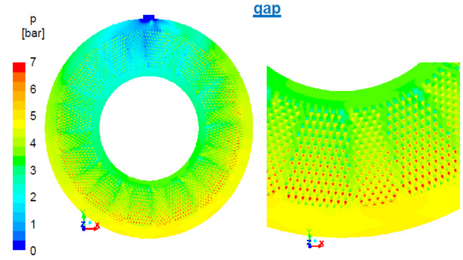
Analysis Diagram:



VELOCITY MAGNITUDE



PRESSURE DISTRIBUTION



PRESSURE DISTRIBUTION BETWEEN THE GAP WHEN PLATES ARE MESHED

Schopper-Riegler:

The Schopper-Riegler test quickly provides an idea of the refining degree relating to the speed of the drainage of the diluted paper suspension. The speed of drainage is related to the surface conditions and the expansion of fibers and provides a useful indicator, of the amount of mechanical treatment (refining) of the cellulose paste. This method is applicable to all types of pastes in watery suspension, except for extremely short fiber pastes.

The scale of measurement in degrees SR.:
A drainage of 1000 ml corresponds to 0 ºSR
A drainage of 0 ml corresponds to 100 ºSR
A drainage of each 10 ml of water corresponds to 1 ºSR.

Specifications:

Cylinder capacity: 1000 ml. above the sieve plate

- Funnel holes: 2 holes, one below and other lateral

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SCOPPER RIEGLER

Weight and Dimensions:

- Dimensions: 400 x 300 x 850 mm (Ancho x Fondo x Alto)
- Box for transport: 500 x 400 x 1050 mm (Ancho x Fondo x Alto)
- Net/Gross weight : 38 Kg / 59 Kg

Delivery Content:

- Schopper-Riegler type Freeness Tester SR-10
- 2 Acrylic Glass measuring Cylinders

Canadian Freeness Tester:

Both the Canadian Freeness Tester and the Schopper-Riegler Tester are used to determine the rate of drainage of a diluted pulp suspension, the rate of drainage being related to the work done on the fibre during beating or refining.

Refining of pulps is one of the most important stages in the paper production process and it strongly influences sheet forming and its physical properties.

CANADIAN FREENESS TESTER

This instrument consists of a drainage chamber, equipped with a calibrated screen-plate, and measuring funnel that has two orifices separated by a specified distance. The orifice at the base of the funnel governs the rate of discharge and the run-off water, which is captured and measured with the measuring cylinder to determine the freeness value.

The CSF also comprises an aluminum frame for wall mounting a nickel-plated bronze drainage chamber, a funnel, spreader cone and sealing cone. It is supplied with two graduated measuring cups.

Performance Data:

- Flow of calibrated bottom orifice 530 ± 5 ml/min
- Calibrated bottom orifice 74.7 ± 0.7 s for 1 l of H2O
- Drainage chamber volume 1000 ml
- Drainage area 100 cm2
- Manual operation

Features:

- Applicable to all kinds of pulps in aqueous suspension
- Reliable robustness and precision instruments
- Non-corrosive components

Advantages:

- It is used for reduction of time
- It gives better perfomance when compared to hollander beater
- It gives more efficiency
- Maintenance will be less
- Easy to manufacture
- Easy serviceability

Applications:

It is mostly used small scale industries.

CONCLUSION:

Our disc refiner which is designed and analysed gives better performance. We designed disc refiner with 5 hp drive that gives 6 tones per day which increases the freeness of the pulp from 20^0 to 25^0 SR.

Our Disc Refiner which has replaced Hollander Beater by cost, area, maintenance and efficiency. From cost wise it has saved nearly 3.2 lakhs. And maintenance cost has been reduced Rs. 60,000/- per year. When compare to area its has been decreased by 90 sq.ft.

It has replaced Hollander Beater by 30 Hp motor to 5 Hp motor which reduces the power consumption of the industry in a tremendous way from 180 units to 30 units.

From these parameters, we are proving that our Disc Refiner has best efficiency when compare to the Hollander Beater.

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