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DEPARTMENT: CHEMICAL ENGINEERING

COURSE CODE: CHE 592

COURSE TITLE: PULP AND PAPER TECHNOLOGY

ASSIGNMENT SOLUTION

1)

i. **What is Pulp Refining**

Pulp refining is a process in which fiber flocs collect on refiner bar edges and are subsequently deformed by compressive and shear forces such that the cell wall of at least some of the fibers is permanently modified. Refining or beating of chemical pulps is the mechanical treatment and modification of fibers 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 fibers for high-quality papers or paperboards.

ii. **Briefly explain the theory of Pulp Refining using qualitative analysis.**

Qualitative Analysis:

It is evident that fiber and pulp properties can be manipulated by altering the refiner plate configuration and the operating conditions of a refiner in order to achieve an optimal combination of paper properties.

The nature of the cell wall modification is dependent on the magnitude of the compressive stresses (or strains) that occur during the deformation of the fiber flocs. The extent of the cell wall modification depends on how frequently fiber flocs are collected and subsequently deformed for a given mass of fiber. In pulp refining, we are interested in both the magnitude and the frequency of these deformations. Within each fiber floc, the average cell wall deformation of individual fibers is directly related to the deformation of the floc itself for example if the floc is only slightly deformed, then the average fiber cell wall deformation will also be slight.

On the other hand, if the floc is greatly deformed, then the stresses and subsequent deformation of individual cell walls will be much greater. If the deformation of the fiber floc is so extreme as to cut it into two, a portion of the fibers within the floc are also likely to be cut. Recognizing that the deformation of the cell wall of an individual fiber during refining can only be accomplished by deforming the fiber floc in which it lies is a very important concept. First, it makes it quite obvious that the nature of deformations is highly varied. Even if it were possible to precisely control the degree of deformation of the floc, the randomly distributed fibers within the floc would be subjected to a wide range of deformations. Therefore, it is only possible to speak of average degrees of deformation and average subsequent effects on fibers. Second, it underscores the importance fiber flocs. How many and how large are the flocs that support the refining load at any instant? What effect does a change in the refiner filling design have on the size and number of fiber flocs?

The two-fold objective of stock preparation refining are described as follows:

- Increase the flexibility of the cell wall in order to promote increased contact area
- Fibrillate the external surface to further promote the formation of hydrogen bonds as well as increase the total surface area of fiber available for bonding.

The more refining that is done, the greater the increase in both fiber flexibility and surface fibrillation. Yet for a given amount of refining, there is no direct evidence linking the nature of the cell wall deformation with the resulting fiber characteristics. This would require a mechanism for precisely deforming a large number of individual fibers and then applying some sort of quantitative inspection criteria on those fibers after deformation.

2)

i. **Show that the Specific Energy "E" delivered to a given quantity of fiber flocs collect on refiner bar edges is given by Equation 1, using the qualitative analysis of Pulp Refining.**

$$E = \frac{P - P_{No-Load}}{QC} \tag{1}$$

Where Q is the volumetric flow rate through the refiner and C is the consistency.

Solution

$$E = I \times N \tag{2}$$

$$I = \frac{P - P_{No-Load}}{\left(\frac{RPM}{60}\right)(Bar\ Edge\ Length)} \tag{3}$$

$$N = \frac{\left(\frac{RPM}{60}\right)(Bar\ Edge\ Length)}{QC} \tag{4}$$

Where, $$Bar\ Edge\ Length = \int_{R_1}^{R_2} \frac{n_1 n_3}{cos\varphi} dr \simeq \sum_{i=1}^{N} \frac{n_{ri} n_{3i}}{cos\varphi} \Delta r \tag{5}$$

$$E = \frac{P - P_{No-Load}}{\left(\frac{RPM}{60}\right)(Bar\ Edge\ Length)} \times \frac{\left(\frac{RPM}{60}\right)(Bar\ Edge\ Length)}{QC}$$

(6)

Therefore,

$$E = \frac{P - P_{No-Load}}{QC}$$

(7)

ii. **Define all the terms and in your derivation**

$I = Specific\ Edge\ Load\ (SEL)$

$N = average\ number\ of\ deformations\ per\ unit$

$RPM = Revolution\ per\ minute$

$P - P_{No-Load} = True\ load\ applied\ to\ the\ fibres$

$BarEdgeLength = total\ length\ bar\ edges\ that\ fibres\ see\ in\ one\ revolution$

$\varphi = The\ angle\ the\ bar\ makes\ with\ the\ radial\ direction$

$n = number\ of\ bars\ at\ the\ radius, r.$

$E = Specific\ Energy$