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Effects of Refining Intensity on Characteristics of Pulp Produced from Bagasse through Neutral Sulfite Semi-Chemical Pulping

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Abstract: This study was directed to characterize effects of refinement intensity on properties of pulp and paper produced from bagasse. Cored bagasse prepared from Pars Paper Company through wet techniques was used for the experiments. Final cooking process of bagasse was done under Neutral Sulfite Semi-Chemical (NSSC) with 20% chemicals, 170°C temperature and 30 min cooking time. This process was followed by refinement using laboratory refiner in three different rotation speeds of 2600, 3800 and 5500 rpm. Eventually, pulp making and measurement of the desired properties such as pulp freeness, tensile strength, tear strength, burst strength and crushing strength were implemented for a ring of paper. The obtained data was then analyzed statistically whose results revealed that the papers which were made from refined pulps at 5500 rpm with 350±25 mL CSF freeness have shown many desirable strength properties. In should be noted that considering factors including minimum standard values and refinement energy, a pulp of 400±25 mL CSF will be advised. In addition to that, tear strength will also be reduced by increasing the refinement intensity, while strength indexes of the paper obtained namely crushing strength in RCT mode, tensile strength and burst strength.

Key words: Bagasse · Freeness · Refiner · Ring crush test · Tear strength index · Tensile strength index

INTRODUCTION

Pulps produced through NSSC are mainly used to produce corrugated medium. The corrugated medium are among the most consumed papers worldwide which are employed to prepare the middle layer of Corrugated board and are used in carton making and packing industries. This layer provides the required stiffness for the carton.

Generally speaking, two operations are done simultaneously on fibers through pulp refinement procedure, including fiber peeling [1]. Refinement is, in fact, a kind of mechanical treatment on the fibers whose nature is different on various equipments [2].

Main objectives of a refinement procedure are:

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

The question "how refinement affects the fibers" has been answered below:

- Removing primary wall of the fibers (P) totally or partially, which results in more water absorption by secondary walls and more inflammation (fig.1). When this layer is removed, fibers can be inflamed since the layer crust (S) will come to surface [1].
- More flexibility in the fibers.
- Secondary walls will be fibrillated.
- Increase in specific surface of the fibers.
- Fibers cut and increase in tiny particles aimed at forming the favorite paper sheets. It should be noted that refinement has an unfavorable effect on water drainage characteristics. In fact, the drainage ability will be decreased with refinement, so there would be a decrease in the production rate per time unit [3].

Adequate fibers must be generally ductile, which means that they must be capable of being rendered into muffler-like layer. There must also be strong enough links formed between the fibers at contact points.

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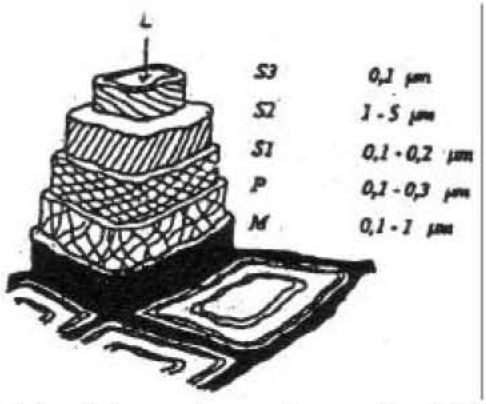

Fig. 1: Intercellular membrane, primary wall and different layers of the fiber's secondary wall [1].

The best properties will be achieved during pulping process if the maximum amount of hemi-cellulose is remained there. Besides, it is possible to enhance the formability, flexibility and binding ability between the fibers by refining the fibers [3].

Afra (2004) concluded that type of the process used during pulping process can affect the quality of fiber refinement significantly. So it has observed that strength properties of papers made by NSSC technique is ranked superior to that of papers made through chemo-mechanical processes. They have also reported that decrease in diameter; cavity diameter and cell wall thickness of the fibers has been occurred after refinement [4].

RouhNia (2003) has conducted research on characteristics of paper made from peel of sunshade seeds. After choosing optimal pulp by using PFI refiner, four different types of pulps with freeness contents of 30, 40, 50 and 60 °SR were prepared. They found that increase in the refinement content through freeness variation range from 30 to 40 °SR was detrimental to tear strength properties. In the studied range (from 30 to 60 °SR), it was observed that the prolonged refinement procedure has been neutral on burst strength and length of the paper break as well [5].

Reme (2000) discovered by studying on a kind of softwood that low-energy refinement of fibers having thin walls has a better condition in comparison to the thick-walled kind with more energy consumption, which leads to better deformation and widening characteristics. This result implies that being thin, the fiber walls, plays a key role in enhancement of compressibility and flexibility [6].

Kevin *et al.* (2000) realized that the tear strength will be decreased when refinement operation is accomplished, although burst strength will be increased in addition to tensile strength in the paper [7].

Main aim of this research is to identify the effect of refinement intensity on properties of the pulp produced through NSSC technique for jagged papers.

Experimental: In order to assess the effects of refinement intensity on pulp properties, bagasse was supplied by Pars Paper Company. Cooking procedure on wood chips was done accordance to table 1 using NSSC.

When cooking procedure was over, pulp is rinsed and its efficiency can be determined. Defibration on obtained pulp was done by a laboratory Refiner. Refinement of pulp was directed in accordance to T248-Om88 code from TAPPI[1] standard using PFI Mill at different rotation speeds of 2600, 3800 and 5500 rpm. Evaluation of pulp freeness contents was done based on T227-Om92 code of TAPPI standard.

Hand sheet paper is produced based on of T220-Om88 of TAPPI standard while its break strength, tensile strength, burst strength and crushing strength are evaluated in accordance to T414-Om88, T414-Om42, T414-Om88 and T414-Om88 regulations from TAPPI standard, respectively. Data analysis was performed using SPSS as common statistical software in the framework of sideway variance analysis design. Comparison and grouping of the average values were done at 95% reliability level.

RESULTS

Pulp Freeness: Results indicated a difference meaningful at 5% level between freeness values obtained for bagasse pulps during various refinement periods (Table 2). As we can be seen in Fig. 1, freeness content has decreased upon the rise in the refinement intensity and rotation speed. Therefore, the highest and lowest freeness values are related to refinement at 2600 and 5500 rpm, respectively.

Table 1: Optimum characteristics of NSSC coking to produce pulp from bagasse

Cooking condition	NSSC pulping	Cooking condition	NSSC pulping
Chemical charge	Sodium sulfite (Na_2SO_3) and bicarbonate ($NaHCo_3$)	Chemical charge (%)	20
Liquor-to-bagasse ratio	10:1	Time of Impregnation and Cooking time (min)	30
Cooking temperature (°C)	170	Yield (%)	74.95

[1]Technical Association of Pulp and Paper Industry

Table 2: Statistical analysis on the effects of refinement intensity on pulp characteristics made from bagasse as raw material

Characteristics	F value	Sig
Freeness (mL CSF)	1093.857	0.000
ring crush test (KN m^{-1})	47.257	0.000
tensile strength (N.m g^{-1})	1.505	0.295
Burst Strength Index (KPa.m^2 g^{-1})	67.305	0.000
Tear Strength Index (mN.m^2 g^{-1})	97.717	0.000

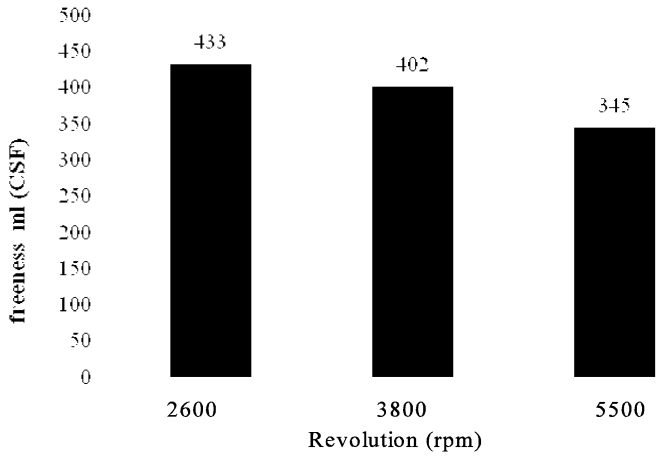

Fig. 1: Effect of refinement intensity on freeness value of the pulp made from bagasse

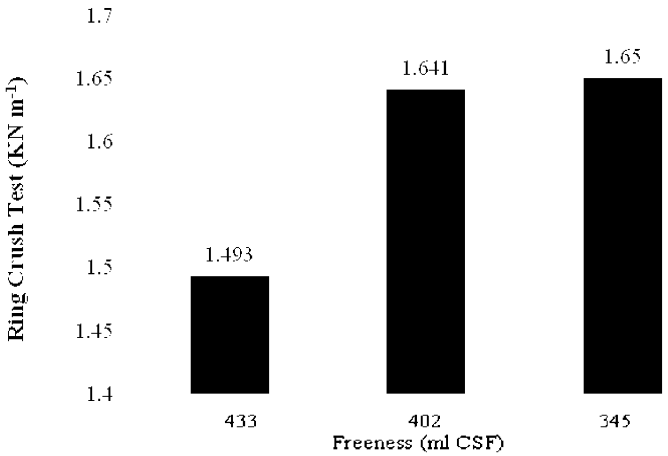

Fig. 2: Effect of freeness on ring crush test of the pulp made from bagasse

Ring Crush Test: Results indicated that the meaningful level was at 5% level for a difference among ring crush tests on papers obtained from bagasse during various refinement periods (table 2). As evident from fig. 2, higher ring crush test values have been offered for higher refinement intensity and rotation speed. Thereby, 5500 and 2600 rpm were associated with the highest and lowest contents of tensile strength, respectively.

Tear Strength Index: It was proved by obtained results that the difference among tear strength indexes of bagasse made papers during several refining times was meaningful at 5% level (Table 2). Based on fig. 3 it can be observed that the tear strength has been enhanced upon higher refining intensities and rotation speeds. Since, the highest and lowest amounts of tensile strength have been proved to occur at 2600 and 5500 rpm, respectively.

Burst Strength Index: Results were indicative of 5% meaningful level as the difference between burst strength indexes of papers with bagasse origin among various refinement durations (table 2). It can be observed in fig. 4. That the burst strength index has experienced a significant growth upon the rise in refinement intensity and rotation speed. Consequently, the highest and lowest amounts of burst strength index are believed to happen at 5500 and 2600 rpm, respectively.

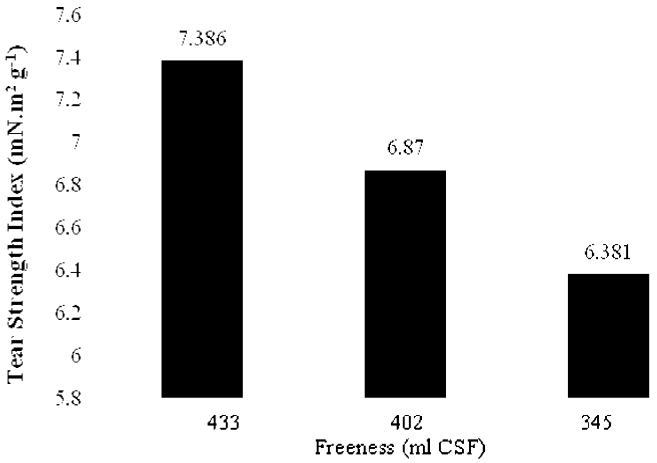

Fig. 3: Effect of freeness on tear strength index of the pulp made from bagasse

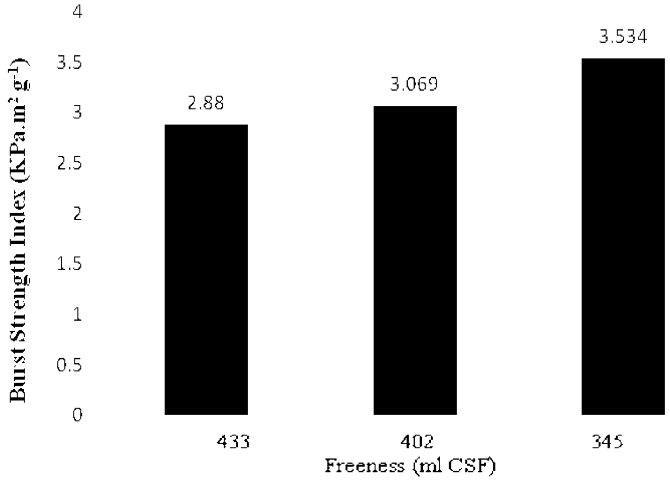

Fig. 4: Effect of freeness on burst strength index of the pulp made from bagasse

Tensile Strength Index: Results exhibited that the difference among tensile strength indexes of papers with bagasse origin is not meaningful at 5% level during different refining times (Table 2). Tensile strength of the paper has decreased when refinement intensity and rotation speed increases. Consequently, the highest tensile strength has been reported to be related to 5500 rpm while its lowest value is associated with 2600 rpm rotation speed.

DISCUSSION AND CONCLUSIONS

Refinement is a kind of process used to change physical and mechanical properties of the pulp using both mechanically and hydraulically driven forces. Refinement can effect a cross sectional shape of the fibers in two ways. First, by decreasing the wall thickness which will increase the compressibility of fibers, their walls will meanwhile lie on each other to produce thicker fibers. Second, through layering of fibers that yields to higher resiliency and flexibility. Upon refining, fibers will be exposed to shear, tensile and compressive forces, which will impose some changes on them [3, 8]. As the result of refinement step, the primary wall of fibers will be removed, to some extent, so the secondary wall will be exposed to water directly. Therefore, it will absorb water easily and shrink, which improves the flexibility of fibers noticeably. On the other hand, refinement when resumed will create some micro-fibrillations on the surface which causes a total surface of the refined fibers to be increased. In turn, links between fibers will be increased in addition to the ductility and strength of paper sheets [9]. However, there may be some undesirable effects besides the positive ones created upon refinement such as breaking and shortening of fibers subjected to shear forces. Additionally, the amount of Fines could be increased during the refinement process which will decrease watering and freeness of the pulp [3].

Generally speaking, the following remarks can be drawn out of this study:

- By increasing the refinement intensity (rotation speed of the refiner), freeness content of the pulp has been decreased since the primary wall is removed and the secondary wall will be exposed to water. So more water will penetrate into the fiber structure and this can raise the flexibility characteristics. Some negative impacts are created besides positive impacts some of which are breaking and shortening of fibers by shear forces, which cause higher tiny particles being produced in the pulp. Indeed, the drainage ability will be decreased upon prolonged refinement times so the production rate decreases with time.
- By increasing the refinement intensity (rotation speed of the refiner), ring crush strength, tensile strength, burst strength and tear strength will decrease due to shorter lengths of the fibers. Because this strength depended on the length of fibers and strength of each fiber. However, other characteristics such as tensile strength and burst strength, ring crush test and tearing length will be enhanced due to the increase in links connecting different fibers to each other [3]. The main parameters which affect fibers during a typical refinement process include:
    - Partial or total remove of the primary wall (P) will increase water absorption of the secondary wall which causes more inflammation. If one removes this layer too, (S) layer will be at the surface and the fibers will all be able to be inflamed.
    - More flexibility of the fibers.
    - Fibrillation of the secondary wall.
    - Increase in the amount of specific surfaces.
    - Fibers cut down and increase in the amount of tiny particles in order to produce paper sheets well.

Fibers which lose their wall layer after refinement will create better flexibility and connectivity in the paper. By decreasing the wall thickness of these fibers, its stiffness will also be decreased, which may cause improved fibrous connections in the paper [1, 8].

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