Comparison Mechanical and Chemical treatments on Properties of Low Yield Bagasse Pulp during Recycling

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***Abstract*—**the effects of refining and alkaline chemicals on potential of recycling bleached chemical pulp of bagasse were investigated in this study. Recycling was done until three times. Handsheet properties such as, apparent density, light scattering coefficient, tear index, burst index, breaking length, and fold number according to TAPPI standard were measured. Water retention value also was used to considering the treatments during recycling. Refining enhanced the strength of recycled pulp by increasing fiber flexibility and swelling ability, whereas by applying chemical treatment didn't observe any improvement. The morphology of recycled fiber was considered with scanning electron microscopy (SEM).

***Keywords*—**bagasse pulp, chemical treatment, recycling, refining, scanning electron microscopy, Water Retention Value

I. Introduction

NON-WOOD lignocelluloses' materials such as bagasse have been used for many years in Iran because there are minimum forest resources. However, the use of nonwood's fibers is increasing in well-forested countries. This increasing is due to a rapid growth in demand for wood in wood products, such as, plywood, veneer, and furniture. On the other hand, paper and paperboard consumption per capita (kilogram/person/year) from 38.04 to 54.48 increased in world and it also increased from 7.39 to 14.06 in Iran during 1960-2005 [1]. Therefore, more studying on nonwood pulps seems to be necessary.Bagasse, a residue by-product form the production of cane sugar, is the crushed cane stalk after juice has been extracted. Literature references about the potential recycling of bagasse pulp are few [2] [3]. Repeated recycling causes fibers to become less suitable for paper making; because they become less flexible than virgin fibers and don't conform as well. Then recycled paper is weaker due to less bonding between the fibers [4]. There are four possible methods to regain the loss of bonding of recycled fibers: (1) beating and refining, (2) chemical treatment, (3) blending with virgin fibers, and (4) fiber fractionation [5]. In this study, the first and second methods were applied. Alkaline-based solutions are the most common chemicals utilized because alkali treatment influences the swelling capacity of the fibers, which is a very important factor in terms of the bonding potential of the fibers [5]-[13]. To investigate the effect of repeated recycling on the bagasse pulp properties, we prepared the pulp of Pars Paper Mill. Handsheets were formed, repulped, and reformed until three stages of recycling. Repulping involves mechanical and chemical treatments, both of which can conceivably affect fiber swelling and sheet strength. Mechanical action, e. g. refining, on the fibers can increase swelling and strength. Chemical effects include losses in yield and ionic effects both of which can influence the level of swelling of fibers and paper strength [12].This work was focused on bagasse, because of the abundance of this residue in Iran.

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II. Procedure

A. Materials

Bagasse bleached soda pulp (Table I) was prepared from Pars Paper Mill was located in Haft Tappeh, Khuzestan, Iran.

TABLE I
BAGASSE SODA PULP COOKING CONDITIONS AND PROPERTIES

Cooking conditions			Pulp quality		
NaOH (%)	Tim. (min.)	Temp. (C)	Kappa no.	Toal Yeild (%)	Freness Degree (csf)
10	15	175	6.5	45	350

B. Treatments

Sodium hydroxide and ethylamine were used for chemical treatment in each stage. These treatments were selected based on previous results of some investigators regarding the effects of aqueous and organic liquids for the recycled pulp fibers [10]-[13]. Chemical treatment of recycled pulp was carried out overnight at a concentration of 5% (based on oven dried pulp) at a pulp consistency of 9% and at room temperature. Then the pulps were washed carefully with water and the moisture content of pulp was reduced to approximately 80%. Finally, the handsheets were made for measuring the properties of recycled pulps.The mechanical treatment was involved only beating of the pulp in a PFI mill at a consistency of 10% to obtain a freeness of 300 or 360 ml csf (Canadian Freeness Standard) before handsheets preparation by TAPPI standard T205-sp-95.

C. Handsheets properties

The handsheets with basis weight of 60 g/m^2 were made in a handsheet former according to TAPPI T205 sp-95 and tested for tear index (TAPPI T 414 0m-95), tensile index (TAPPI T 494 om-95), burst index (TAPPI T 403 om-97), and fold number (TAPPI T220 0m-95). Light scattering coefficient was measured using ISO 2469. The surface morphology of pulp fibers was observed using a Philips scanning electron microscope (XL30 model). The water retention value was calculated according to equation 1 [14] [15].

$$WRV = \frac{m_2 - m_1}{m_1} \times 100 \qquad (1)$$

Where m_1 equals the mass of dry sample, and m_2 equals the mass of moist sample.Treatments were applied in every stage. The properties were measured after every stage and finally the effects of mechanical treatment with chemical treatment were contrasted.

III. Results and Disscution

Tables II and III show the properties of handsheets were made from virgin pulp and recycled pulps in three stages.

TABLE II
THE PROPERTIES OF RECYCLED PULPS WITH MECHANICAL TREATMENT

Pulp	Virgin pulp	Recycled pulps					
		300 ml csf			360 ml csf		
		First stage	Second Stage	Third stage	First stage	Second Stage	Third stage
Apparent density (gr/cm^3)	0.631	0.72	0.716	0.75	0.66	0.69	0.72
Light Scattering Coefficient (m^2/k)	29.80	23.76	24	21.75	28.6	25.6	23.6
Tear Index (mN.m^2/g)	4.57	5.01	4.73	4.5	4.29	4.63	4.67
Breaking Length (Km)	6.84	7.64	7.24	7.85	7.3	7.14	7.66
Burst Index (Kpa.m^2/g)	2.75	3.2	2.9	2.8	2.77	2.98	3.18
Fold Number	361	640	997	1215	503	648	881
WRV (%)	243.68	244.97	213.74	213.13	223.7	208.03	221.3

TABLE III
THE PROPERTIES OF RECYCLED PULPS WITH CHEMICAL TREATMENT

Pulp	Virgin pulp	Recycled pulps					
		NaOH			$C_2H_5NH_2$		
		First stage	Second Stage	Third stage	First stage	Second Stage	Third stage
Apparent density (gr/cm^3)	0.631	0.596	0.590	0.591	0.61	0.57	0.52
Light Scattering Coefficient (m^2/k)	29.80	39.06	43.4	41.56	36.27	40.67	51.22
Tear Index (mN.m^2/g)	4.57	4.93	4.43	4.7	4.89	4.78	3.56
Breaking Length (Km)	6.84	5.3	3.6	2.22	4.92	4.33	3.57
Burst Index (Kpa.m^2/g)	2.75	1.85	1.28	1.51	1.87	1.27	0.63
Fold Number	361	55	17	28	71	16	3
WRV (%)	243.68	187.3	153.2	141.76	206.7	171.9	149.74

It can be seen that refining during recycling due to fiber fibrillation (fig. 1), significantly increased all of strength properties except for the tear index. Fibrillation develops the bonding ability of the fibers [13]. When treated with hydroxide sodium or ethylamine, recycled pulp shows significant decrease in strength properties (Table III).

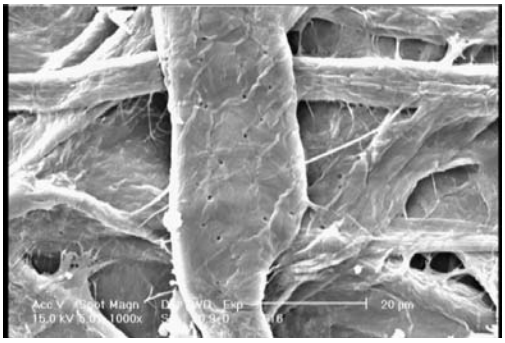

Fig. 1 SEM micrograph refined recycled fibers with magnification 1000x

Apparent density is one of the most important physical properties of paper, since is a good indicator of fiber flexibility and fiber bonding, and is used by some as a predictor of paper strength, since bonding in the sheet increases both strength and density [16]. In the case of pulps, which treated chemically during recycling, had significantly lower density than refined recycled pulps (Table III). It can see of fig. 2 that chemical treatments has no positive effect on the density and the lowest density of pulps was indused with ethylamine, but refining not only prevented of decreasing but also increased density during recycling.

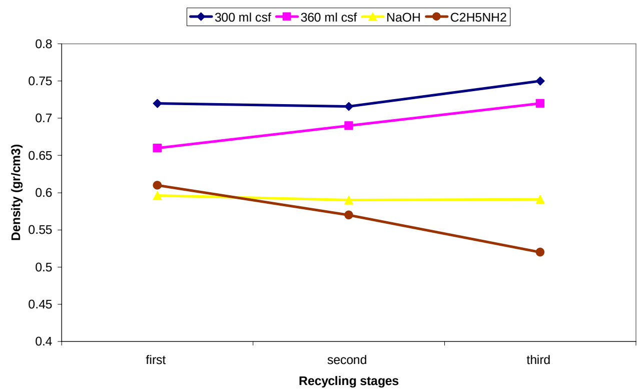

Fig. 2 The changes of handsheets density during recycling

The light scattering coefficient indirectly indicates unbonded area between the component fibers, thereby providing an inverse estimated degree of bonding [16]. The refined recycled pulps had a lower light scattering coefficient

(Table II). Refining significantly decreased the light scattering coefficient. But, unrefined recycled pulps had high light scattering coefficient (Table III). Traces of solids on their surface were observed (Fig. 3), whereas there were very little solids on refined recycled fibers (Fig. 4). These solids were analyzed by an EDX[1] system. It contains Ca. Si., Cr., Mg., and Fe elements (fig. 5). Bagasse fibers typically contain these elements and also occluded sand and dirt which contaminants the fibers at the time of harvesting of the canes [17]. Alkaline conditions during recycling may cause to create these traces on fibers.

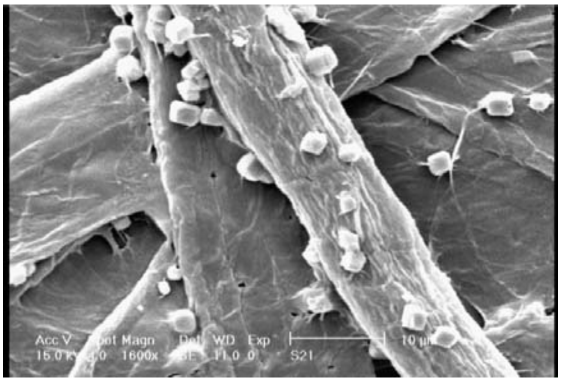

Fig. 3 SEM micrograph recycled fibers (treated with $C_2H_5NH_2$) with magnification 1600x

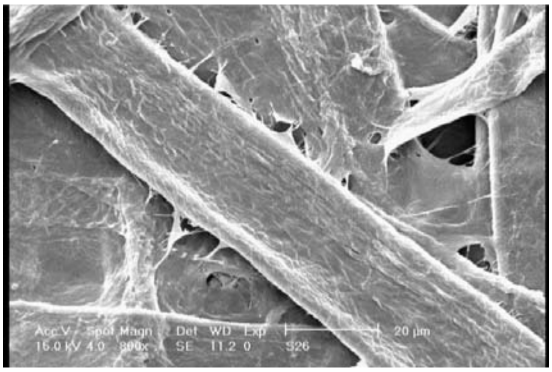

Fig. 4 SEM micrograph recycled fibers (360 ml csf) with magnification 800x

Water retention value, which is defined as a ratio of water to dry fiber after centrifugation of a fiber pad under standard conditions, is used as a measure of fiber swelling. Fiber swelling is accompanied by an increase in fiber flexibility and fibrillation, which are important in developing fiber-fiber bonding in paper [18]-[19]. It can be seen that refining in a PFI mill was kept the water retention value to its virgin pulp level at first stage of recycling by refining and didn't decrease at second and third stages such as recycled pulp treated with alkaline chemicals that decreased significantly (Tables II) (Table III). This result also observed that sodium hydroxide had no significant effects on swelling of low yield unbeaten bleached pulps [12.Tear index didn't change significantly with the exception of pulp that three times recycled by ethylamine. According to the Table III this pulp due lower fiber bonding, as indicated by lowest density and the highest light scattering coefficient, had lowest tear index. In this study, refining didn't decrease tear index of recycled pulps. Tearing resistance depends strongly on the fiber length, fiber bonding, and the total number of fibers that are involved in the sheet rupture [16]. This can be resulted refining didn't affect the fiber length drastically.Breaking length and burst index are dependent on fiber bonding [16] and showed similar trends in this study. Chemical treatments showed significantly lower breaking length and burst index than refined pulps even after three times recycling. There was not different between two levels of freeness (Table II) (Table III). Higher breaking length and burst index can be explained as because of fibrillation and improved of fiber bonding. This was indicated by lowest light scattering coefficient and highest sheet density as explain earlier.

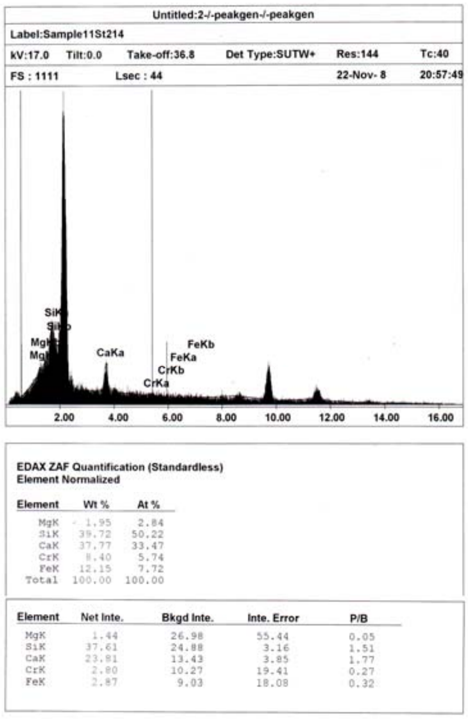

Fig. 5 A sample of elements on recycled fibers by alkaline chemicls

The fold number of recycled pulps with chemical treatments decreased tremendously on three successive recycling. It decreased from 361 to 3 and 28. Whereas, it increased from 361 to 881 and 1215 on three successive recycling by mechanical treatment. Property fold number is somewhat a modified tensile strength, but it is greatly affected by the flexing ability of the paper [22].

IV. Conclusion

Impact of recycling on properties including apparent density, breaking length, burst index, fold number and light scattering coefficient were considered. Properties which are direct function of interfiber bonding increased with refining, while the properties which are inversely related to interfiber

[1] . SEM was equipped with an EDX system which can recognize the elements in the solids.

bonding increase during recycling. Apparent density increased while light scattering coefficient decreased with mechanical treatment. It is believed that the increase in density and loss of light scattering coefficient are due to mechanical attrition during recycling which progressively flatten the fibers [17]. It can be seen that the recycled fibers with mechanical treatment were flatten very more than recycled fibers with chemical treatments (Fig. 6)-(Fig. 7).

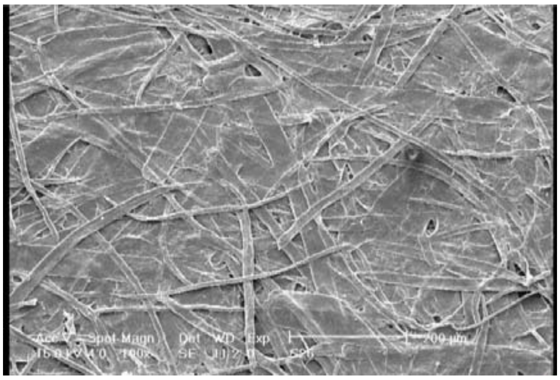

Fig. 6 SEM micrograph twice recycled fibers with mechanical treatment (360 ml csf) with magnification 100x

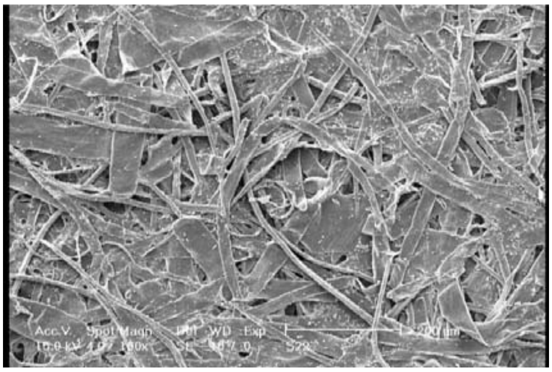

Fig.7 SEM micrograph twice recycled fibers with hydroxide sodium with magnification 100x

Totally, this investigation revealed the following:

1. The difference between two levels of refining was not very much.
2. By applying refining the strength of handsheet was kept more than or the same unrecycled handsheet.
3. Chemical treatments didn't cause any improvement in recycling pulps.
4. Decreasing strength by applying ethylamine was more than hydroxide sodium.

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