EFFECT OF BEATING ON FIBRE CRYSTALLINITY AND PHYSICAL PROPERTIES OF PAPER SHEETS

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SUMMARY: Bagasse, wood pulp and rice straw pulps were beaten to different degrees, paper sheets were prepared from each beaten sample. Physical properties and crystallinity of each sample were determined. The results obtained shows that the strength properties of prepared paper sheets increased by increasing beating except the tear factor. A rough positive relation can be found between tear and crystallinity.

Key Words: Paper pulp, crystallinity.

INTRODUCTION

Beating is the most important physical treatment carried out on pulp before paper making, it highly affects the physical properties of the prepared paper sheets. It serves the purpose of increasing the area of contact between the fibers by increasing their surface through fibrilation and by making them more flexible (18). Beating can also be carried out on synthetic fibers (3), (4). The rate of beating of grafted pulps was higher when the affinity between the dispersing solvent (water or methyl alcohol or acetone) and the grafted polymer was stronger (23). During beating some additives can be added with the aim of decreasing the beating time and/or improves the strength properties of the produced paper (1, 13, 16, 17). Up to 0.8% of the dry cellulose was dissolved through beating, xylane and arabinose are detected in the beating liquor (19). Adsorption of the dissolved xylane on the fibers led to an increase in the strength properties of the prepared sheets. However dry beating were recently mentioned (5).

Many factors affects beating such as pH of pulp slury, electrolyt concentration (10), consistency (11), beater design (2), beating load, beating speed and time of beating (15). Also the components of pulp plays an important role during beating. The presence of hemicellulose during beating improve beating characteristics and increases fiber adhesion (7). Addition of less than 0.15% surface active agent to the pulp during beating resulted in an increased strength properties, this increase almost go linearly with the amount of surface active agent (6).

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It was found that ∝-cellulose, pentosane and alkali soluble substances did not change during beating but the cry-stallinity and fines contents increased with increasing beating from 17 to 78 Schopper riegler freeness (°SR) (21), also tearing strength, breaking length, burst factor and folding of kraft paper increased by increasing beating. However, not only the crystallinity but also the preparation condition of pulp affects its mechanical properties (8).

The aim of this work is to study the effect of beating bleached bagasse, rice straw and wood pulp to different degrees on their crystallinity and strength properties also to find relationship between strength properties and crystallinty of the tested pulps.

MATERIALS AND METHODS

Materials

Bleached paper grade wood pulp (bleached birch, Betula Verrucosa, sulfate wood pulp), unbleached kraft pulp provided by Edfo Mill, Egypt was bleached by the conventional three stages method, and unbleached soda rice straw pulp provided by Rakta Mill, Alexandria, Egypt was bleached by the conventional three stages method, were used in this study. The chemical analysis and crystallinity of the used pulp were shown in the following Table 1.

Methods

The three pulps were beaten by using Jokro Mill to different degree of freeness (°SR) by increasing the beating time, then paper sheets were prepared from each sample according to the Swedish standard method (S.C.A.). The strength properties (24) and brightness (20) of the prepared sheets were determined. The crystallinity of the original pulps and that of the beaten samples were also determined by X-ray method (22) using Philips PW 1373 apparatus.

Table 1

analysis / pulp	∝-cellulose %	hemicellulose %	lignin %	crystallinity
wood pulp	85.5	6.7	traces	52.6
bagasse pulp	73.1	25.0	0.2	58.8
rice straw	69.8	19.5	1.2	63.3

Statistical evaluation of the results

The mean value of 10 measurements was calculated and the variability of these measurements was expressed as coefficient of variation (C.V.), and calculated as follows (14):

$$\text{C.V.} = \frac{\text{Standard deviation}}{\text{Mean value}}$$

The standard deviation was calculated according to the method expressed by Moroney 1974.

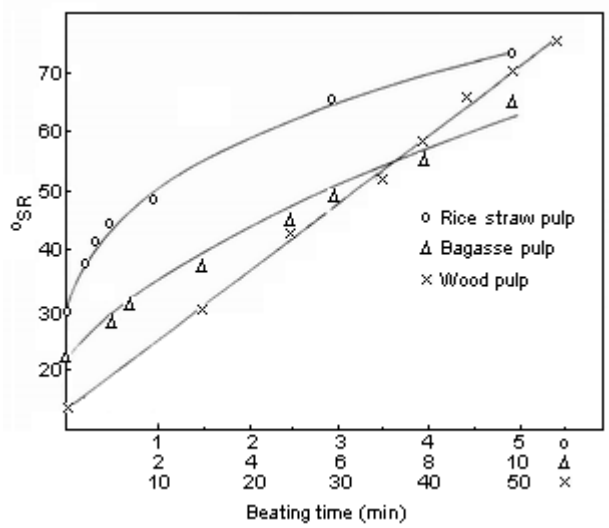

Figure 1: Effect of beating time on freeness (SR).

RESULT AND DISCUSSION

1. Effect of beating time on Schopper riegler (° SR) for different pulps

The used wood pulp, bagase and rice straw have initial Schopper Riegler of 14.22 and 30 (°SR) respectively; each pulp were beaten to different degrees in a Jokro Mill beater at 150 r.p.m. for different time intervals. The results are shown in Figure 1, and it can noticed that increasing the beating time increases the Schopper Riegler linearly in all cases. The beatability of the tested pulps are differed, as rice straw was beaten to about 70 °SR in 5 minutes whereas bagasse need 10 minutes to reach 65 °SR and wood pulp reach 70 °SR after 50 minutes. These differences can be due to the differences in the fibers structure and chemical composition of pulps (Table 1).

2. Effect of °SR on the strength properties and crystallinity of bagasse

Table 2 shows the effect of beating degree on the strength properties, brightness and crystallinity of paper sheets made of bleached bagasse pulp. The density of bagasse pulp increases as the beating increased, a density of 1.6 g/cm^3 at 22 °SR increased to 1.699 g/cm^3 as the beating reach to 68 °SR. From the table, it is clear that the breaking length increased gradually with the increase of beating degree. Bleached bagasse of 22 °SR have a breaking length of 2000 m., which increased to 6400m, when the degree of beating reach to 68 °SR. It can be noticed that the rate of increase in the breaking length with beating was high at first (up to 38 °SR) then became less after that.

Burst strength increased also with the increase of beating, it increased from 0.68 to 2.5 kg/cm^2 by increasing the beating degree from 22 to 68 °SR. The tear factor increased with the increase of beating degree, it start with 66 at 22 °SR and increased to 83.2 at 48 °SR, after that tear factor begin to decreased with the increase of beating. This can be explained by the fact that increased coherence in the sheet tends to concentrate the tearing

Table 2: Effect of beating on mechanical properties, brightness and crystallinity of paper sheets made of bagasse pulp.

beating time/min.	°SR	density g/cm^3	breaking length m		burst kg/cm^2		tear factor		fold number		brightness %		crystallinity %	
			mean	C.V.	mean	C.V.	mean	C.V.	mean	C.V.	mean	C.V.	mean	C.V.
0	22	1.600	2000	0.025	0.68	0.042	66.0	0.033	41	0.051	76.3	0.026	58.8	0.021
1	24	1.612	4800	0.019	1.56	0.038	70.8	0.040	52	0.063	74.3	0.029	60.8	0.019
1.5	32	1.620	5200	0.016	1.66	0.019	74.2	0.031	160	0.057	72.6	0.021	61.6	0.013
3	38	1.642	5540	0.021	2.30	0.021	76.4	0.040	340	0.041	71.4	0.016	63.5	0.030
5	45	1.661	5680	0.027	2.32	0.020	82.8	0.048	635	0.052	70.2	0.013	55.6	0.024
6	48	1.668	5820	0.023	2.36	0.018	83.2	0.053	883	0.048	69.5	0.026	54.7	0.017
8	55	1.684	6140	0.018	2.42	0.019	70.4	0.043	1020	0.029	68.8	0.018	53.6	0.020
10	68	1.699	6400	0.024	2.50	0.017	68.4	0.037	1200	0.030	67.4	0.019	53.1	0.025

forces into a small area instead of permitting it to diffuse over a wide path. As it is known tearing resistance depend on three factors; total number of fibers participating in the sheet rupture, fiber length and number and strength of the fiber to fiber bond. Increased beating affects these factors adversibly specially the last one.

Fold number also increased gradually with the increase of beating. It increased from 41 to 1200 as the degree of beating increased from 22 to 68 °SR. This can be explained by considering that folding, in a sence, is a modified tensile strength, but the results are greatly affected by the flexing ability of the paper. Brightness decreased slightly with increasing beating it decreased from 76.3 to 67% as the beating degree increased from 22 to 68 °SR. This can be due to the impurities which may leach out of metal cups, and interfere during the prolong beating.

Bleached bagasse pulp has a crystallinity of 58.8%, on beating the crystallinity increased up to 63.5% when the degree of beating reaches 38 °SR, then the crystallinity decreased againe to 53.1% when the beating was continued to 68%°SR. The increase in the crystallinity at the beginning of beating can be explained by increased ordered cellulose and loss of fins at early stage of beating. It was stated by Lyer that when prehydrolyzed cotton samples of crystallinity below 35-40% were ball milled recrystallization occurred and higher crystallin, percent were obtained after milling (12). Prolonged beating begins to affect the cellulose chains and some of it begins to broken dawen, crystalline fraction is highly affected and hence crystallinity begin to decrease, some of the fine produced go into solution. This can be explained by the D.P. produced as a result of high beating and hence crystallinity gradually increased by increasing beating (21) but these results obtained for unbleached bagasse which containe some lignin. This lignin may protect cellulose chains during beating and so no reduction in the crystallinity of the unbleached were obtained in the case of bleached bagasse.

3. Effect of °SR on strength properties and crystallinity of wood pulp

Table 3 illustrates the effect of beating degree on the strength properties, brightness and crystalinity of paper sheets made of bleached wood pulp. From that table, it can be seen that the density of the different samples increased by increasing beating degree it increased from 1.632 to 1.68g/cm^2 for 14 and 74 °SR respectively. Also we can notice that the breaking length increased with increasing beating up to 74 °SR, after 65 °SR, the rate of breaking length increasing was decreased.

Table 3: Effect of beating on mechanical properties, brightness and crystallinity of paper sheets made of wood pulp.

beating time/min.	°SR	density g/cm^3	breaking length m		burst kg/cm^2		tear factor		fold number		brightness %		crystallinity %	
			mean	C.V.	mean	C.V.	mean	C.V.	mean	C.V.	mean	C.V.	mean	C.V.
0	14	1.632	2600	0.019	0.42	0.038	12.8	0.060	53	0.052	77.7	0.019	52.6	0.015
15	30	1.638	4460	0.023	2.16	0.031	134.4	0.047	148	0.030	75.0	0.023	65.7	0.019
25	42	1.642	5520	0.021	2.52	0.040	140.8	0.042	314	0.041	74.6	0.030	67.3	0.013
35	52	1.645	5920	0.017	2.66	0.029	134.4	0.048	668	0.029	73.4	0.031	68.2	0.022
40	58	1.648	6400	0.019	2.6	0.025	124.6	0.052	416	0.021	71.1	0.027	59.3	0.015
45	65	1.557	6820	0.025	2.78	0.027	128.2	0.033	1440	0.017	72.2	0.015	58.7	0.017
50	60	1.662	7140	0.018	2.82	0.019	121.6	0.043	1865	0.013	70.4	0.029	55.5	0.025
55	74	1.681	7200	0.020	3.12	0.021	121.6	0.037	2110	0.066	70.0	0.017	51.9	0.023

Table 4: Effect of beating on mechanical properties, brightness and crystallinity of paper sheets of rice straw.

beating time/min.	°SR	density g/cm^3	breaking length m		burst kg/cm^2		tear factor		fold number		brightness %		crystallinity %	
			mean	C.V.	mean	C.V.	mean	C.V.	mean	C.V.	mean	C.V.	mean	C.V.
0.0	30	1.426	2850	0.019	0.79	0.013	54	0.033	25	0.048	79.2	0.029	63.6	0.021
0.25	38	1.435	3250	0.017	1.27	0.018	71.8	0.029	98	0.037	78.1	0.019	66.1	0.025
0.33	42	1.448	3400	0.020	1.31	0.015	73.1	0.041	160	0.029	77.6	0.015	67.9	0.018
0.50	45	1.460	3625	0.012	1.43	0.017	75.0	0.025	243	0.031	77.3	0.023	71.4	0.029
1	49	1.476	3800	0.031	1.55	0.023	72.8	0.042	385	0.025	76.8	0.013	66.6	0.016
3	65	1.488	4140	0.018	2.11	0.015	70.4	0.020	518	0.052	76.0	0.022	62.5	0.017
5	72	1.497	4415	0.025	2.32	0.019	57.6	0.025	680	0.044	74.8	0.033	59.3	0.015

Burst strength increased linearly with the beating degree. As in the case of bagasse, tear factor increased with the increasing of beating up to about 42 °SR where it reaches to its maximum value of 140.8, then the value of tear factor begin to decrease. The fold number increased by increasing the beating degree and it reaches to about 2110 at 74 °SR. Brightness decreased slightly but gradually with increasing beating. Brightness of 77.7% at the beginning (14°SR) decreased to 70.0% only when the beating reaches 74 °SR.

Considering the crystallinity, wood pulp has an initial crystallinty of 52.6%, by beating this value increased to 68.2% at 52°SR, continuation of beating after that decrease the degree of crystallinity fill it reaches 51.9% at 74°SR.

4. Effect of °SR on strength properties and crystallinity of rice straw

Table 4 illustrates the effect of beating degree on the strength properties, brightness and crystallinity of bleached rice straw pulp. The results of Table 4 can be treated as tables 2, 3 and the same comments can also be obtained.

CONCLUSION

1. All the determined properties increased with the increase of beating except tear factor which decrease after certain limits and whiteness which decreased gradually with beating increase.

2. Crystallinity were found to increase at first till certain limits of beating then begin to decrease after that.

3. A rough positive relation can be found between crystallinity and tear factor for all pulps under investigation.

4. Bagasse and rice straw pulps behave similarly and parallel to wood pulp on beating, differences due to the chemical compositions and physical structures of the pulps where found.

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