Fibre Strength and Bonding in Paper Using Thermal Treated Filler Materials

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ABSTRACT: Native eucalyptus, bamboo and mixed pulps have been used with alumina hydrate and talc fillers at addition level of 20%. The fillers have been heat treated in air at 400, 600 and 800°C. Properties of hand sheets made with the samples have been studied and the effect of heat treatment on filler quality has been discussed specially in terms of fibre strength and bond factors.

INTRODUCTION

Thermal treatment of kaolinite clay upto the calcination stage (1000-1200°C) is already in practice (1) for enhancing filler property in paper. The sharp exothermic reaction in kaolinite at 900°C brings in structural modification (2) where the individual kaolin platelets disintegrate and fuse together at 1000-1200°C in a random structure with high level of internal void volume (1). On controlled pore size and distribution, high light scatter is achieved leading to enhanced brightness and opacity of paper.

Perusal of literature showed that heat treatment on other fillers such as talc and specially alumina hydrate has not been carried out to find the effect on filler property. Both talc and alumina hydrate possess platelet structure (3) as in kaolinite clay. While use of talc as filler is common, alumina hydrate is confined commercially to coating purpose only. The thin hexagonal platelet structure of alumina hydrate presents high brightness with a high reflectance across the entire visible and in UV range (4) for which it is quite effective as paper filling pigment when optical brightners are used.

It was therefore considered worth undertaking the present study of heat treating talc and alumina hydrate and then use the heat treated products as fillers. The results on fibre strength (FS) and bond factor (BF) of the resultant hand sheets, show some interesting findings, leading to the fundamental understanding of the filling mechanism and location of fillers in the paper furnish. The advantage of such study is obvious because on heat treatment properties such as water of crystallization, surface area, surface charge, particle size and void volumes can be changed to desired level which play important role in determining the paper properties (5-8).

EXPERIMENTAL

Materials

The fillers used in the experiments are alumina hydrate and talc. These fillers are heated for four hours at 400°C, 600°C and 800°C separately in an electrical muffle furnace in air. Pulps of bamboo, eucalyptus and their admixture at 80 : 20 ratio have been taken.

Cooking of bamboo and eucalyptus chips were carried out by kraft process. The cooking conditions are as follows:

Active alkali	-17.0%
Bath ratio	- 1 : 2.7
Diluent	- Water
Time to 165°C	- 2 hours
At 165°C	- 1.5 hours.

The pulps are bleached following CEH sequence to a brightness level of 80% El.

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Stock Preparation

Both the pulps were beaten in a Laboratory valley beater. Stocks were prepared using rosin, thermally treated fillers and alum. Filler addition level was 20% for all the sets. Stock pH was maintained at 4.5.

Property Evaluation

Hand sheets of 60 gsm were prepared in British hand sheet making machine and tested for fibre strength and bond factor using Pulmac trouble shooter (Made in USA, Model TS 100). Bulk, tear factor, breaking length, burst factor and double fold were determined according to standard TAPPI test method (1991).

RESULTS AND DISCUSSION

Properties of alumina hydrate and talc used are given in Table 1. while properties of pulp samples are shown inTable 2. The particle size of the two fillers is 0.5-1 um (9). At 45μ percentage of alumina hydrate is nil while for talc, it is 0.2% (10). Alumina hydrate loses 33-34% of its weight at 400-800°C while the weight loss in talc is 0.4, 1.2 and 5.3% at 400, 600 and 800°C. The brightness of alumina hydrate is highly superior (94-97% El) to that in talc.

Table 1.

Properties of thermal treated fillers used

	Weight loss (%)	Brightness (% El)
Alumina hydrate		
As such	--	94.3
400°C	33.7	96.0
600°C	34.4	96.2
800°C	34.7	97.2
Talc		
As such	--	80.2
400°C	0.4	80.2
600°C	1.2	58.6
800°C	5.3	45.7

Table 2.

Properties of pulp samples used

Property		Eucalyptus	Bamboo
FS factor		18.1	20.0
Bond factor		3.0	2.7
Bulk,	(cc/g)	1.4	1.5
Tear factor		47.3	49.6
Breaking length,	(M)	6447	6182
Burst factor		39.6	34.5
Double fold,	(no.)	11	5
Ash,	(%)	1.5	1.4

On heat treatment, the brightness of talc goes on decreasing from 80% El to 46% El at 800°C. From the colour, it is therefore evident that alumina hydrate can be used as dominant filler over all other traditional fillers. On the other hand, no advantage should be expected as far as brightness is concerned on using heat treated talc. However, apart from its use in kraft paper, product with special shade can be obtained on using heat treated talc.

Surface area of the filler is important as higher the surface area, higher will be the light scattering (1). Alumina hydrate, on heat treatment, shows increase in surface area (11). The BET (N_2) surface area of the hydrate was found previously (11) to be 374 m^2/g at 400°C, 224 m^2/g at 600°C and 102 m^2/g at 800°C. The surface area of talc also increases on initial heat treatment (12). Increase in porosity on heat treated products, further helps the light scattering and ultimately the brightness. The cost of the hydrate, however, remains the hurdle now for its immediate commercial application. It is forecasted that price of alumina hydrate (9) is bound to come down and in the face of dwindling resources of good quality talc and clay, the future stands bright for alumina hydrate.

Let us discuss now the strenght properties of the hand sheets produced with the two fillers after heat treatment at 400, 600 and 800°C. Table 3 contains the properties of alumina hydrate in eucalyptus and Table 4 for talc in the same pulp. Results of the bamboo based hand sheets are shown in Table 5 and 6 using alumina hydrate and talc respectively. Results with mixed pulp using alumina hydrate are contained in Table 7 and for talc in Table 8.

Table 3.

Properties of paper made using thermal treated alumina hydrate with eucalyptus pulp

Property		As such	400°C	600°C	800°C
FS factor		16.7	15.8	15.0	11.5
Bond factor		3.2	3.3	3.1	3.0
Bulk,	(cc/g)	1.4	1.4	1.4	1.4
Tear factor		44.8	52.9	46.5	43.4
Breaking length	(m)	5274	5398	4705	4625
Burst factor		31.3	32.7	32.2	30.6
Double fold,	(no.)	14	16	14	16
Ash,	(%)	12.8	13.1	13.4	14.3

Table 4.

Properties of paper made using thermal treated alumina hydrate with bamboo pulp

Property		As such	400°C	600°C	800°C
FS factor		15.3	15.3	15.0	10.2
Bond factor		2.8	2.8	2.5	2.5
Bulk,	(cc/g)	1.5	1.5	1.5	1.5
Tear factor		42.0	42.2	40.1	39.6
Breaking length	(m)	4400	5622	5322	4909
Burst factor		30.5	30.8	31.2	28.3
Double fold,	(no.)	9	9	7	8
Ash,	(%)	12.6	12.9	12.6	14.3

Table 5.

Properties of paper made using thermal treated talc with eucalyptus pulp

Property		As such	400°C	600°C	800°C
FS factor		16.7	16.2	14.6	14.4
Bond factor		3.0	2.7	2.9	3.2
Bulk,	(cc/g)	1.4	1.4	1.4	1.4
Tear factor		41.4	43.5	42.4	41.6
Breaking length	(m)	5050	5201	4549	4545
Burst factor		28.1	31.0	30.1	29.4
Double fold,	(no.)	9	13	14	11
Ash,	(%)	13.6	13.0	12.7	14.3

Table 6.

Properties of paper made using thermal treated talc with bamboo pulp

Property		As such	400°C	600°C	800°C
FS factor		14.7	14.8	15.2	15.7
Bond factor		2.6	2.6	2.7	2.7
Bulk,	(cc/g)	1.5	1.5	1.5	1.5
Tear factor		34.2	35.6	41.1	37.3
Breaking length	(m)	5026	4115	4985	5120
Burst factor		28.3	25.6	28.0	27.3
Double fold,	(no.)	5	6	5	5
Ash,	(%)	12.8	13.5	10.8	13.5

Table 7.

Properties of paper made using thermal treated alumina hydrate with bamboo-eucalyptus pulp

Property		As such	400°C	600°C	800°C
FS factor		14.9	14.8	15.4	15.1
Bond factor		2.7	2.9	2.7	2.8
Bulk,	(cc/g)	1.5	1.5	1.5	1.5
Tear factor		39.4	46.7	40.2	39.8
Breaking length	(m)	4695	5703	5400	5615
Burst factor		28.6	33.8	32.3	30.3
Double fold,	(no.)	9	10	8	11
Ash,	(%)	12.0	12.7	12.3	12.3

Table 8.

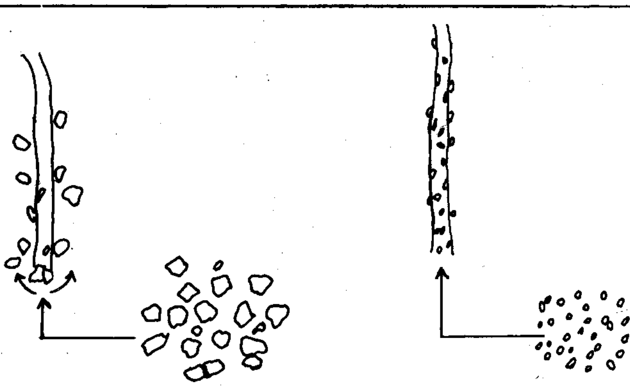
Properties of paper made using thermal treated talc with bamboo-eucalyptus pulp

Property		As such	400°C	600°C	800°C
FS factor		15.0	14.6	15.6	15.4
Bond factor		2.9	2.6	2.6	2.7
Bulk,	(cc/g)	1.5	1.5	1.5	1.5
Tear factor		39.4	39.3	37.1	36.9
Breaking length	(m)	4843	4406	4828	4936
Burst factor		28.5	29.6	28.9	28.2
Double fold,	(no.)	8	8	10	8
Ash,	(%)	12.9	13.1	12.8	12.9

The heat treatment effect on talc is not insignificant vis-a-vis the fibre strength property in both bamboo and eucalyptus furnishes. On the other hand the effect with alumina hydrate induces abrupt change in FS factor specially when heated at > 600°C. Unlike in talc, the FS factor decreases gradually with rising of temperature upto 600°C. However, it is reduced to 10 at 800°C from 14 at 600°C. Such changes in FS factor as a consequence of increase in temperature with alumina hydrate, can throw light on the mechanism and site of filler retention on the fibre as it will be seen in the following discussions.

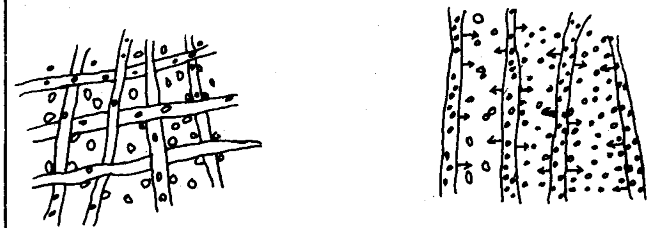
Alumina hydrate is highly hygroscopic in the initial state having gibbsitic structure with the formula $Al(OH)_3.xH_2O$. The higher surface area value of the hydrate is exhibited at 300-400°C but slowly it is lowered as the temperature is increased. The decrease in surface area from an initial value of 576 m^2/g at 300°C, it is reduced to 56 m^2/g at 1000°C with practically total elimination of water (12) which is likely to be accompanied by fall in the adsorption capacity (13), and increase in particle size.

The likely effects of the products on the furnish properties are schematised in Fig. 1 and 2. During stock preparation stage the alumina hydrate particles, heat treated upto 400°C are more favoured for adsorption at the fibre surface (13) as well as for lumen loading than particles heat treated at 600°C. Higher lumen loading leads to improvement in fibre strength and thus hand sheets produced with alumina hydrate heated upto 400°C, possess higher FS values than that at higher temperatures. Changes in the bond factor, can be interpreted also in terms of these structural changes taking place on heat treatment of the fillers.



Al- hydrate (< 400°C) Al-hydrate(600-800°C)

Fig. 1. Schema showing difference in lumen filling mechanism of Al-hydrate (as such) and heat treated at 800°C governing FS factor.



Al- hydrate (< 400°C) Al-hydrate (600-800°C)

Fig. 2. Schema showing difference between Al-hydrate (as such) and Al-hydrate (400°C) governing bond factor.

The tear factor is colsely linked with the FS factor (10). In case of alumina hydrate with eucalyptus, tear factor increases from 45 to 53 when the temperature of alumina hydrate is increased to 400°C. As expected, however, it slowly decreases above 400°C; it is 46.5 at 600°C and 43 at 800°C (Table 3). With bamboo pulp (Table 4) the change is not as remarkable as in eucalyptus but the highest tear factor 42.2 is with filler heated to 400°C. In case of hand sheets made with talc, the highest tear factor is also observed at 400°C with eucalyptus (Table 5) and at 600°C with bamboo (Table 6). The temperature of dehydroxylation of talc is not sharp (14) and produces non-homogenous products with verying surface area values and therefore the difference has been observed between eucalyptus and talc. The tear factors follow the same trend for alumina hydrate with a value of 47 at 400°C (Table 7).

The breaking length value of alumina hydrate with eucalyptus is highest for sample heat treated at 400°C i.e. 5400 m which is 4705 m at 600°C and 4625 m at 800°C. Thus the breaking length is also dependent on the structural modification occuring in alumina hydrate on thermal treatment. In the mixed pulp also the breaking length found with alumina hydrate heated at 400°C is 5703 m which is the highest. The results obtained with talc are, however, variable in the three furnishes studied.

The double fold values are also found to follow similar changes for alumina hydrate and talc i.e. the highest is at 400°C for the former and at 600°C for the later in the three furnishes studied.

The changes brought out in the burst factors on using fillers heat treated to different temperatures, are not significant. However, the highest values are found to be with alumina hydrate heated to 400°C and talc at 600°C.

The bulk properties are little effected on heat treatment of the fillers. The % retentions of filler are also fairly same for both talc and alumina hydrate, the ash content being 12-13%.

Thus filler can play its role when the surface area of the solid is enhanced. Heat treatment is certainly one of the ways to increase the surface area of the filler. The degradation in colour of talc on increasing the temperature is due to the oxidation of Fe^{2+} to Fe^{3+}. Apart from the colour, the strength properties of paper increase on heat treatment. The reactions for the two solids can be written as follows:

$$Al(OH)_3.xH_2O \xrightarrow{120^{\circ}C} Al(OH)_3.3H_2O \xrightarrow{400^{\circ}C} Al(OH)_3 \xrightarrow{800\text{-}1000^{\circ}C} Al_2O_3$$

and

$$Mg_3(Si_2O_3)_2(OH)_2\ MgO.4SiO_2H_2O \xrightarrow{600^{\circ}C} MgO.4SiO_2 \xrightarrow{800^{\circ}C} MgO \text{ and } SiO_2 \xrightarrow{1200^{\circ}C} Mg_2SiO_3$$

SEM micrograph of mixed pulp without any filler is shown in Fig. 3 and with alumina hydrate filler in Fig. 4. The micrographscorrespond to samples after testing in the pulmac trouble shooter. The fractured surfaces are micrographscorrespond to samples after testing in the pulmac trouble shooter. The fractured surfaces are shown in both the micrographs. It can be seen in Fig. 4 that the smaller particles occupy spaces near to the fibre surfaces while the bigger particles remain away from the surfaces. When the filler particles are away from the fibre surfaces, naturally their role in fibre bonding becomes less important. The micrograph is of samples without heat treatment but it demonstrates the situation that can arise for bigger particles at heat treatment of 800°C.

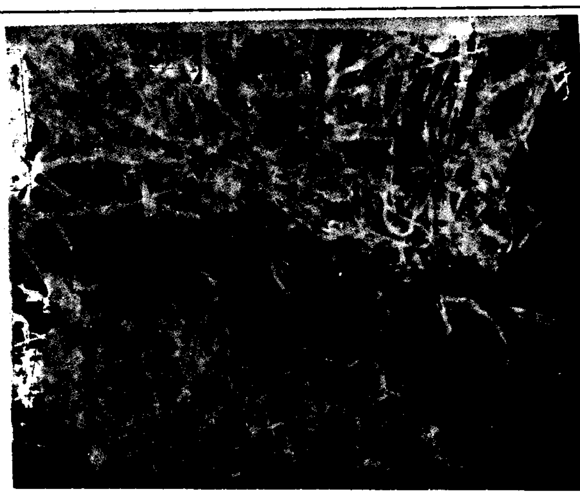


Fig. 3. SEM micrograph of mixed pulp without filler.

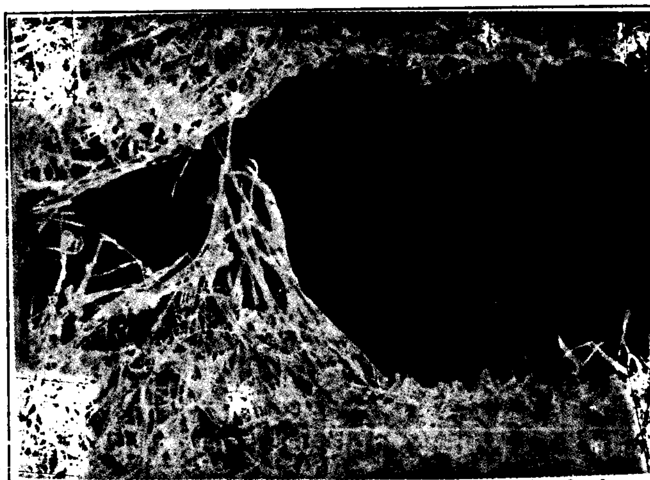


Fig. 4. SEM micrograph of mixed pulp with alumina hydrate.

CONCLUSIONS

Alumina hydrate can enhance its filler property in paper by heat treatment to 400°C. The surface area of the solid increases substantially at this temperature bringing in improvement in brightness as well as fibre strength, bond factor, tear factor, breaking length and double fold values of the paper. The optimum temperature for talc is 600°C for increase in strength properties. The higher surface area with low particle size values of the fillers have been presumed to favour lumen loading and adsorption phenomena.

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