Studies On Increasing Filler Loading of Paper to Save Cellulosic Raw Material

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ABSTRACT:-- Cellulosic raw materials can be saved and cost of paper reduced by improving and optimizing the filler retention. Increasing the filler content in paper within certain limits may yield the benefits such as reduced raw material costs, lower steam consumption in drying, improved optical properties and better print quality. Laboratory scale studies with different types of fibrous raw materials viz bagasse, wheat straw, eucalypt and softwood pulps indicated that in the absence of any retention aid, the amount of filler retained was highest for wheat straw pulp and lowest for softwood pulp. Eucalypt and bagasse pulps both had comparable filler retention capability but higher than that of softwood pulp. With the increase in filler content, softwood and eucalypt pulps showed continuous increase in the apparent density, whereas in the case of bagasse and wheat straw pulps after an increase upto certain filler level a slight drop was observed. Tensile and tearing strength dropped with the increase in filler content. At 15% filler content in the sheet the percent drop in tensile strength observed for softwood, eucalypt, bagasse and wheat straw pulps was 25, 20, 28 and 30 percent respectively. The relative drop in the tearing strength with increase in filler content was lowest in the case of softwood pulp. The improvement in the Sp. Scatt. co-eff. with increased filler content was highest in the case of bagasse and least for eucalypt pulp. The effect on the improvement of Sp.Scatt. co-eff. for softwood pulp and wheat straw pulps was somewhere between bagasse and eucalypt pulps.

The filler retention in pulps studied improved by addition of either cationic starch or hydrocol (a dual type retention aid). Hydrocol gave better effect than starch on the filler retention and maintained higher paper strength at increased filler level.

INTRODUCTION

The paper industry is constantly under pressure to economize paper-making methods because of the ever increasing price of raw materials worldwide. As the expenditure on raw materials is almost the largest cost factor in papermaking, cost cutting in this sector would be the most effective means of reducing the need to economize. The largest cost reduction can be realized by replacing more expensive pulp fibrous materials with relatively cheaper mineral fillers to the highest possible extent. Increasing the filler content in paper can provide the paper maker apart from the savings in the cost of raw

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materials, other benefits like lower steam consumption for drying, improved optical properties and better print quality. The prices of fillers are 3.5 to 10 times lower than the prices of cellulose fibres. A variety of fillers in the amounts varying from 3 to 20% by weight are used in most kinds of papers to decrease production cost or to impart specific sheet properties. Common and commercially used fillers include talc, clay, diatomaceous silica, calcium carbonate, titanium dioxide, aluminosilicate, hydrated aluminium oxide, zinc sulphide and calcium sulphate. The general properties, availability and use of the various fillers are described elsewhere (1). Clay and calcium carbonate are most widely used in many countries. In our country, soap stone (Talc) is the main filler used for papermaking. Presently the maximum amount of filler used in cultural papers is upto 15%. Filler loading around 25% or even more is being practised in developed countries using mainly wood pulps. It would be of interest to examine behaviour of increased level of filler on the papers from indigenous papermaking raw materials.

In the present investigations on laboratory scale the effect of increasing the amount of filler on the papermaking properties of the indigenous pulp from bagasse, wheat straw, eucalypt and imported softwood for comparison was studied including possible ways of improving their retention.

RESULTS AND DISCUSSION

Filler Retention Capability of Different Pulps

In a sheet, filler is retained by mechanical entrapment and electrokinetic interactions (2, 3, 4). In the present laboratory studies it was found that in the absence of any retention additive, soap stone filler retention was lowest in the case of softwood pulp and highest for wheat straw pulp (Fig. I).

The retention capability of eucalypt and bagasse pulps for this filler was however comparable but interestingly higher than softwood pulp. The lower filler retention in the case of softwood pulp was probably due to relatively more porous mat formed by its fibres due to which only relatively large sized material had chance to be hold up in the fibre structure of the mat. The smaller particles and fines which are generally in the size range of 0.001

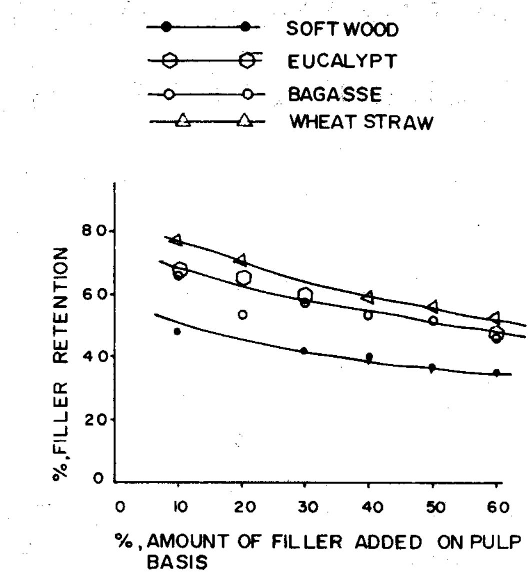

FIG.1. FILLER RETENTION IN THE HAND SHEETS PREPARED FROM VARIOUS PULPS.

to 1 μm get filtered out from the sheet. Few of such small particles however could get entrapped in the fibrillar network extending from fibres and also in their lumens as white water drains away during sheet formation. On the other hand wheat straw, bagasse and eucalypt pulps formed relatively a closer sheet matrix which enabled them to retain higher amount of filler. Secondly these pulps had high amount of fines which could co-floculate with the filler to form bigger particles thus helping in better retention.

EFFECT ON THE PAPER PROPERTIES DUE TO INCREASED FILLER CONTENT

Apparent Density

Softwood and eucalypt pulps indicated continuous increase in the apparent density with the increase in filler content (Fig. 2). This may be due to the higher specific gravity of fillers. The specific gravity values for most of the fillers are in the range of 2.5 to 3 g/cm^3 which is relatively quite higher than that of cellulosic fibres which is around 1 g cm^3 (5). In the case of bagasse and wheat straw pulps after the initial increase upto the filler level of around 17 percent there was a slight drop in the density. This drop for these pulps at higher filler loading could be probably due to prevention of the

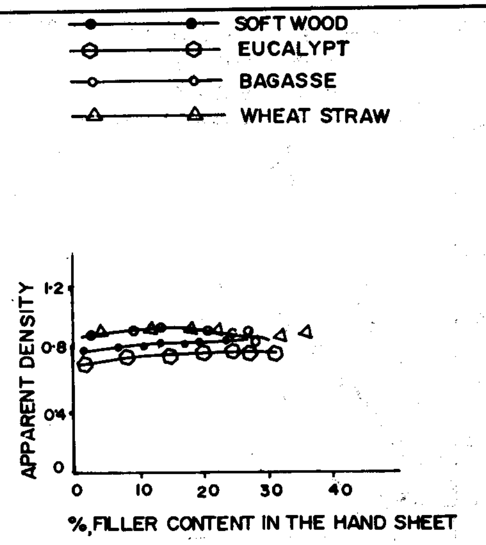

FIG.2, EFFECT OF FILLER LOADING ON APPARENT DENSITY OF DIFFERENT PULPS.

formation of fibre to fibre-bonds. The fibres become more stiffer & slightly increase the bulk. However it needs investigations.

TENSILE STRENGTH

Tensile strength is one of the most important properties in papermaking. The behaviour of different pulps with increase in the filler content is shown in Fig. 3.

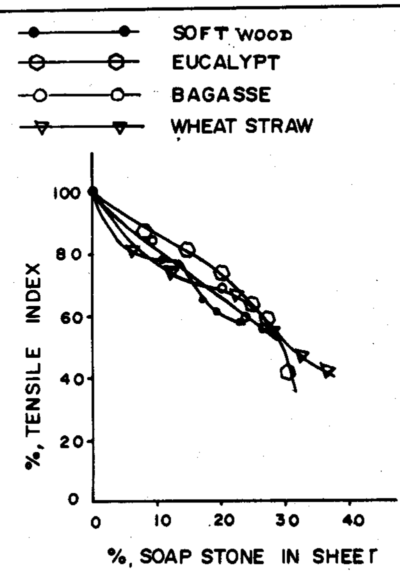

FIG.3, EFFECT OF FILLER LOADING ON THE TENSILE STRENGTH OF DIFFERENT PULPS. (TENSILE WITHOUT FILLER TAKEN AS 100% FOR EACH PULP)

Softwood pulp had shown a sharp drop in tensile strength when filler level was increased to 6%. Then onwards upto 14% filler level the drop was less pronounced and thereafter there was again a sharp drop. This could be probably due to the reason that at lower filler dose the filler try to settle between the contact area of fibres in the beginning and then it settles on other sites i.e. imperfections on the fibre walls. At the higher dosage however the filler gets diffused into the lumen of the fibres which causes sharp drop in tensile due to lowering in the collapse tendency resulting in lower degree of fibre bonding. The particle size distribution and the specific gravity are important characteristics of fillers for fibre bond interference (6, 7, 8).

Eucalypt pulp showed increasing drop in tensile strength with the increase in filler content. Bagasse pulp also showed regular drop, however, the rate of drop was more in the case of bagasse pulp as compared to eucalypt pulp. Wheat straw pulp showed very sharp drop upto the level of around 12.5% filler which dropped afterwards. Again beyond 22% filler level the drop became more pronounced. The continuous drop in tensile strength in short fibred pulps may be due to interference of the filler particles in the fibre bond formation.

At 15% filler level the percent drop in the tensile strength observed for softwood, eucalypt bagasse and wheat straw pulps was 25, 20, 28 and 30 percent respectively.

TEARING STRENGTH

Increase in the filler content in the paper made from all the four pulps caused continuous reduction in the tearing strength. (Fig. 4).

The drop was relatively lesser in the case of softwood pulp as compared to the other three pulps of eucalypt, bagasse and wheat straw which showed almost the same extent of drop. For softwood pulp the reduction in tearing strength was about 10% when 20% filler was added whereas for other pulps reduction to the extent of 15% was noticed. This drop in the tearing strength might be due to the

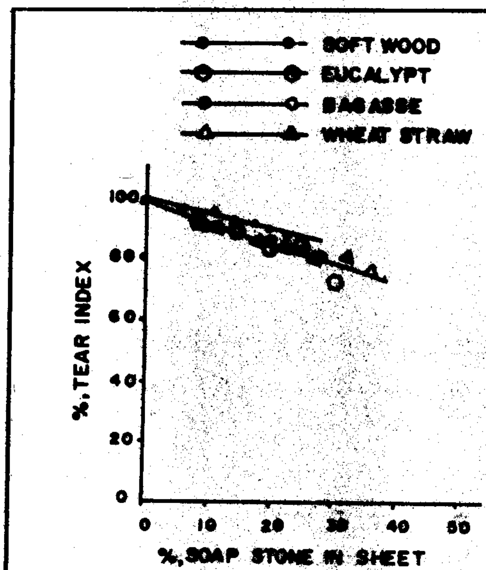

FIG.4, EFFECT OF FILLER LOADING ON THE TEARING STRENGTH OF DIFFERENT PULPS.
(TEAR WITHOUT FILLER TAKEN AS 100% FOR EACH PULP)

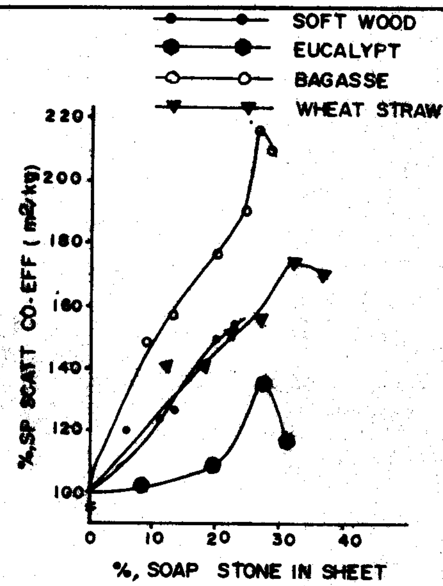

FIG.5, EFFECT OF FILLER LOADING ON THE SP. SCATT. CO EFF OF DIFFERENT PULPS. (SP. SC.CO-EFF WITHOUT FILLER TAKEN AS 100% FOR EACH PULP)

interference of filler particles with the bonding of fibres.

SCATTERING CO-EFFICIENT

This is an important property for printing grade papers as it affects opacity and hence print show through. The effect of filler on the Sp.Scatt. co-eff. of different pulps is shown in (fig.5)

The improvement in Sp.Scatt.co-eff. with increased filler content was highest in the case of bagasse pulps and least in the case of eucalypt pulp. As bagasse fibres have tendency to collapse more easily than eucalypt fibres the effect of filler in preventing fibre bonding and creating new fibre air interfaces becomes more apparent in the case of bagasse. The new interfaces increase the Sp. Scatt. co-eff. The improvement in the Sp.Scatt.co-eff. for softwood and wheat straw pulps was found to be in between the corresponding values for bagasse and eucalypt pulps. A drop in the Sp. Scatt. co-eff. was observed in all the pulps as the amount of filler increased beyond 28% level. This may be due to the fact that at higher filler level, more pigment to pigment interfaces are formed rather than pigment to fibre interfaces. The former interfaces have lesser ability to scatter light. At higher dosage levels the pigment particles may agglomerate which means more particle coming closer together and forming optical contact which will not scatter light and cause reduction in specific scattering coefficient.

IMPROVING THE FILLER RETENTION

The above findings indicated that increasing the soap stone (Talc) content had relatively more adverse effect on the paper properties of straw pulps than those of wood pulps. By changing the filler from talc to calcium carbonate it was observed that calcium carbonte was retained relatively more than talc (Fig. 6) even in the absence of retention aids. Relative improvement in the value of scattering coefficient due to addition of calcium carbonate was higher by 2-5 m^2/kg than talc (Table-I). Addition of either the cationic starch or the hydrocol (a dual type retention aid) improved the retention of filler appreciably, however, the effect was more pronounced in the case of hydrocol (Fig. 6). This higher retention is due to reduction in the anionic forces between fibres and filler particles. In water, cellulosic fibres and fines are negatively charged because of the ionization of the their carboxyl groups (9, 10, 11). The filler particles are also negatively

Table-I

Properties of Various Pulps in the Presence of Different Fillers and Retention Aids

Pulp with	Apparent density (g/cm³)	Tensile index (N.m/g)	Tear index (m.N.m²/g)	Sp.Scatt.co-eff. (m²/kg)	Ash (%)
		Wheat Straw			
Blank	0.46	46.0	7.25	42.4	2.7
$CaCO_3$	0.48	32.5	5.60	57.6	20.0
Talc	0.48	32.2	5.70	53.8	18.5
$CaCO_3$ + starch	0.49	26.5	4.90	62.7	26.8
$CaCO_3$ + hydrocol	0.45	27.5	5.80	65.2	27.8
Talc + starch	0.49	24.5	4.50	60.8	26.7
Talc + hydrocol	0.48	25.5	5.35	63.0	29.6
		Bagasse			
Blank	0.45	32.0	5.40	38.6	0.5
$CaCO_3$	0.47	26.5	4.95	52.7	13.8
Talc	0.48	22.0	4.80	49.7	15.3
$CaCO_3$ + starch	0.52	16.5	3.15	55.9	25.4
$CaCO_3$ + hydrocol	0.49	17.5	3.40	57.0	29.2
Talc + starch	0.51	13.5	2.80	50.0	23.1
Talc + hydrocol	0.48	15.5	3.15	50.3	26.2
		Eucalypt			
Blank	0.44	52.5	8.40	42.0	0.4
$CaCO_3$	0.46	37.5	5.50	48.4	11.4
Talc	0.41	35.0	5.05	47.7	10.4
$CaCO_3$ + starch	0.45	24.0	4.00	58.1	25.9
$CaCO_3$ + hydrocol	0.46	28.0	4.35	59.6	30.3
Talc + starch	0.47	21.0	4.15	56.5	24.3
Talc + hydrocol	0.45	23.5	3.75	56.9	28.5
		Softwood Pulp			
Blank	0.47	51.3	18.2	27.6	0.2
$CaCO_3$	0.48	48.0	17.8	35.0	7.5
Talc	0.48	47.0	17.6	33.7	6.7
$CaCO_3$ + starch	0.49	25.5	14.6	44.7	23.2
$CaCO_3$ + hydrocol	0.48	28.5	15.3	46.3	27.4
Talc + starch	0.48	18.5	12.5	43.4	22.4
Talc + hydrocol	0.48	26.6	14.9	44.7	23.7

charged. The negative charges present both on the fibres and the filler particles produce repulsive ionic forces which are stronger than attractive van der waal's forces thus preventing particles of similar charges coming together and coagulating. With the addition of either cationic starch or hydrocol the anionic repulsive forces amongst fibre and filler get neutralized. The additives introduce counter ions (i.e. cations) which break the electrical double layer on the surface of fibres, fines and fillers, and cause better retention.

For all the studied pulps the drop in strength properties tensile strength and tearing strength was lesser when filler was used alongwith hydrocol as retention aid than cationic starch. Calcium carbonate as filler caused lesser drop in strength properties than talc. The Sp.Scatt. co-eff. improved appreciably when calcium carbonate alongwith hydrocol was used. The increase was more than that observed for talc. This indicated that improvement in opacity of these pulps could be expected appreciably when $CaCO_3$ alongwith hydrocol is used as retention aid.

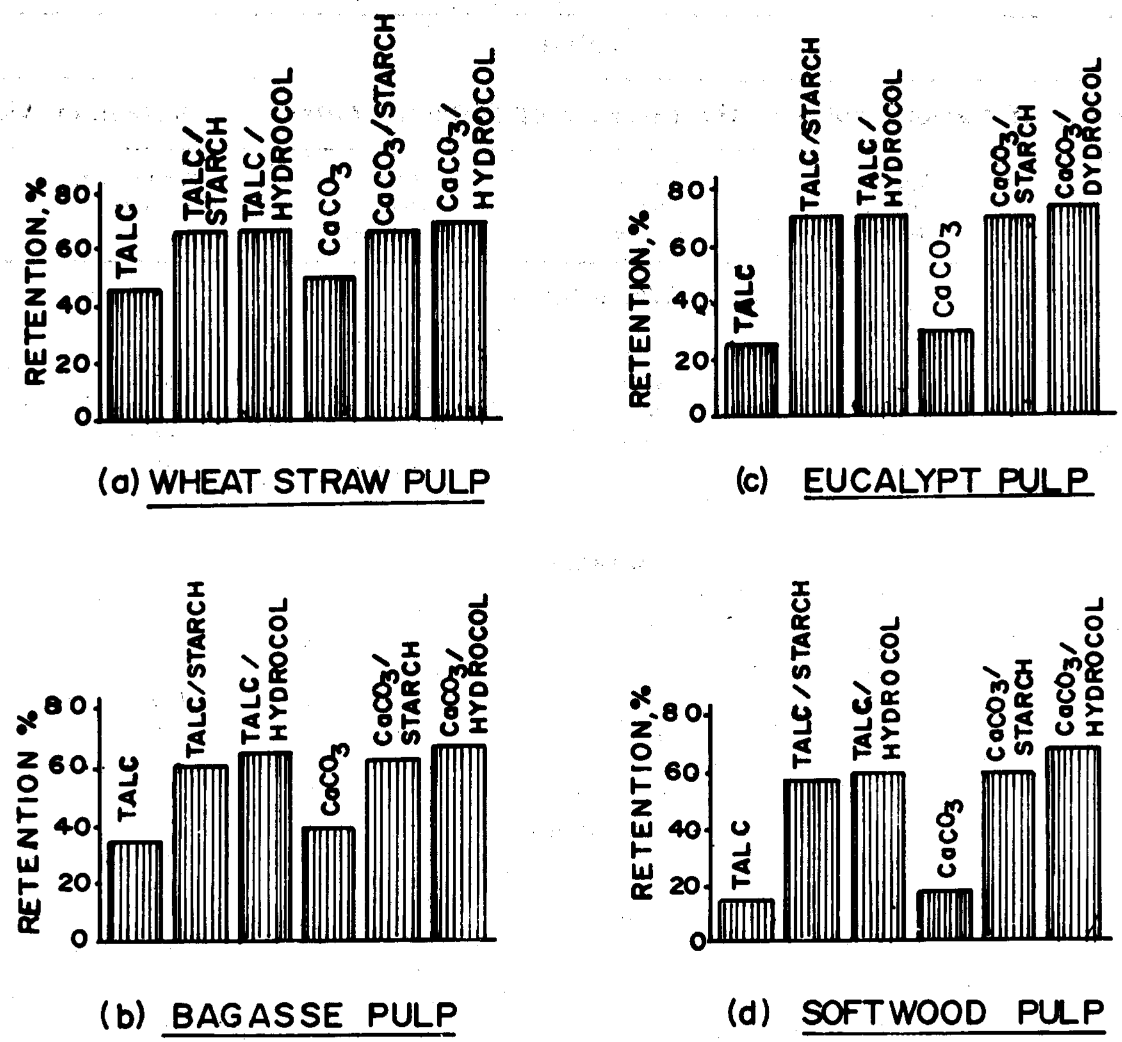

FIG. 6, FILLER RETENTION IN (a) WHEAT STRAW (b) BAGASSE (c) EUCALYPT (d) SOFT WOOD PULPS WITH & WITHOUT RETENTION AIDS.

EXPERIMENTAL

Pulps used

Hypo bleached soda cooked wheat straw pulp
Hypo bleached soda cooked bagasse pulp
Bleached eucalypt kraft pulp
Bleached softwood kraft pulp

The pulps were beaten in the PFI mill to freeness level of 350-400 CSF. Talc (Soap stone) or $CaCO_3$ were used as filler. The talc used was having brightness of 85% and 99% passing 300 mesh. $CaCO_3$ used was PCC type having brightness 95% and average particle size 1.6 micron. Cationic starch (1% on pulp basis) or dual component retention aid (Hydrocol) comprising of 0.2% hydrocol polymer percol 47 and 0.2% hydrocol pigment was used as retention aid. Handsheets were prepared using British sheet making machine having back water recirculation system. The retention of the filler was taken as the percentage retained in the handsheet of the amount added in the pulp stock (i.e. if ash content in the handsheet is 5% on o.d. basis and the filler added to the pulp stock was 10% on o.d. basis, the retention figures were taken as 50%).

Tests

Handsheets were conditioned at temperature 27 ± 1°C and 65 ± 5% relative humidity prior to testing.

Thickness	:	ISO R438
Tensile strength	:	ISO 1924
Tearing strength	:	ISO 1974
Ash content	:	ISO 2144
Brightness	:	ISO 2470
Sp. Scatt.co-eff.	:	SCAN C 27:69

CONCLUSIONS

- The present studies on laboratory scale revealed that in the absence of any retention aid, the amount of talc filler retained was highest for wheat straw pulp and lowest for softwood pulp. Eucalypt and bagasse pulps had comparable filler retention capability and it was higher than softwood pulp.

- With the increase in filler content, softwood and eucalypt pulps showed continuous increase in the apparent density. In the case of bagasse and wheat straw pulps after an increase upto certain filler level a slight drop was observed.

- At 15% filler level in the sheet the percent drop in the tensile strength observed for softwood, eucalypt, bagasse and wheat straw pulp was 25, 20, 28 and 30 percent respectively. With increase in filler content the relative drop in the tearing strength was lowest in the case of softwood pulp.

- The improvement in the Sp.Scatt. co-eff. with increased filler content was highest in the case of bagasse pulp and least in the case of eucalypt pulp. The effect on the improvement of Sp.Scatt. co-eff. for softwood and wheat straw pulps was somewhere between bagasse and eucalypt pulps.

- Calcium carbonate as filler had relatively better retention than talc. Addition of either cationic starch or hydrocol (a dual type retention aid) improved the retention of filler. The improvement was more pronounced in the case of hydrocol which caused comparatively lesser drop in the strength properties and improved better the Sp.Scatt. co-efficient.

- These studies which were mainly aimed at understanding the behaviour of agricultural residues pulps when filler loading was increased. As per normal expectations the strength properties dropped, however, with the use of suitable additives like dual type retention aids it could be possible to retain the strength properties even at increased levels of filler loading. More studies are however needed & being pursued by the authors.

RECOMMENDATIONS

There is a good scope to increase the filler loading in cultural papers. Even 1% increased loading may save about 2 to 2.5% cellulosic raw material or financially a saving of about rupees 20 to 25 lakhs per annum for a mill producing 50 tonnes paper per day. The filler loading should however be optimized using the actual pulp furnish and proper retention aid.

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