Effect of Cationic Starch and Long Fibered Bamboo Pulp on The Double Fold of Recycled Bagasse Paper

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ABSTRACT

The various qualities of the papers possess the different types of strength properties as per their end use. The double fold is an important property of the paper, which is very important for currency, bond and legal document papers. The bleached bagasse pulp was used by adding strength improving chemicals to develop the surface as well as the other strength properties of the paper sheet on the basis of blending of long fibered pulp into the furnish. To attain the optimized strength properties of the paper produced for the specific use, the blending of long fibered pulp and the addition of strength improving chemicals was carried out on the stoichiometric basis in the furnish for paper making. The bleached bagasse pulp was used for this study. Bagasse is abundantly available in northern India as the waste product from the sugar mills. In this work the improvement in double folds of the recycled bagasse based paper was studied at various beating degree of the pulp samples by the addition of strength improving chemicals like cationic starch, retention aids along with the blending of long fibered bleached bamboo pulp, to produce paper of different strengths for the desired quality**.** So that a paper maker can select the various parameters of paper making of his own choice to make paper of desired quality on economic basis by adjusting breaking even point of process so that the process may consume minimum time, energy and other inputs. This work is based on multiple studies on different parameters, as no such data was available in this field till date.

INTRODUCTION

The time has come when the recycling of agri- residue based paper is playing the most important role to meet out the future demand of the paper to protect the forest cover and ecological balance. In addition to pursuing the ecological balance and saving of raw material, the reduction of power requirement per ton of paper produced is another advantage. In addition to this the utilization waste paper and bagasse from the sugar mills, have become the essential part of waste management for the society and industries. The major limitation for the use of recycled fiber as the raw material for paper production is that recycled fibers have lower strength due to hornification and higher drainage resistance than virgin fibers [**8**].

The paper industry has turned to fast growing wood species, alternative non-wood fibers and the use of secondary fiber for paper production for the sake of fast depletion of forest resources and its impact on ecological balance. The selection of best fibrous raw material which will be available on sustained basis appears to be of prime importance and further, the quality of end product will largely dependent on the type of fiber and their blends in making the stock [**5**]. The agri-residues and secondary recycled fibers seem to be the promising raw materials of the future.

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While looking for increased utilization of recycled fiber, there are technical bottlenecks limiting its use [**4**]. Most important of them are being the reduction in strength and other desirable properties of fiber during recycling **[1]**. Recycling of chemical pulps made from agri-residues is very limited due to short fiber and low strengths and requires the effective retention aids for improved properties of paper [**7**]. Very little information is available on the characteristics of recycled agri-residue pulps **[3]**. More efforts have not been made to improve the characteristics of the recycled pulp [**2**]. But more pulp will be produced from agri-residue, which needs to be recycled for economic and environment reasons. Therefore an attempt has been made to study the recycling of agri-residue pulps for their characteristics and to explore the possibility of improving its properties by the addition of cationic starch [**6**]. The objectives of the present work are to study the effect on the folding endurance of paper prepared from the agri-reside pulp (bagasse) and improvement in double folds of recycled paper.

Experimental

The bleached bagasse commercial pulp was used in the present study. The pulp was collected from a large integrated paper mill. The bagasse pulp was produced in continuous digester and bleaching sequences CD - EOD were used. The long fiber bamboo pulp was used for blending with the bagasse pulp. The rest experimental procedure has been published in journal *Inpaper India 10 (4) 22 (2007).*

Study of recycling of bleached bagasse paper sheet at different CSF by adding fortified rosin size 1.2%, Ecorite PAC 2014, soap stone filler 15% and retention aids N*(N7607 and N7530) in presence of cationic starch

For the study of strength improvement in paper, the cationic starch of different doses was added while making the standard paper sheet for different CSF pulp samples. The standard paper sheets of 60 g/m^2 basis weight were prepared by adding 1.2% fortified rosin size and ecorite PAC 2014 to control the pH of the pulp admixture at 5.0±0.5. The soap stone filler was also added. The quantity of soap stone filler added was 15% of the quantity of oven - dried pulp.

The cationic starch in the standard paper sheet was added in different doses to observe the effect in folding endurance and the strength development in the standard paper sheet. The cationic starch added was 0.5%, 0.7%, and 1.0% of the total quantity of the oven-dried pulp. For maintaining the good retention of

chemicals in the paper sheet, the retention aids chemicals N* [N-7607 (0.1%) coagulant and N7530 (0.25%) flocculent] were added in the admixture.

Effect on double folds of paper due to blending of fresh bleached bagasse with bamboo pulp using varying doses of cationic starch T25.

The experiments were performed to study the effects of cationic starch on the double fold of paper. Initially bagasse pulp was blended with fresh bleached bamboo pulp in varying proportions and cooked cationic starch was added in the admixture. Then coagulant N-7607 was added and 15 seconds were provided for the reaction to take place. After this flocculent N-7530 was added and again 15 seconds were provided for reaction to take place. The standard paper sheets were prepared and strength properties were evaluated. The paper sheets were tested for strength properties in terms of the double fold of the paper.

Study of recycling of paper sheet made from bleached bagasse pulp

The standard paper sheet prepared from the bleached bagasse pulp was recycled five times. The double fold of paper sheet was measured after each recycle and the results are plotted in **Fig.1**. Normally the double fold of the paper sample improved up to the 310 CSF in this case, but if the degree of polymerization of the bagasse pulp is less, then it may start decreasing prior the CSF value mentioned above, because when the sugar mill starts in the beginning of the season, the sugar cane supplied to the mills may have immature grown sugar cane along with low sugar content. The bagasse prepared from such sugar cane may contain the short fibers with low degree of polymerization. It is observed that the double folds of paper sheet increases with a decrease in CSF up to a certain limit, afterward it starts decreasing. This is due to the fact that the specific surface area of the bagasse fiber increases due to the beating action on the fiber. The increase in surface area due to beating action on the fiber leads to the strong bond formation among fibers resulting in an increase in double folds of the paper sample. It can be noticed that the maximum loss in double folds was noticed in case of first recycled stage. The much loss in double fold is due to the hornification of the fibers, which takes place due to drying and aging effect on paper sheet in the initial stage**.** The loss in double folds from second to 5th recycled paper sheet is gradual. The gradual decrease in double folds indicates a gradual decrease in folding endurance of the paper sample and it can be maintained by the addition of strength improving chemicals, retention aids and by blending with long fibered pulp. In this case the bleached bamboo pulp was used for blending as a long fibered pulp with the bagasse pulp.

Fig.1 shows that at high CSF the reduction in double folds of paper sheet is less as compared to low CSF. This higher reduction occurs due to the hornification of the fiber in drying process at the initial stage which leads to low bonding capacity at low CSF and moderate bonding at high CSF **[8]**. At low CSF, the fibers are well beaten having greater specific surface area and the pulp contain more fibrillated fibers having good water retention value. When the paper sheet is made for first recycled stage, loss in folding endurance is more due to the moderate bonding of well-beaten and fibrillated stock. The only loss occurred in this case is due to the reduction in intrinsic strength and microcreeping of the fibers. This loss can be recovered by blending with beaten long fibered pulp. For the study of folding endurance of

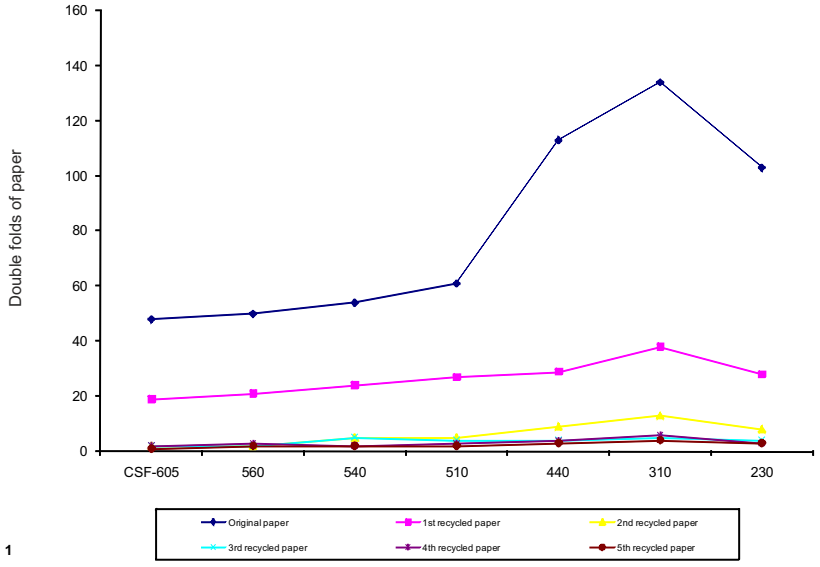

Fig. 1

Figure 1 - Double folds of pure bleached bagasse paper sheet at various CSF for different recycled stages

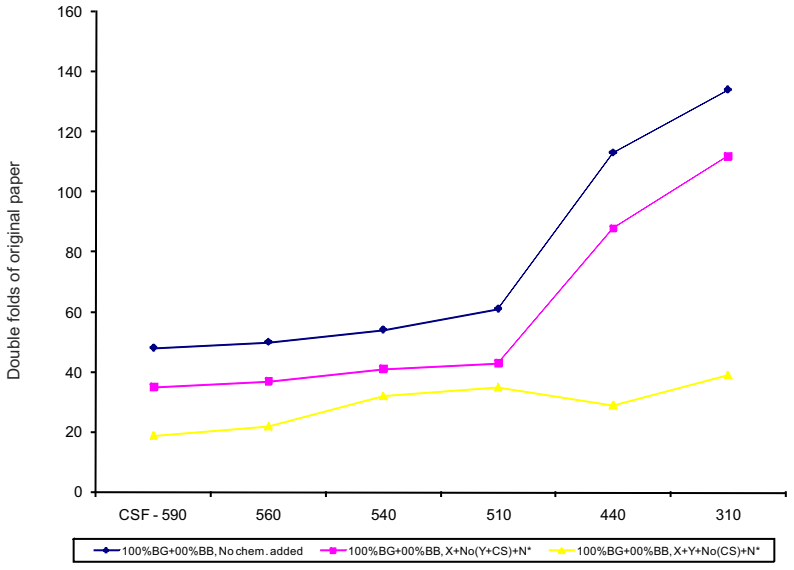

Fig. 2

Figure 2 - Double folds vs. CSF of original paper prepared by pure bleached baggase pulp with the addition of sizing chemicals, soap stone filler and varying doses of cationic starch and retention aids (N*).

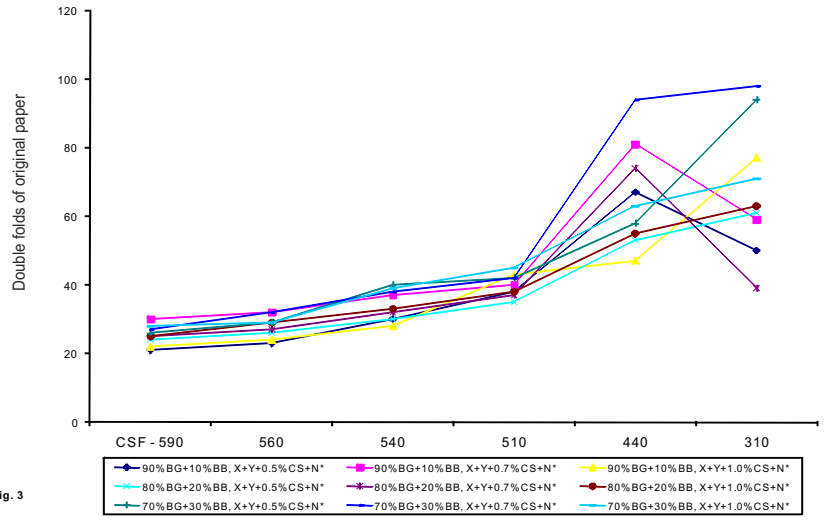

Fig. 3

Figure 3 - Double folds vs. CSF of original paper prepared by blending of bleached bamboo pulp with bleached bagasse pulp with addition of sizing chemicals, soap stone filler, varying doses of cationic starch and retention aids (N*).

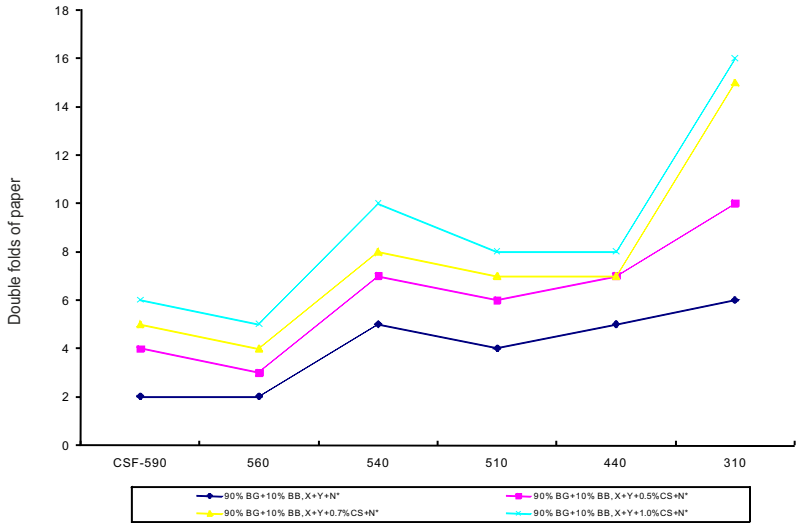

Fig. 4

Figure 4 - Double folds vs. CSF of 1st recycled paper prepared by blending of bleached bamboo pulp with bagasse pulp with addition of sizing chemicals, soap stone filler, & varying doses of cationic starch & retention aids (N*).

different beaten pulp samples contained in different containers having different CSF of pulps like 605, 560, 540, 510, 440, 310 and 230 ml CSF, the standard paper sheets were tested after conditioning them at standard temperature and humidity. The seven varieties of standard paper sheets were made of each sample of beaten pulp separately (e.g. at 605 CSF). The first variety of paper sheet was made by pure bleached bagasse pulp without adding any chemical in the paper sheet. The second variety was made by pure bagasse pulp by adding fortified rosin size, poly-aluminum chloride (PAC) and retention aids N*, like (100% BG, X + N*). The third variety of the standard paper sheet was prepared by pure bagasse pulp adding fortified rosin size, poly aluminum chloride (X), soap stone filler (Y), and retention aids N*, like (100% BG, X+Y +N*) **Fig 2**. The fourth verity of standard paper sheet was prepared by 90 % bagasse pulp and blending of 10% bleached bamboo pulp, adding fortified rosin size, PAC2014, soap stone filler and retention aids N*in it, like (90% BG + 10% BB, X + Y + N*). The fifth variety of standard paper sheets were prepared by 90 % bleached bagasse pulp and 10% bleached bamboo pulp by adding fortified rosin size, PAC-2014, soap stone filler and 0.5% cationic starch and retention aids N*, the brief composition of the paper sheet may be written as (90% BG + 10% BB, X + Y + 0.5% CS+ N*). The sixth variety of standard paper sheets were prepared from 90% bleached bagasse pulp and 10% bleached bamboo pulp by adding fortified rosin size, PAC- 2014, soap stone filler and 0.7% cationic starch and retention aids N*. The composition of sheets may be written as (90% BG + 10% BB, X + Y + 0.7% CS + N*). The seventh veriey of paper sheets were prepared by 90% bleached bagasse and 10% bleached bamboo by adding fortified rosin size, PAC 2014, soap stone filler and 1.0% cationic starch and retention aids N*. Its paper sheets composition may be written as (90% BG + 10% BB, X + Y + 1.0% CS + N*). The composition of the standard paper sheets are the same at different CSF like 605, 560, 540, 510, 440 and 310 as given in the **Fig. 3**. Similarly the blending of long fibered bamboo pulp was increased to 20% on oven dry basis of pulp. The fiber composition in the stock has become 80% bagasse and 20% bamboo pulp i.e. (80% BG + 20% BB) and the standard paper sheets were prepared on the similar pattern changing the dose of cationic starch as 0.5%, 0.7% and 1.0%. Moreover the blending of long fibered bamboo pulp was increased on the oven dry basis of pulp to 30%, and the stock composition of bagasse and bamboo pulp may be written as (70% BG + 30% BB). The standard paper sheets were prepared on the similar pattern by varying the doses of cationic starch as 0.5%, 0.7%, and 1.0%. The double folds of the standard paper sheets were tested and results are tabulated in **Fig.3.** The graph represents that the average folding endurance in terms double folds of standard paper sheets as per the paper sheet composition given in the legend at the bottom side of the graph in **Fig. 3**. It was observed that the maximum double fold i.e. 98 was achieved at 310 ml CSF with pulp composition (70% BG + 30% BB, X + Y + 0.7% CS + N*) of the pure bleached bagasse pulp. The folding endurance was observed on decreasing trend after the 310 ml CSF.

First recycling of paper sheet:

The standard paper sheets were recycled for first time after providing 20 days aging effect. The folding endurance of paper decreases in the first recycle stage by the addition of fortified rosin size and poly-aluminum chloride and retention aids to 6, which indicate that the folding endurance decreases significantly by the addition of rosin size and alum contents. It is also observed that the maximum folding endurance was obtained 16, which is achieved by the addition of 1.0% cationic starch content with the blending of 10% bleached bamboo pulp at 310 ml CSF (**Fig.4**).

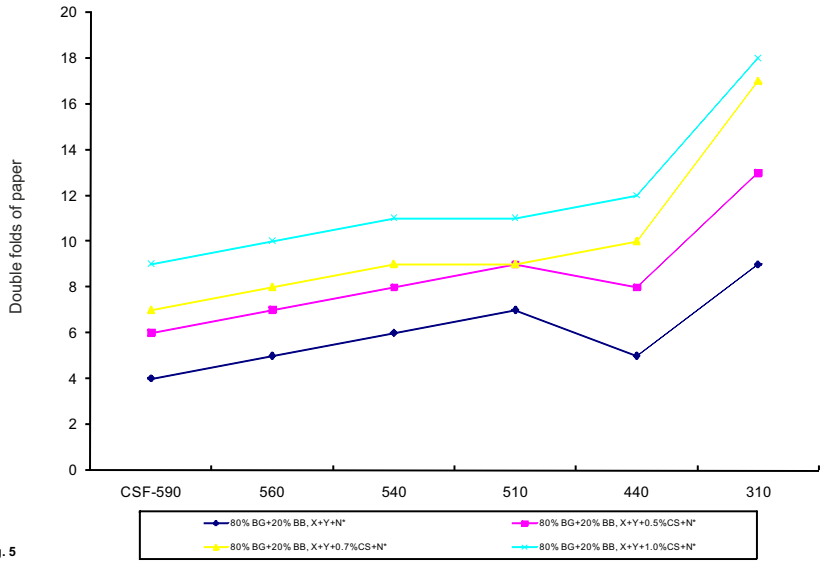

Fig. 5

Figure 5 - Double folds vs. CSF of 1st recycled paper prepared by blending of bleached bamboo pulp with bleached bagasse pulp with addition of sizing chemicals, soapstone filler & varying doses of cationic starch & retention aids (N*)

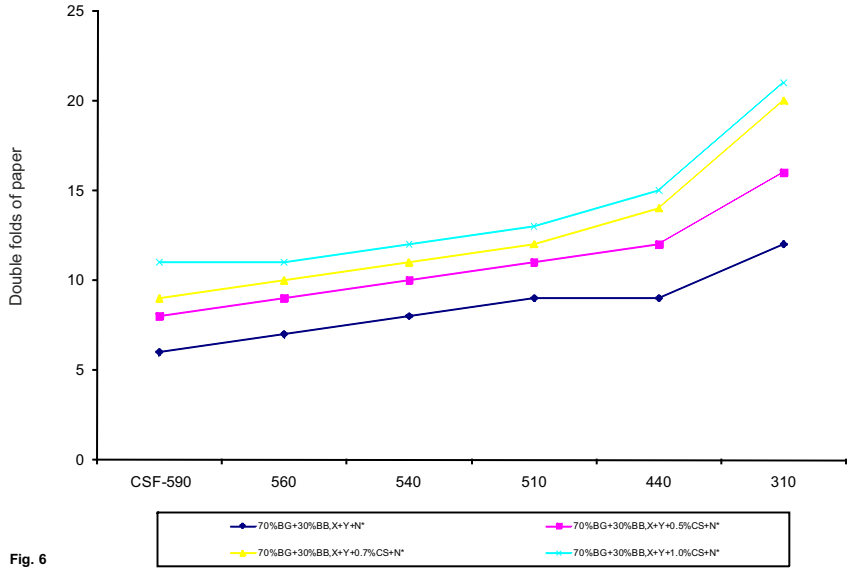

Fig. 6

Figure 6 - Double folds vs. CSF of first recycled paper sheet prepared from blending of bleached bamboo pulp with bagasse pulp in various ratios with addition of cationic starch in varying doses and retention aids (N*).

Experiments were conducted by blending of bamboo pulp with bleached bagasse pulp. The effect of blending of bamboo pulp with bleached bagasse pulp and addition of fortified rosin size, poly aluminium chloride 2014 and retention aids on the folding endurance of paper sheet are shown in **Fig.4**.

The reduction in folding endurance of the paper sheet occurred due to the mixing of fortified rosin size and poly-aluminum chloride 2014. The further reduction in folding endurance occurred by addition of 15% soapstone filler but blending with long fiber bamboo pulp and retention aids prevented further loss in folding endurance. **Fig.4** shows that with the addition of 1.0% cationic starch in the standard sheet, improvement in folding endurance was observed up to appreciable extent. Improvement in the folding endurance was observed with an increase in blending of the bamboo pulp 10%, and the improvement in folding endurance was observed from 5 to 10 at 540 ml CSF. The results of the folding endurance of standard paper sheets are given in **Fig. 4. Fig. 5** depicts the effect of rosin size, PAC, and the effect of bleached bamboo pulp blending along with varying the doses of cationic starch. It was also observed that maximum double folds of the paper (i.e.18) was achieved at 310 CSF with 20% bamboo pulp blending along with 1.0% cationic starch dosing. The increase in double folds was observed due to increase in bamboo pulp blending on increasing the proportions i.e. from 10 to 20 %. This increases the folding endurance about 12.5 %, which shows that the blending of bleached pulp is helpful in achieving good strength development in folding endurance of paper sheets. When 20% blending of long fibered bamboo pulp was carried out, a 12.5% increase in folding endurance was observed from 16 to 18 at 310 CSF with 1.0 % addition of cationic starch dosing (**Fig.4 and Fig. 5**). The 20% blending of bleached bagasse pulp on O.D. basis has improved the folding endurance from 10 to 11 with the use of 1.0% cationic starch at 540 CSF along with retention aids, which indicate that bonding of long fibered pulp is much effective in case of some strength improving chemicals like cationic starch. The cationic starch was used along with the mixture of long and short fibered pulp, where the bagasse pulp is an agri-residue pulp and bamboo is the long fibered agri-residue pulp, which has imparted significant increase in double folds of paper (**Fig. 6)** at 310 and 540 CSF. These results indicate that further beating is not beneficial as per the study of results of the double folds of the paper. This decrease has been recovered by the addition of 1.0% cationic starch and 30% long fibered bamboo pulp in the stock. It was observed from **Fig. 6** that when blending of bleached bamboo pulp was carried out up to the level of 30 % along with 1.0 % cationic starch dosing, maximum folding endurance was obtained 21 at 310 ml CSF, which is 31.3 % more strength development than that the value given in **Fig. 4** (folding endurance 16). So this increase in folding endurance is helpful in making specialty paper of desired strength for specific purpose.

The blending of 30% long fibered bamboo pulp and 1.0% cationic starch resulted the increase in folding endurance up to 16 from 21. This improvement was only possible by use of cationic starch and 10% to 30% blending of beaten long fibered bleached bamboo pulp as per the **Fig. 4 and Fig. 6.**

Second Recycled of paper

The double folds of the paper sheet was found very low after first recycle as in

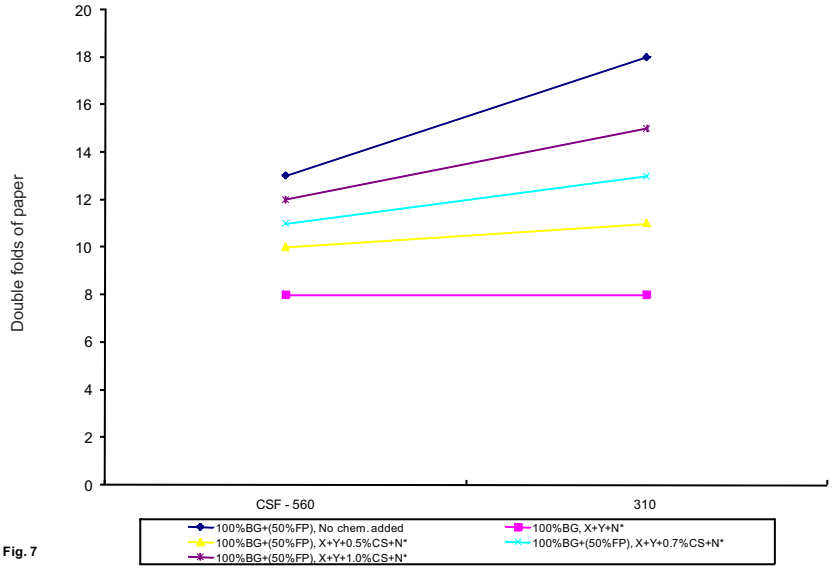

Fig. 7

Figure 7 - Double folds vs. CSF of 2nd recycled paper prepared by blending of bleached bamboo pulp in bleached bagasse pulp by adding fresh pulp, sizing chemicals, soap stone filler, varying doses of cationic starch & retention aids (N*).

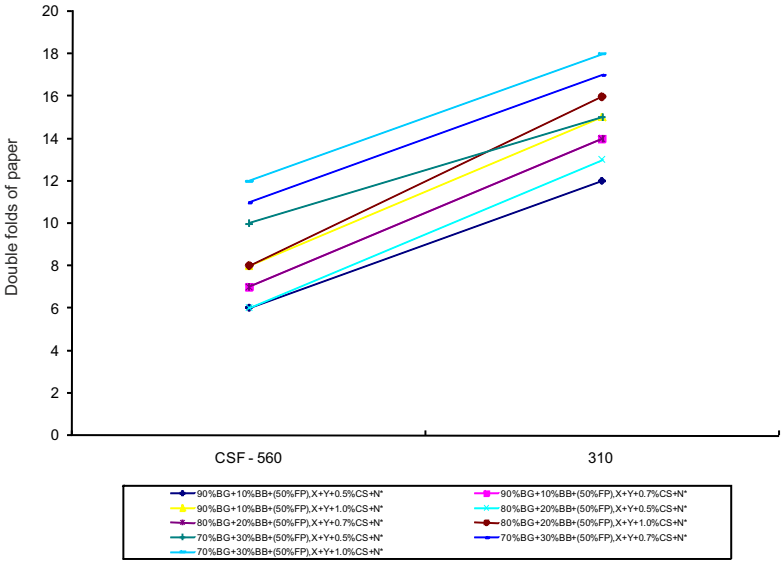

Fig. 8

Figure 8 - Double folds vs. CSF of 2nd recycled paper prepared by blending of bleached bamboo pulp in bleached bagasse pulp by adding 50% fresh pulp, sizing chemicals, soap stone filler, varying doses of cationic starch & retention aids (N*).

the re-slushing process of first recycled paper, there was more wear and tear of the fibers in disintegration stage. This was due to the fact that starch creates hydrophobic characteristics in paper sheet in dried condition, which was possessing considerable wet strength**.** The wet strength nature of the paper sheet requires considerably more soaking time in water and mechanical treatment in the process for converting the paper sheet into pulp slurry and also consume more electric power and results weakening of intrinsic strength of pulp fiber. Therefore, 50 % fresh pulp (A mixture of 70 % bagasse pulp and 30 % bamboo pulp) on oven dried basis was mixed with 50 % first stage recycled pulp (for all the four different sheets) for making second recycled paper sheet. There were four paper samples after second recycle stage with following compositions:

1. Pure bagasse pulp + 50 % fresh pulp
2. Bagasse pulp with 10 % bamboo pulp + 50 % fresh pulp
3. Bagasse pulp with 20 % bamboo pulp + 50 % fresh pulp
4. Bagasse pulp with 30 % bamboo pulp + 50 % fresh pulp

Results of second recycled papers prepared from these papers are mentioned in **Fig. 7** and **Fig. 8**. In this case of second recycled paper sheets were made from papers of first recycled papers. The strength of paper sheet was decreased significantly. So to improve the folding endurance of the second recycled paper sheet 50% fresh pulp was blended to improve the strength and surface properties of paper in each case. It was observed that the previous papers having pure bleached bagasse pulp with 50% fresh pulp and 1.0% cationic starch fibers attained maximum folding endurance 15 at 310 ml CSF **Fig. 7**, which is good enough for writing or specialty paper. Second recycled papers having 10% bleached bamboo pulp, blended with 50% fresh pulp and 1.0% cationic starch dosing, possesses maximum double folds 12 at 560 CSF as shown in **Fig. 8**. Double folds of second recycled paper was observed 8 at 560 CSF. The stock containing 20% bleached bamboo pulp blended with 80% bagasse pulp and 1.0% cationic starch dosing (**Fig. 8)**, which results the 20% more double folds when the blending of bleached bamboo pulp was increased to 30% with 1.0% cationic starch dosing, maximum double folds 18 at 310 ml CSF was observed which is 12.7% more than previous result (i.e. 15) as shown in **Fig. 7**. From observation of the above results, it can be concluded that good strength-full recycled bagasse paper can be prepared many times by blending of the long fibered bleached bamboo pulp in the agri-residue pulp (bagasse pulp) which is a fast growing specie by adding strength improving chemical like cationic starch.

In the case of second recycle of paper it was observed that improvement in the double folds was not much as per the desired extent. For improvement in the double folds 50% fresh pulp was blended at the time of second recycled paper sheet making. This mixture of fresh pulp contains 70% fresh bagasse pulp and 30% fresh bleached bamboo pulp in it. In case of second recycle stage, paper sheet results the folding endurance 15 as given in **Fig. 8**, which has been improved by addition of 1.0% cationic starch, and 10% blending of bamboo pulp. Folding endurance could be increased up to 15 (**Fig. 8)**. For further improvement in folding endurance 1.0% cationic starch and 20% long fiber pulp was blended and enhancement in the folding endurance

was observed 16 and 18 with the use of 1.0% cationic starch and 30% long fibered bamboo pulp blending as mentioned in the **Fig. 8**. From the study of **Fig. 1** to **Fig. 8** of recycling of agri-residue bagasse pulp, it can be concluded that bagasse based recycled paper can be recycled many times using strength improving chemicals and blending of long fibered pulps for making various grades of specialty papers for specific use in daily life. The folding endurance of the bagasse pulp may be achieved in optimized range by study of various beating degree i.e. from 560 to 310 CSF range for getting significant double folds of paper sheet.

Improvement in the strength properties concludes that bagasse pulp can be recycled many times by mixing of long fibered pulp and strength improving chemicals prior to paper sheet making.

CONCLUSIONS

For manufacturing of paper sheet, fortified rosin size and poly aluminum chloride were used, but these chemicals also reduced the strength properties of paper produced. More reduction in strength properties occurs due to addition of inorganic chemicals like soap stone filler which provide surface smoothness, glaze and ink receptivity in the paper sheet**.** In addition to the above-mentioned effects some loss in strength properties occurs due to aging and fungus decay of the paper, which spontaneously lowers strength properties of paper. Efforts were made in the present study to recover double folds of paper by adding strength improving chemical like cationic starch. Cationic starch adsorbs on the large surface area of fiber fines, improving retention of fillers and fiber fines in the paper sheet and it also improves consolidation of wet web on wire part of the British sheet former. To improve various strength properties of paper, some appropriate quantities of retention aids like coagulant and flocculent were also added at the time of standard paper sheet preparation.

The addition of above mentioned chemicals are effective up to a certain limit but for more improvement in double folds of paper sheet, it is necessary to add some quantity of long fibered pulp next to the first recycling stage. The long fibered chemical pulp like bleached bamboo pulp blending was carried out for improvement of double folds of paper**.**

The present study indicates that bagasse pulp possesses the significant potential of recycling of bagasse paper. It has been observed that long fibered pulp and cationic starch are beneficial in increasing the folding endurance of recycled paper sheet. The paper produced using cationic starch has high gloss and good surface properties. The recycling of bagasse paper sheet will be economical for the agri-residue based paper manufacturing mills. Moreover, use of bagasse as the raw material for paper making will help in conserving the ecological balance as bagasse pulp requires low bleaching chemicals compared to other raw materials. The cooking and bleaching chemicals are major pollutants of paper industry. Recycling of the bagasse paper reduces pollution load of the paper mills and will require low consumption of chemicals, water, electricity and manpower. Further, it will also reduce the transportation charges of raw material and crowdedness of transport vehicles on roads. Therefore it will not be wrong to say that recycling of the bagasse-based paper is eco-friendly.

(a) gsm (basis weight of paper) = (Weight of paper in grams having one square meter Area)

Nomenclature

X	Fortified rosin size and poly aluminium chloride
Y	Soap stone filler (SS)
CS	Cationic starch T-25
CSF	Canadian standard freeness
DF	Double folds of original paper
BG	Bleached bagasse pulp
FE	Folding endurance of paper sheet
BB	Long fiber pulp (Bleached bamboo pulp)
N*	Retention aids (Coagulant N-7607 and flocculent N-7530)
FP	Fresh Pulp (Mixture of 70% bleached bagasse and 30% bleached bamboo pulps)

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