Studies on the effect of recycling on fiber and paper properties

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ABSTRACT

Bleached kraft virgin pulp made from Bamboo, Hordwood and Softwood in the ratio 6:3 :1 by a mill is used for the present investigation with an aim to find the effect of recyciing of fiber on paper properties The pertinent properties studied were density, bulk, thickness, fiber length, strength properties like Tensile, burst, tear, double fold and optical properties like opacity and brightness. It is reflected that with the increase in recycle number the burst, tear double fold, density, fibre length and brightness decrease whereas Bulk and opacity increase Recycling upto 3 has been attempted. The above findings are in agreement with earlier studies.

1. Introduction :

Increasing use of Secondary fiber is being practised World over as a means of reducing demand on virgin fiber resources and improving environmental damage Greater use of waste paper results in lower specific energy usage, lower water and chemical demand, lower investment costs besides lesser dependence on forests and agricultural residues and reduced pollution load generation. Most of the studies on secondary fibers relate to deinking, fiber cleaning, problem of collection, sorting, processing and stickies problems. The impact of recycling on pulp and paper properties has not received the attention, it deserves. Secondary fibers loose many mechanical properties. The optical properties change depending on degree of recycle. Recyling leads to loss of flexibility, dacrease in bonding strength and capacity to become dimensionally stable in fibers Recycling leads to greater generation of fines. Therefore, it is inherent that after a certain degree of recycle to maintain a desirable pulp quality, a part of the secondary fiber must be taken out of circulation.

Recycling of waste paper and its impact on strength properties have been dealt by many workers (1—10). Bobalek etal (4) have discussed the effect of recycling on physical properties of specific fiber species and their net works. In a series of experiments on bleached sulphite pulps the effect of recycle number on different properties for selected species of fibers have been investigated. Under minimal refining, decrease in strength properties and constancy of optical properties of sheets is reported. Similar work has been reported by Horn (6), Konig (7), Klingness (8), McKee (9), Gudst etal (10) and Moore (11).

Present experimental investigations are aimed at finding the effect of number of recycles on a commercial fiber furnish from virgin fibers on different paper properties. This information will be helpful in deciding the degree of recycle of secondary fibre.

Experimental :

(a) Raw Material :

The raw material used in this study was unbeaten, bleached kraft pulp from a nearby paper mill, containing a mixture of 60% bamboo, 30% hardwood (Eucalyptus) and 10% softwood (Pine).

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(b) Beating :

The pulp was beaten in laboratory valley beater upto a freeness of 45° SR, achieved within 20 minutes This beaten pulp was subjected to British sheet former. Use of any sizing chemicals were purposely avoided. This was done to avoid the possible influence on shadowing effect of fibre characterisitics on the sheet.

(c) Sheet formation & testing :

10 sheets of 60 gsm were taken for testing mechanical and optical properties and the remaining sheets were disintegrated in laboratory disintegrator to form the feed stock for first recycle. The zero recycle can thus be referred as paper from virgin pulp. All the sheets, classified according to their recycle numbers are conditioned for various testings. All the test sheets were evaluated according to TAPPI Standards for Tensile, double fold, burst, tear, bulk, density and caliper.

(d) Bauer-McNett classification :

Apart of the virgin pulp were subjected to Bauer McNett classification and the weight retained in each stream of 14 min , 23 min, 48 mins., and 100 mins. were collected and weighed. The fibre lengths of the sample from each compartment were measured microscopically & then averaged as per TAPPI specification .

(e) Experiments for the recycles :

For first, second and the third recycle fibre beating in the vally beater is not done The pulp is obtained by dispensing the sheet from previous cycle in water The fibre size distribution of each recycle were done. In all cases, 60 gsm hardmade sheets were made for strength & optical properties measurement.

The experimental data on various strength and optical properties are shown in Table-1. Average fibre length of the fibres before and after recycle is also given therein. The variation of thickness is shown in Table-2.

3. Results & Discussions :

Based on the data obtained from the experiment graphs (1-4) are plotted for Tensile, Burst, Tear, double fold, opacity and brightness with recycle number as parameter. The results are given in Table-1-2 and graphs are interpreted in the following paragraphs.

3.1 Effect of recycle on physical properties :

The physical properties studies include density bulk thickness and average fiber length. The data is shown in tables 1 and 2. The fig. 1 shows the variation of these properties.

Table—1

Physical, Strength and Optical Properties of Paper with Recycle [12],

Sl. No.	Property	Recycle Number 0 (Virgin Pulp)	1	2	3
	Physical Properties				
1.	Density, g/cc	1.5	1.0	0.92	0.92
2.	Bulk, cc/g	0.66	1.0	1.08	1.08
3.	Av, Fibre length, mm	1.22	0.89	0.80	0.73
	Strength Properties				
4.	Burst, kg/cm²	24.4	11.5	10.6	10.4
5	Tear, kg/cm²	61	69	55	53
6.	Tensile kg/cm²	5.0	3.7	3.0	1.7
7.	Double fold	3.5	3.0	2·25	2.0
	Optical Properties				
8.	Opacity,%	88.4	92.4	92.5	93.4
9.	Brightness,%	70.5	69.3	66.7	52.7

Table—2

Variation In Thickness of Paper with Recycle[12]

Sl. No.	Thickness, mm X/o[3]			
	Recycle Number			
	0	1	2	3
1.	49 5/42 5	55/65/57.5	55/62.5/65	57.5/65/67.5
2.	35/40	62.5/60/60	65/67.5/65	62.5/65/60
3.	42.5/39	65/55/57.5	70/60/65	65/65/65
Average	41.4	60.8	63.9	63.6

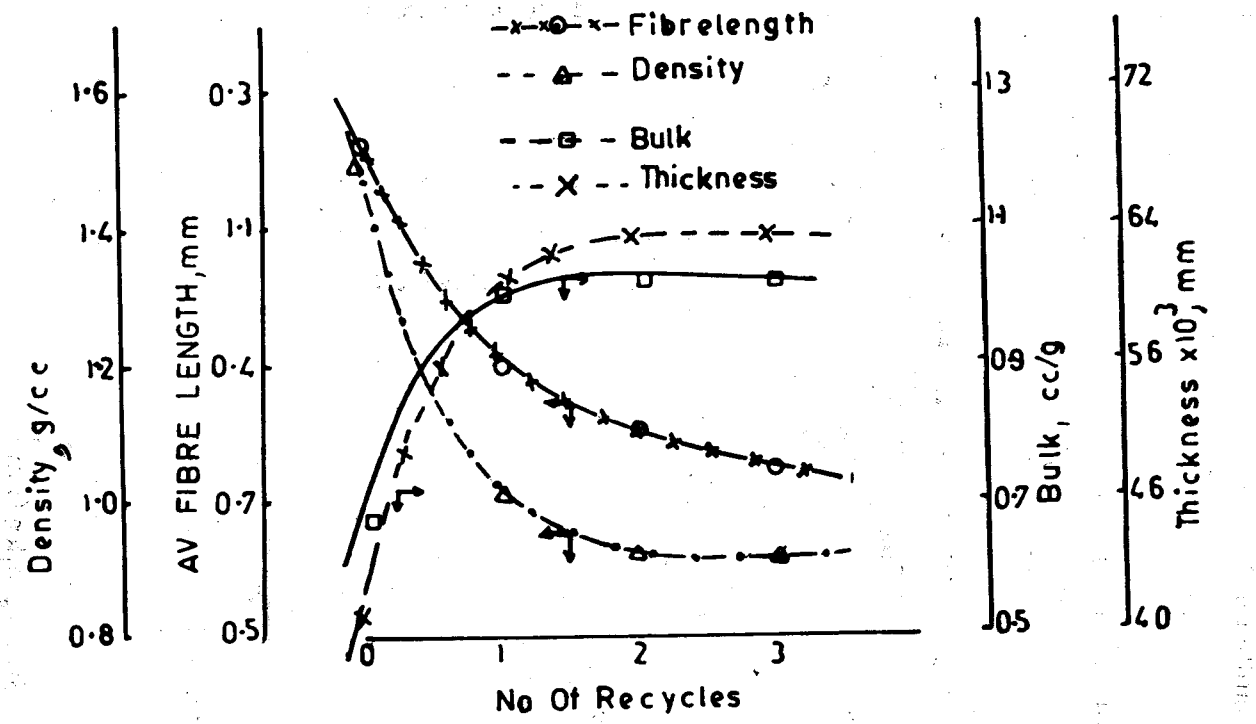

FIG 1 EFFECT OF NUMBER OF RECYCLES ON PHYSICAL PROPERTIES

It will be observed that with the increase in number of recycles, there is a gradual decrease of density and gradual increase of bulk. The changes are significant in first recycle while they are very marginal in subsequent recycles.

The consolidation of the sheet is affected with increase in recycle.

There is a slight variation in the average thickness of sheets ranging from 0.041 mm to 0.063 mm. However, majority of the values lie around 0.04 mm in zero recycle. The increase was sharp in first recycle and their after the variation is negligible. Most of the thickness values with recycle remained around 0.06-0 065 mm.

The average fiber length obtained from various fractions of Bauer Mc-Nett classifier shows a decrease with increase in recycle. The change is significant from 1.22 mm for virgin pulp sheets (zero recycle) to 0.73 mm in third recycle.

These data clearly indicate generation of more fines with increased degree of recycle. The result is shortened average fiber length. The decrease in fiber length and presence of more fines effects the sheet formation and consolidation. This trend correlates well the observed values of sheet density, bulk and thickness of other workers.

3.2 Effect of recycle on strength properties :

Fig. 2 shows the impact of recycle on different strength properties namely, tensile, tear, burst and double fold. The percentage change in the strength values over zero recycle (taken as reference value are shown in fig. 3.

The tensile strength and double fold decreases with increase in recycle number almost in a similar fashion. The percentage decrease is more in case of tensile strength than double fold.

The brust strength decrease sharply in first recycle to almost 50% value of the original (zero recycle) and thereafter the decrease is marginal with increase in number of recycles.

The tear strength on the other hand registers an increase in first recycle (by almost 15%) and then falls below the original in 2nd recycle and thereafter the decrease is marginal.

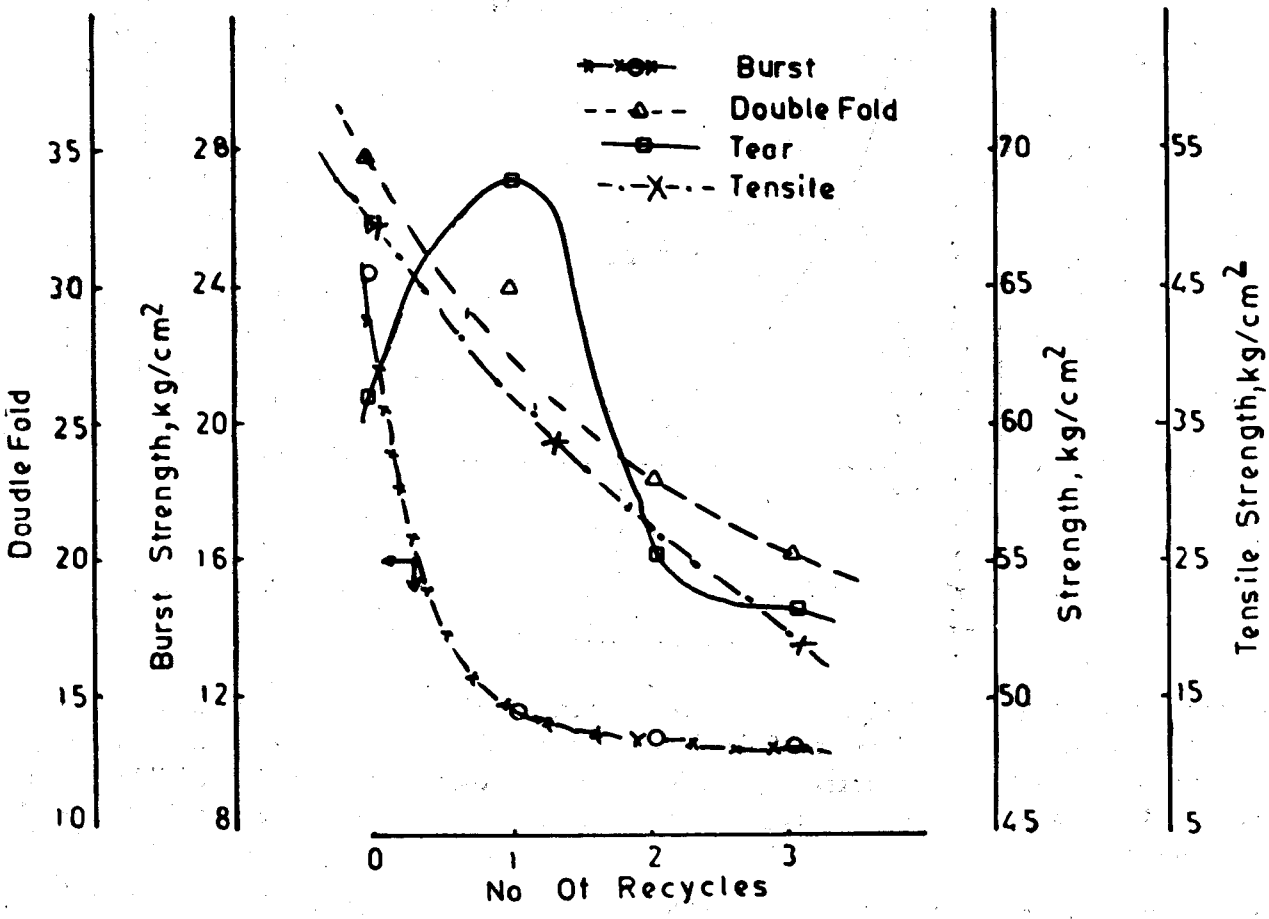

FIG. 2 EFFECT OF NUMBER OF RECYCLES ON STRENGTH PROPERTIES

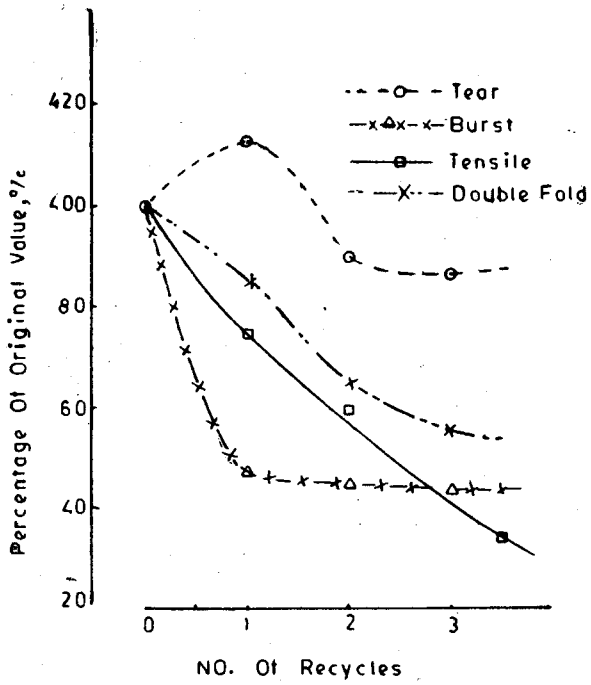

FIG. 3 : EFFECT OF NUMBER OF RECYCLE ON STRENGTH PROPERTIES

(EXPRESSED AS PERCENTAGE OF ORIGINAL VALUES)

In general it can be said that strength properties decrease with increase in recyle, sharply, at first recycle and marginally later except tear strength. This is an expected behaviour and is in confirmity with earlier findings of Horn[6] and Bobalek al[4]. With recycle the fines percentage increases and hemicelluloses decrease and this results in a decrease in bonding strength leading to decrease in strength properties. However in case of tear, the initial increase in value is due to the effect of drying on fibre stiffness. Such trend is reported in literature.

Clark[13] has shown the dependence of strength properties on mean fibre length (L) and specific volume (V) of the test sheets. The correlation are as under

Burst factor $= K_B \; L \; V^{-1.0}$

Breaking length $= K_P \; L^{0.5} \; V^{-1.0}$ beyond maximum

and Folding endurance $= K_F \; L^{5.0} \; V^{0.5}$

The effect of coarseness and intrinsic tensile strength is practically negligible. These correlations are essentially for virgin fibre papers. Thei validity is checked for recycled paper. The experimental and predicted valves of strength properties based on above correlations expressed as percentage of original value (zero recycle) are shown in Table—3.

Table indicates that there is a good match between the predicted and experimental values of burst; however, for double fold, tear and tensile (or breaking length) large deviations are observed. Therefore it can be concluded that the above formula except for burst, cannot be used for predicting the strength properties of paper from secondary fibre.

Table—3

Experimental And Predicted* Strength Properties

(Expressed as percentage of original zero recycle value)

Variable	PECENTAGE VALUE, % Recycle Number 0	1	2	3
Burst Factor				
Experimental	100	47	43	42
Predicted	100	48.1	40.07	36.57
Double Fold				
Experimental	100	85.7	64.3	57.1
Predicted	100	25.4	15.5	9.8
Tear Factor				
Experimental	100	113	90	86.9
Predicted	100	41.1	32.4	28.3
Tensile Strength				
Experimental	100	74	60	34
Predicted	100	56.4	49.5	47.3

*Predicted fro n Clark's Correlations.[13]

3.3 Effect of recycle on optical properties :

Fig. 4 reflects the impact of recycle on opacity and brightness of paper. Opacity is observed to increase with increase in recycle. The increase is almost linear initially tapering off to a constant value at later recycles. Brightness, however, decreased with increase in recycle, slowly at first and sharply later. These can be explained by the fact that with the increase in recycle, more fines are produced; fibres become more rigid and less flexible and less permeable, compared to virgin fibres. Relative magnitude of optical parameters (opacity) are negatively correlated to fiber length. Reverse will be true for brightness. These findings are however at variance with those of Bobalek[4].

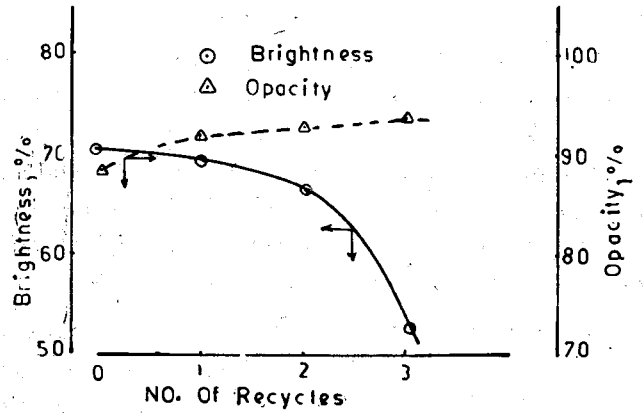

FIG. 4 EFFECT OF NUMBER OF RECYCLES ON OPTICAL PROPERTIES

4. CONCLUSIONS :

During repulping adverse changes occuring to fibres include loss of external fibrils leading to reduced fibre cohesiveness, a more tightly bound fibre structure hindering fibril formation. These make the fibres springy and lead to bulky sheet formation. The fibres tend to get shortended and stiff on repulping. The hemicelluloses get deploted on repulping The combined result is an over all decrease in fibre strength.

From the detailed analysis of the experimental data and its interpretation through graphs, the following conclusions can be made.

1. With increase of recycle, the burst, tensile, double fold decrease progressively with non-linear characteristics. Tear strength values however increases at first, reaches maximum at recycle and then decreases at first rapidly and then slowly.
2. The optical properties such as brightness and opacity behave oppositely i.e. with increase of recycle opacity increases where as brightness decreases.
3. With the increase of recycle, the density decreases while bulk increases, at first very fast and then levels off at higher recycle.
4. The average fibre length decreases with the increase of recycle.

The available correlations for virgin pulps for predicting relative strength properties based on fibre length and specific volume of sheet are not applicable to recycled fibres except for burst.

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