Studies on Effect of Recycling on Sheet Properties and Fibre Characteristics

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ABSTRACT:- To combat with the environmental pollution and also gradually depleting forest resources, the recovery of secondary fibers/ waste paper and its recycling as an alternative raw material in pulp and paper industry is increasing all over the world. With this in view, pulp and paper industry in the country is very much attracted towards the utilization of secondary fibers to substitute the conventional raw material to some extent and also to meet the demand of raw material partially.

The present communication concerned with the effect of repeated papermaking recycles has on the regeneration potentials in terms of sheet properties. The secondary fibers refined to the same degree of freeness exhibit lower fiber strength and bonding potentials than the same fiber in the virgin form. The loss in bonding potentials appear to overshadow the loss in fiber strength as they relate to sheet properties. The sheet properties, which are a direct function of fiber-to-fiber bonding and fiber strength decrease markedly with the number of times recycled. While on the other hand, those sheet properties like tearing strength show an improving trend with increase in number of times recycled at the same freeness level. Therefore, it is necessary to increase the proportion of long-fibered virgin pulp to improve the overall physical strength properties alongwith drainage characteristics of recycled fibers.

INTRODUCTION

Socio economic importance of paper and paper boards to a nation's development has its own values, as it is directly linked with the industrial and educational growth.

The Indian industry has met the various challanges by adopting itself to the changed conditions. The country has an installed capacity of about 2.8 million tonnes producing a large varieties of paper and paper board from varieties of raw materials, while the present level of production of paper and boards in our country is about 2.4 million tonnes with a capacity utilization of about 85% only. Considering the fact that the present per capita consumption of 3.2 kg has to increase, and considering the tremendous population growth, it is visualised by expert groups that by the end of this century, the requirement of paper and paper board would be in the range of 42.5 lakh tonnes of paper and 12.9 lakh

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tonnes of newsprint.

It is well known fact that the present forest resources can not meet the demand of fibrous raw material even for the existing units leaving aside the additional requirement for the future growth of Indian pulp and paper industry.

The forest based raw materials are in tremendous short supply and can not meet the projected paper capacities. The depleting forest cover and the thrust to conserve ecological balance will force the industry to look to alternative fibrous raw materials other than wood and bamboo. The alternatives available includes the use of primary fibrous raw material sources like nonwood fibers including agricultural residues or the secondary fiber sources like waste paper. The present policy of the Government of India is clearly aimed at increasing use of these nonconventional materials to reduce the pressure on forests. Better utilization of these primary & secondary sources of fibers can be made if they are blended with some long fibered material/ pulp.

Under the present stress and strain on land for agricultural production and utmost emphasis to conserve forests both for ecological reasons and to meet the basic fuel needs, continuous efforts are on for creation of sustained supply of wood through "man made forests, afforestation and social forestry" to which various agencies are working actively, but all these are long term projects and have a considerate gestation period. Therefore, the immediate focus of the industry is towards the use of recycled fibers, which has been extablished as a potential source of furnish for paper industry.

The waste paper utilization as a source of fiber supply offers tremendous potential. The recycling of waste paper in the manufacture of paper and paper board is of utmost importance when viewed from the angle of maintaining ecological balance. It helps in conservation of forests, land and waters. At a time when natural resources are getting deplete and the pulp and paper industry is threatened with the shortage of fibrous raw materials, not only in India, but throughout the globe, the subject attains a greater importance for the survival and growth of this particular industry. As a matter of fact many countries of the world use large quantities of waste paper to supplement their production. The figures range from 35-55% of the total fiber demand, while on the other hand, there are mills which work on even 100% waste paper.

The growing shortage of primary fibrous raw material and attractive fiscal incentives of the government have led to large usage of imported paper. The percentage of usage of waste paper is bound to increase in the comming years. The waste paper sources could be indigenous or imported, but from both the sources, the quality and quantity will remain uncertain. The collection of indigenous waste paper will pose enormous difficulties, as at present there is no organised method of collection of waste paper, except perhaps getting newsprint variety papers by door to door collection. The so called road sweepings represents a very poor secondary fiber source with lot of extraneous materials, similarly the imported waste paper unless properly sorted and packed, can cause a lot of difficulties in processing.

The demand for recycled fiber has grown twice as fast as the demand for virgin fiber worldwide (5.30% per year against 2.5% per year from 1970 to 1990). In Western Europe, the use of recycled fiber has grown four times as fast as the demand for virgin fiber. But the highest growth can be seen in Asia and Japan, where the consumption of waste paper increased at an avaerge rate of some 8.5% per year from 1970-1990[1].

In the gross sense, secondary fibers differs from virgin fibers in that secondary fibers have been through at least one paper making cycle. From a papermaking standpoint, we are concerned whether this exposure to at least one papermaking cycle has so changed the characteristics of the fibers that the properties of the sheet made with the repulped fibers are significantly different from the virgin sheet properties.

The fibers, which are the structural element in a sheet, are held together by means of molecular forces. In order for these forces to be effective in bonding, the fibers must be brought very close to one another. Thus, it is important that the fibers be so prepared that they can be brought into intimate contact with one another as the sheet dries. It is

now accepted that the strength of a sheet of paper is primarily dependent on the intrinsic strength of the individual fibers and the number and strength of the fiber bonds. Both of these entities i.e. fiber strength and fiber bonding are a function of the nature of the fibers. Although fibers may vary as to dimensions and composition etc., they all utilizes the same mechanism of bonding when made into a sheet. The same also applies to the recyled fibers.

In the process of making virgin fibers into paper, physical and chemical phenomena are brought into play which may have a marked influence on the characteristics of the fibers and hence the resultant sheet properties e.g. the mechanical attrition during refining causes the fibers to imbibe water and swell. The swelling appears to activate the surface of the fibers by creating at the fiber-water interface a partial solution of cellulose and/ or hemicellulose which promotes bonding between fibers when dried. During refining, the fibers become crushed, linked, twisted and cut and in a sense unravelled. The dimensional changes adversely affect the strength of the fibers. In contrast, however, the swelling and fibrillation greatly increase the exposed fiber area and make the fibers softer and more flexible and lead to a closer interweaving of the fibers during web formation and subsequent wet pressing and, hence, a great number of potential fiber bonding sites on drying. Although drying is necessary to develop the inter fiber bonding required for sheet strength, it can adversely affect the subsequent paper making characterisitcs of the fibers. It is well documented that when swollen cellulose fibers are dried, they undergo a loss in swelling power which is partially irreversible i.e. the fibers will not reswell to the same degree as the virgin fibers. Most of the investigations carried out regarding the relationship between pulp properties, processing and sheet properties have been concerned with virgin pulp fibers[2-6]. The present study concerned with effect of repeated paper making cycles has on the regeneration potentials in terms of sheet properties. The extent of the influence of refining and drying on the intrinsic fiber strength, the degree of swelling and the strength and number of fiber to fiber bonds may vary with each repulping cycle. Each time the fibers are recycled they are subjected to mechanical attrition and swelling, which are subsequently followed by deswelling as the fiber is dried, as a result, it would not be surprising if such excursions of environment had a marked effect on the paper making characteristics of the fibers subjected to repeated repulping and hence, on the resultant sheet properties.

INVESTIGATIVE METHODOLOGY

In order to investigate the effect of repeated pulping on the various properties of the fiber and the resultant sheets, a series of repulping experiments were carried out using virgin unbleached Kraft pulp as the fibrous material. The procedure used was to fiberize and refine the virgin pulp in a laboratory valley beater to 40^0SR freeness. After beating to this level, a quantity of stock was removed for stock tests and for conversion into hand sheets on a British sheet former. The balance of the stock was also converted into hand sheets on a mold equipped with a circulating white water system and then dried on a electric heated drier. The hand sheets from the first beating cycle, corresponding to zero repulping, which were not used for test purposes, became the raw material for the first repulping cycle. This procedure was repeated until six repulping cycles has been completed on the same lot of fibers by dispering the sheets from the previous cycle in water without further beating. The sheets were not wet pressed, so as to eliminate the effect of that variable. No additives (size, fillers etc.) were used, since these could have obscured the effect of the fiber characteristics on the sheets. The test hand sheets corresponding to each beating cycle were evaluated as per standard method for various physical strength properties at a temperature of 27 ± 2^0C and at a relative humidity level of $65 \pm 2\%$.

RESULTS AND DISCUSSIONS

Effect of Repulping on Fibres:

Due to mechanical attrition to which the fibres are subjected in beating, it might be anticipated that under repeated recycling, the fibres would undergo dimensional changes which would effect their strength. Accordingly the fibre length measurements were made and are tabulated in table-I. In interpreting these data, it should be borne in mind that in all recyclings the freeness level, remains practically

Table-I

Fiber Length Classification

Fiber retained on, %	Number of recycles						
	0	1	2	3	4	5	6
+ 20 mesh	72.0	69.0	65.7	63.1	62.3	60.6	59.2
+ 40 mesh	6.1	6.5	7.2	7.7	7.9	8.2	8.6
+ 60 mesh	5.0	5.6	6.3	6.8	7.0	7.3	7.4
+ 150 mesh	3.9	4.5	5.0	5.4	5.5	5.9	6.3
- 150 mesh	13.0	14.4	15.8	17.0	17.3	18.0	18.5

constant. It may be seen that under these conditions the changes in fibre length was very modest. The major changes being on + 20 mesh fraction, which tended to decrease.

The effect of recycling on the strength of fibres as measured by means of zero span tensile is shown in fig.-1. It may be observed that the zero span tensile and hence, fibre strength decreased moderately as the number of recycles increased being approximately 5% & 25% after Ist and 6th recycles respectively, than the virgin fibres at zero recycling.

Wood fibres have the characteristics of swelling when subjected to mechanical attrition, in presence of water. As the fiber takes up water, it swells, thereby increasing in exposed area, deformability and flexibility, all of which are conductive to more intimate contact between fibres on drying and hence better bonding. The effect of repulping on the ability of fibres to take up water at the same freeness level is shown in figure-1. The degree of swelling decreased with the number of times, the fibres were recycled.

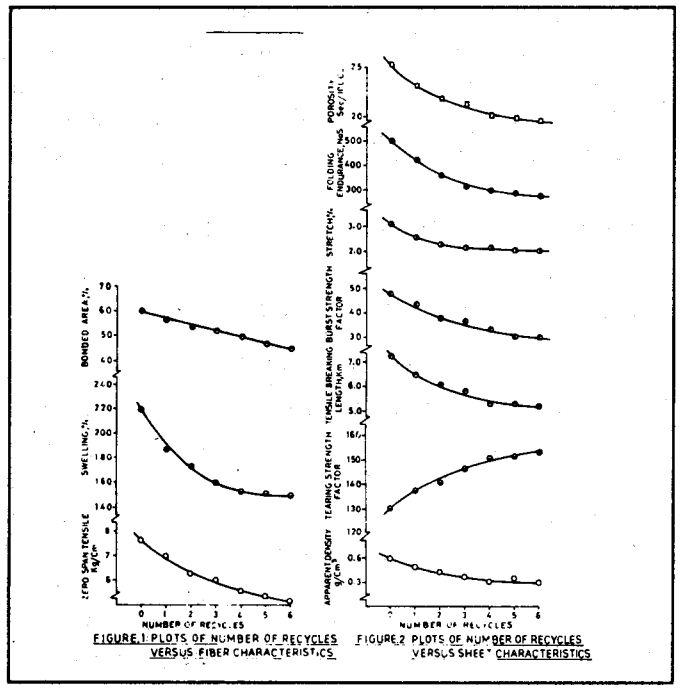

FIGURE.1 PLOTS OF NUMBER OF RECYCLES VERSUS FIBER CHARACTERISTICS

FIGURE.2 PLOTS OF NUMBER OF RECYCLES VERSUS SHEET CHARACTERISTICS

Effect of Recycling on Sheets

The effect of recycling on sheet characteristics is illustrated in figure-2, where the number of recycles is plotted along the abscissa and the sheet characteristics along the vertical axis. The zero recycles/ repulping represent the sheet characteristics of virgin fibers at 40°SR freeness.

Figure-2, shows the effect of recycles on apparent density, tearing strength, tensile strength, bursting strength, stretch, folding endurance and porosity. It may be observed that apparent density decreased continuously with an increase in number of times the fibers were recycled. After one recycling, the apparent density had decreased approximately 5% and after six recycles approximately 15%. For a given pulp, density may be considered as an indirect indication of the degree of refining and hence bonding. In as much as all recyclings were carried out at the same degree of beating measured in term of freeness, the apparent density data indicate a decrease in bonding.

- either a decrease in the strength of the bonds or the number of bonds.
- as the number of recycling increased.

It may be noted (Figure-2) that the decrease in apparent density and presumably the fiber bonding, is accompanied by a marked decrease in stretch. After six recycles, the tensile and stretch decreased approximately 35% and 30% respectively. The bursting strength, which is function of tensile and stretch charateristics of sheets decreased approximately by 8% on the first recycle and approximately by 37% after six recycles.

The bursting strength decreased rapidly with the number of recycling. The first recycling lowered the bursting strength by approximately 15% while after six recyclings, the bursting strength decreased

by approximately 40%. Further the slope of bursting strength curve indicates that the rate of change decreased slightly with the number of recyclings.

The tearing strength exhibits the opposite trend, in that the tearing strength increased with an increase in the number of recyclings. It has been shown that the total energy in tearing a sheet of paper is composed of the work required to

(a) repture individual fibers in tension and

(b) pull individual fibers out of the mesh of the fibers.

In this case, as the apparent density and presumably bonding decreases with the number of recyclings, hence tearing strength would be expected to increase, because more fibers are being pulled out and fewer are being ruptured.

Regarding the effect of recycling on folding endurance, it may be seen that the folding endurance decreased rather markedly with an increase in number of times the fibers were recycled. The folding endurance characteristic of paper is generally considered to be a function of fiber length, degree of bonding and strain characteristics etc., all of which decreased in varying degrees with increase in the number of times a fiber recycled.

The porosity versus recycling curve indicates that these data are quite variant, however, the general trend is for the porosity values to decrease with the number of recyclings indicating that sheet compaction decreases with recycling and thus offers less resistance to the passage of air.

Bonded area measurements were made using a light scattering technique for the purpose of determining if the bonded area and hence the number of bonds changed with recycling. It may be observed in Fig. 2 that the bonded area decreased only moderately with the number of recycles.

The above results may be interpreted as indicating that both the bond strength and the number of bonds decreased with the number of recyclings. This behaviour is compatible with the noted observations that bursting strength, tensile characteristics and folding endurance decreased while the tearing strength increased with the number of recycling.

One of the beneficial characteristics of the recycled stock for printing papers etc. is the comparatively higher opacity relative to virgin stock. It may be noted that where as the opacity of the virgin fiber sheets decreased with beating while the opacity of the recycled fiber sheets increased. The recycled fiber sheet exhibited a slightly lower brightness than that the virgin fiber sheet.

Fiber Characteristics Versus Sheet Properties

It is very difficult to predict quantitatively the effect which the observed changes in fiber characteristics will have on the sheet properties. However, on the basis of the observed percentage change in fiber characteristics with recycling, the results imply that the change in sheet properties may be due more to a decrease in the strength of the fiber bond and to lesser extent to decrease in fiber strength and the number of bonds.

The fiber strength as indicated by the zero span tensile measurements, supported by the fiber length measurement, and bonded area measurement exihibited only a modest decrease with the number of recyclings. The fact is also supported in part at least by the data obtained for the degree of swelling-the lower the degree of swelling the lower the bonding potentials. In support of this, it has been observed that the recycled fibers are stiffer than the virgin fibers at the same freeness level. As a whole it may be concluded that the changes in sheet properties on recycling are due to the progressive decrease in:-

- Fiber to fiber bonding and
- Fiber strength

As a result of recycling of fibers, the overall physical strength properties (except a few) lowered substantially, because the fibers get continuously shortened and the stock will become slow, resulting in poor drainage properties. In all such cases it is necessary to increase the proportion of long-fibered virgin pulp to improve the overall physical strength properties alongwith drainage characteristics of recycled fibers.

CONCLUSIONS

The recycled fibers refined to the same degree in terms of freeness exhibit lower fiber strength and poor bonding potentials than the same fiber in the virgin state. The loss in bonding potentials appear to overshadow the loss in fiber strength as they relate to sheet properties. The sheet properties which are a direct function of fiber bonding and fiber strength, decrease markedly with the number of times recycled. In contrast the sheet properties like tearing strength and other similar properties which in one sense are universely related to bonding, increase with increase in the number of times recycled at the same freeness level. The repeated recycling of fiber lowered most of the physical strength properties and the stock will become slow. Therefore, it is advisable to increase the proportion of long-fibered virgin pulp to improve the overall physical strength properties alongwith drainage characteristics of recycled fibers.

The use of recycled fiber will continue to grow and due to the pressure of shortage of fibrous raw material and environmental concern, its importance as an alternative raw material will be increasingly emphasised. The world consumption of waste paper of about 85 million tonnes in 1990 is expected to exceed 100 million tonnes in the mid 1990s and should reach 130 million tonnes by 2001.

Assuming an average growth of 2.6% per year in global consumption and an increase in production of paper and board from 238 million tonnes in 1990 to 317 million tonnes in 2001, the world wide recycled fiber utilization rate will rise from 32.8% in 1988 to 41% in 2001. This means an increase of 45 million tonnes in the worldwide recycled fiber consumption between 1990 and 2001.

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