Effect of Recycling on Fibre Characteristics

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ABSTRACT

The use of recycled fiber is increasing in the country. However the quality of paper produced particularly with regard to strength properties is weaker. The bonding and other properties of pulp fibers change during recycling of pulp. The changes are dependent on the types of raw materials and the method of pulping. Relevent literature on these aspects has been reviewed.

The recycling seems to have an opposing effect on strength properties of mechanical pulps and kraft pulps. While the properties decreased for kraft pulps, they seems to increase for mechanical pulps on recycling. Blending of mechanical and kraft recycling pulps can be one way to improve strength properties. The other approaches for improving properties of recycled pulps include refining, chemical addition, alkali and enzyme treatment.

INTRODUCTION

Use of recycle fibers is increasing in India in the recent years. However the performance of recycled fiber process industry has not been satisfactory essential due to poor quality of recycled fiber locally available and poor quality of finished products produced. In the post globalization era the recycled fiber processing industries have to improve the product quality failing which the industry will have difficulties in survival. In this contest an attempt has made to look at improving the quality of output from secondary fiber processing.

While looking for increased utilization of recycled fibre there are technical bottlenecks limiting its use, most important of them being the reduction in strength and other desirable properties of fibre during recycling. The loss of intrinsic fibre properties such as bonding capacity, flexibility and swelling potential during papermaking is associated with the phenomena of irreversible hardening or 'hornification' of fibres occurring during drying. An essential feature of recycling is repeated drying and rewetting-disintegrating of the paper sheet. During drying hydrogen bonds are formed between cellulose chains in the cell wall and parts of these bonds remain unbroken upon rewetting. We find in the literature, quite a few studies conducted to cover this aspect.

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The extent of hornification of fibres has been reported to be dependent upon the type of raw material and the method of pulping used. The literature on the subject has been reviewed and the effects of recycling on different fiber characteristic like water retention value, freeness and fiber length, tensile strength, tear strength, burst strength and effect of calendering are summarised. The possible techniques for enhancing the strength of recycled fibers is also indicated in the following paragraphs.

WATER RETENTION VALUE

The water retention value (WRV) represents a measure of surface area of fibers as it relates to the fiber bonding. A similar measure is some times obtained by an alternative method known as fiber saturation point. WRV has been found to be one of the most useful pulp characteristics to determine the changes in recycling potential of pulp fibers.

The drying process brings the lamellae of the cell wall closer together with possibility of adherence. Rewetting dose not reverse the situation causing reduction in WRV and reduction in fiber bonding potential [1]. This is predominant with chemical pulp fibres High yield pulp (TMP, CTMP etc) can however recover to take up more water [2]. This indicates greater flexibility of recycling high yield pulps compared to chemicals pulps. Fibre saturation point is unaffected after four recycles for TMP, whereas its reduce by 30% and 40% respectively for ultra high yield sulfite (UHYS) and kraft pulps. The difference in the behavior of low and high yield pulp to recycling is due to the difference in the amount of lignin present in the fibers [3] and to the cross-linking within cell wall and coating of pores leading to coupling between the lignin and the cellulose by hemicellulose. On rewetting the water goes through the pores and turns the ligno-hemicellulose into a gel contributing to covalent hydrogen bonding. Chemical pulps due to lower ligno-hemicellulose content have lower water absorbing ability on rewetting. The mechanical pulps experience best gains in WRV in the first cycle. The loss of swelling capacity of all pulps are irreversible [4].

FREENESS AND FIBER LENGTH

The change (increases or decreases) in freeness during recycling depend on the refining energy applied to the pulps prior to recycling. The freeness of high energy (low freeness) softwood TMP pulps was observed to decrease during recycling [5], in contrast to the low energy (high freeness) pulps. The recycling behavior of pulp fibers on freeness is process dependent [6] and it is reported that no change in freeness for unbeaten kraft pulp, a 20% decrease for UHYS and 25% reduction for TMP after four cycles of repeated drying-rewetting. The measurements of freeness indicates the degree of refining or the levels of internal and external fibrillation. As the degree of fibrillation increases, the elasticity of the cell wall decreases enhancing the fiber saturation point [2, 7, 8] and upon drying greater hornification should be expected.

All pulps recycled with fines retained showed a drop in freeness [9]. In the case of chemical pulps, most of the drop occurred at first recycle. On the other hand, the two chemical pulps from which fines were lost during sheetmaking (one beaten, the other unbeaten) both showed an overall gain. Since fines have long been regarded as the main factor influencing freeness [10], The obvious implication is that fines accumulation in a closed system causes the freeness drop. In an open system, a freeness increase can be expected during recycling although this situation might change if the recyled stock is reslushed very vigorously.

Contrary to the popular belief that the fibres become fragile as a result of recycling and are dramatically shortened, fiber length chages are small on recycling [4, 9]. However, the results can be changed when the sheets are hot cylinder dried and calendered.

TENSILE STRENGTH

The recycling induces different effect on tensile strength of chemical and mechanical pulps. While TMP and UHYS shows practically no loss in breaking length. The kraft pulp shows 50% drops in original strength after four recycles with major loss occuring in first two cycles. Mechanical pulp become progressively flatter after each recycle. In some cases marginal strength gain is reported for SWG and CTMP [15]. The bleached kraft has a reduction of 15% in breaking length after five cycles. The 50/50 blend of TMP and kraft undergoes an initial reduction in strength with a subsequent restoration of the initial strength after five cycles.

Ferguson [14] indicated the results for a blended pulp (70/30 ONP/OMG) which has an unknown amount of kraft fibre. In this case the tensile strength initially increases then returns to the start value after five cycles and then increases again. The reason for the cyclic response was not given, but it is possible that, to some extent, the loss of strength by the kraft fibres is causing some of the strength reduction of the blend. It is also possible that the alkaline environment used for pulping (pH=10.2) increased the osmotic pressure generated within the fibre wall, thereby drawing in more water and giving a more flexible fibre.

Additional swelling can be obtained by ionizing chemical groups attached to the cell wall [2]. Zero-span tensile for kraft fibers on recycling may not decrease if fines are removed and average fiber length remains same. Loss in fiber bonding potential which was particularly evident in the first cycle(4),was observed in all as per pulps except for the TMP that showed practicing no changes. Insignificant changes in tensile strength during recycling of softwood TMP were also reported by Cui [6]. On the other hand increases in tensile strength of mechanical pulps during recycling were observed by other workers [3, 9]. This suggests that the history of the pulps is an important factor.

Kwei etal [4] also reported some increase in fiber strength measured by zero-span breaking length for high yield pulps. Most of the fiber strength changes were relatively small, particularly for the commercial pulps that had been dried once during their manufacturing process. However, that the two CMPs with the lowest pulp yield showed larger changes in fiber strength, which is occured the first cycle. This might be due the fact that as more lignin (and some hemicellulose as well) was removed from the cell wall during the chemical treatment, more internal bonding occurred during drying, thus increasing the fiber strength.

TEAR STRENGTH

Tear strength of TMP and UHYS are unaffected, whereas the kraft samples lose tear strength on recycling [16]. Interestingly, the stone groundwood tear strength is unaffected by five recycles, and the CTMP shows a small reduction. However some authors claim kraft fibres show a significant gain in tear strength [14, 15]. These differences may be due to freeness variations in pulp [16]. An initial increase in tear followed by a slight reduction after three-four recycles for a blend of ONP and kraft is reported by Ferguson [14] and Howard [15]. All the pulps studied showed positive changes in tear index during the first 3 cycles, which is principally associated with the decrease in fiber bonding potential. After cycle 3 most pulps exhibited a tendency of decrease in tear index.

BURST STRENGTH

The mechanical pulp fibres gain in burst strength after five recycles whereas the kraft fibres lose burst strength [15]. The 50/50 blend of CTMP/ kraft shows an initial reduction followed by a gain in burst strength. Ferguson [14] reports a steady increase in burst. The reason for the gain in burst strength may possibly be due, as was discussed in the tensile strength results, to the flattening of the mechanical pulp fibres increasing the portential bonding area and the alkaline environment making the fibres more flexible for all aspen pulps except TMP. Loss in fiber bonding potential is noticed in the first cycle [4] for all pulps except for the TMP which has partically no changes in burst strength during recycling [4, 6].

CALENDERING

While drying-reslushing are considered to be the most important processes effecting the recyclability of fiber, other processes such as calendering also have effect on recycling potential of fibers. The effect of calendering on the recycle potential of both of groundwood containing and woodfree paper has been examined by Gottsching and Sturmer [13]. They showed that the heavier the calendering the greater the loss in breaking length of handsheets made from the calendered paper and this effect corresponded to both a loss of WRV and a reduction of fiber length. Tear strength also suffered and the drainage rate of the stock worsened. The effects occurred at all levels of initial stock freeness, but the results indicate that paper made from a lightly beaten stock suffered greater damage, than that from an initially heavily beaten stock.

Calendering also has a significant impact on the initial strength properties of the sheet. In the temperature gradient and extreme type of calendering the fibres are generally permanently deformed and flattened. Damage done in calendering is not reversible by reslushing and recycling. Calendering significantly reduces the elastic modulus of all handsheets, most likely due to bond breakage and fibre damage [17].

The magnitude of density change [4] was rather small, generally no more than 5%. The TMP showed an increase in sheet density while all other pulps exhibited a tendency of decrease. Increases in sheet density of softwood mechanical pulps as a result of drying-rewetting processes resulted in improved fiber flexibility and collapse, as reported by other workers [9]. However, the increased sheet density does not necessarily promote strength property in softwood TMP [6].

TECHNIQUES FOR ENHANCING THE STRENGTH OF RECYCLED FIBERS

Recycled paper loses strength mainly becuase of the fiber stiffening and hornification that occur when virgin fibers are dried during their initial papermaking cycle. This phenomenon is difficult to reverse. Strength loss generally can be regained by refining [18]. Unfortunately, this usually reduces drainage and production capacity. Increased refining also limits the amount of strength that can be regained by refining in future cycles.

High-shear-field (HSF) treatment [24], in a pulp consistency range of 10-20%, can be used.to produce an effect similar to refining. Perhaps during HSF treatment the fiber wall structure is modified by the brushing and bending action, which increases the bonding area. The HSF treatment produces less fines than refining, and this results in less freeness loss.

The use of chemical additives, which improve the strength properties without changing the repulping requirement can provide an alternative method to refining [19]. Two resins often used are an anionic polymer [19], which is facilitates hydrogen bonding, and a cationic polymer, which is capable of forming strong electrostatic bonds between fibers and fines. These resins improve the dry strength of paper by increasing both the strength and the area of the interfiber bonds [20].

Treatment of wastepaper with sodium hydroxide increases the freeness and the strength properties of recycled fiber [21]. Sodium hydroxide treatment promotes fiber swelling, thereby increasing fiber flexibility and surface conformability. Both alkaline treatment and delignification can improve the papermaking potential of recyled fibers. Alkali treatment helps to swell the secondary fiber, which increases the surface area available for bonding. A 3% NaOH treatment at 10% pulp consistency for 30 min at 70°C are typical of conditions commonly used [24].

Oxygen - alkali delignification has recently been studied as a means of improving strength properties in old corrugated container recycled pulp [22]. The delignification treatment was found to improve bonding and strength characteristics, probably becuase of softening, swelling, and lignin removal. The strength improvement in the fiber is especially noticeable in the higher burst value and strain-to-failure value at a given drainage rate [23].

A combination of alkali and HSF treatment may be a better alternative to obtain high product quality from secondary fiber. The strength properties of the recycled paper obtained by the combination alkali/ HSF treatment are higher than those obtained by refining and, in some cases, are comparable with the virgin pulp. The combination treatment seems most effective in restoring Ring crush and Concora flat crush strength. This treatment offers a potentially valuable, practical method of increasing the use of secondary fiber in boxboard as well as corrugating medium.

Enzymes can be used to increase the freeness of the secondary fiber without affecting the quality of the final product. A preparation of cellulase and hemicellulase at 0.2% enzyme concentration, 30 min, 10% pulp consistency, pH 5, and 45°C was the most economical and partical level examined for the pulps investigated [23].

The blending of high yield recycle pulp with kraft recycle pulp can also lead to improvement in strength properties. This area can offer attractive option in terms of economic advantages. Its important that initial study be conducted to find optimum blending proportion of recycled high yield and kraft pulps and examine possible combination with refining, HSF treatmentm chemical addition, alkali treatment or oxygen alkali treatment for improved pulp qualities.

CONCLUSIONS

The above review of literature indicates the following:

1. The behavior of high yield pulps is significantly different from those of chemical pulps on recycling.
2. It is possible to get improvement in strength properties by blending of kraft and mechanical recycle pulps.
3. Optimizing condition of refining, chemical additon, HSF treatment and alkali treatment can increase the strength properties of recycled fibers.

4. Suitable experiments are necessary to extablishe right levels of blends and treatment conditions to get the best results from recycled fiber.

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