UPGRADING OF PAPER FROM MIXED OFFICE WASTE PAPER PULP BY BLENDING WITH VIRGIN SOFTWOOD KRAFT PULP FOR TROPICAL CONDITIONS

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Pulp blending, one of the methods for restoring the strength of secondary fibres, is the focus of this study, utilizing virgin softwood kraft pulp as the strength enhancing material. A series of blending experiments were conducted by adding 0 to 25% virgin pulp, with varying freeness levels (610-320 CSF), to mixed office waste (MOW) pulp to produce high-quality paper. The physical and mechanical strength properties of the paper, including density, tensile, burst, and tear strengths, were measured. The strength of various pulp blends increased significantly compared to MOW pulp, and pulp drainage also improved when the freeness of the virgin pulp was higher than that of the MOW pulp. By replacing inactive secondary fibres with active virgin fibres, physical strength was enhanced due to improved interfibre bonding. Additionally, second-order univariate polynomial regression models were developed based on the experimental results.

Keywords: recycled paper, mixed office waste paper, blending, papermaking properties, physical strength, univariate regression

INTRODUCTION

Papermaking involves the removal of water from an aqueous slurry (approximately 0.5% solids) composed of cellulosic fibres, fines, and various chemical additives to form a wet mat that is subsequently pressed and dried to produce paper. Many commercial papers contain multiple fibre types in their furnish and may also contain non-fibrous materials to enhance properties, allowing for the cost-effective production of sheets that meet customer specifications. The selection of materials for a given furnish is affected by the relative costs, availability, beatability and overall wet-end performance, *e.g.* runnability and formation, of different pulps and the desired final paper properties.

Most countries face the challenge of meeting the increasing demands for paper products, while simultaneously conserving forests and ensuring environmental and economic sustainability. Recycling plays a crucial role in addressing these challenges. Besides being a low-cost source of fibre for paper and board production, recycled fibres help conserve scarce forest resources, reduce environmental pollution and contribute to water and energy savings. The global consumption of paper and paperboard, which reached 417 million tons in 2021, is projected to rise to 476 million tons by 2032.[1] Over the past decade, the use of recycled fibres has surged, particularly in the packaging industry.[2] More than half of the paper produced worldwide is now made from recycled pulp. Given the increasing scarcity of conventional wood-based raw materials for papermaking and growing environmental concerns, paper mills are increasingly adopting higher levels of system closure and utilizing secondary fibres from waste paper.

The need for fibre recycling will continue to grow due to rising environmental concerns, the rapid depletion of suitable landfill sites, stricter EPA guidelines on recycled fibre content, sustainable development goals, market demands, and the cost of raw materials. Recycling is set to become the inevitable future of all paper production.[3] Papermakers are focusing on recycling as an economic necessity.[4,5] In India, recycled fibre is a key raw material across all industry segments. Currently, about 70% of Indian paper mills use waste paper as their primary raw material, accounting for approximately 50% of the country's total paper production. The increasing use of secondary fibres across all paper grades has necessitated the processing of lower-quality waste paper. While India has begun to exploit the environmental and economic benefits of recycled pulps, fibre recovery efforts are hindered by low collection rates and outdated technology. The pulp and paper industry faces two significant challenges: (a) producing high-quality paper in an economically viable manner, while meeting both legislative and consumer demands; (b) efficiently utilizing an increasing volume of recovered paper streams.

However, paper recycling has inherent limitations, as fibre properties deteriorate with repeated recycling. This decline is primarily due to a reduction in fibre bonding strength.[6] Exposure to pulping and drying conditions causes fibres to lose their ability to swell, reducing their flexibility and, consequently, their strength potential. This phenomenon, known as hornification, results in the irreversible hardening of fibres.[7] The extent of strength loss and its reversibility depend on the original pulp type and the papermaking process used. While the effects of recycling on papermaking properties are well documented, methods for restoring or minimizing recyclability loss remain less understood. In addition to strength loss, secondary fibres present drainage challenges, limiting paper machine speed and affecting overall production efficiency. Various approaches have been explored to enhance the papermaking properties of recycled pulps. Currently, known methods for improving drainage or restoring the strength of secondary fibres can be categorized into seven general approaches: mechanical treatment, chemical additives, fractionation, blending, chemical treatments, enzymatic treatments and paper machine modifications. Numerous studies have examined these topics, contributing to ongoing advancements in fibre recycling technologies.[8-26]

To address issues related to recycled pulps, blending chemical or mechanical virgin pulps with recycled pulp serves as a physical upgrading treatment. This process relies on the interactions between the two fibre types and is a key aspect of improving pulp quality. The literature provides numerous examples of quality enhancement through this approach.[26-38] Pulp blending is essential for meeting the growing demand for stronger papers. The proportion of virgin pulp added varies depending on the paper type, ranging from 0-15% in newsprint to 40-55% in lightweight coated (LWC) paper. Pulp blends are designed so that the overall properties of the resulting pulp and paper are more acceptable than those of the individual components. To maintain raw material costs at an acceptable level, the use of expensive chemical reinforcing pulp should be minimized, while still achieving adequate strength properties. The properties of paper made from a blend cannot typically be determined by simply adding the property values of the pure components in their weight proportions. This is particularly true for strength properties – the very attributes that reinforcing pulp is intended to enhance.

A more quantitative understanding of the effects of blending long-fibre pulps with recycled pulps is necessary, as it can lead to higher production rates and improved paper quality. It is crucial to understand how recycled pulp behaves when mixed with virgin pulp. This study explored potential furnish options for paper manufacturing using locally sourced waste paper. The objective was to develop blends of recycled pulp from mixed office waste paper (MOW) with long-fibre softwood kraft pulp to produce paper of acceptable quality. The study assessed the potential benefits of pulp blending, a major fibre processing operation, in improving both process efficiency and product quality. Laboratory experiments examined the impact of blending different proportions of softwood kraft pulp at varying freeness levels on the final pulp and paper properties. Such insights are highly valuable to the Indian paper industry, where minimizing the use of costly chemical reinforcing pulp, while achieving acceptable strength properties, is crucial due to economic constraints.

EXPERIMENTAL

Pulp samples

Indigenous mixed office waste paper was repulped in a high-consistency disintegrator at 70 °C for 25 min, with the addition of 2% NaOH, 1% H_2O_2, 0.4% EDTA, 2% sodium silicate, and 0.4% oleic acid as fatty acid. The pulp was then diluted with water to 1% consistency, followed by the addition of 0.4% EDTA, and deinked at 40 °C for 10 min using a Lamort flotation cell. After post-flotation bleaching with 1% H_2O_2, the final pulp brightness reached 74% ISO. Bleached softwood kraft pulp with an ISO brightness of 82% was used as the virgin pulp.

Evaluation of pulp and pulp blending

Pulp stock drainage, as measured by freeness – which is mainly influenced by fibre fibrillation and the amount of fine elements – is of practical importance in papermaking and was measured following Tappi standard method T 227 om-99. Beating of softwood kraft pulp samples to different freeness levels – 610, 490, 390 and 320 CSF – was carried out in a PFI mill according to Tappi test method T 248 sp-00. Freeness was used as an indicator of the beating process. A series of blending experiments, ranging from 0 to 25% virgin pulp of varying freeness levels (610-320 CSF), were conducted to produce high-quality paper with an improved tear index, using MOW pulp as the primary raw material. For each freeness level, virgin pulp was added at six different proportions – 5, 10, 12.5, 15, 20, and 25% – to MOW pulp at 2% consistency for pulp blending, prior to dilution for handsheet preparation.

Handsheet making and paper testing

In all the experiments, standard handsheets (60 g/m^2) were prepared using a British sheet-forming machine, following Tappi standard method T-205 cm-80. The handsheets produced from blended pulp samples were subsequently tested for physical strength properties according to various Tappi test methods, after conditioning at 27±2 ºC and 65±2% relative humidity. This was done to evaluate the suitability of different pulp furnishes for the manufacture of quality paper with specified strength properties.

RESULTS AND DISCUSSION

The results show the quality of pulps used in the study, papermaking properties of their blends in terms of pulp freeness, sheet density, tensile, burst and tear indices.

Quality of MOW pulp and virgin pulp

The characterization of MOW pulp and virgin softwood kraft pulp (unbeaten and beaten) used in the study is presented in Table 1. The results are based on three replicates. The freeness of recycled MOW pulp was apparently lower as the repulped fibres had already undergone various papermaking operations, such as repulping, screening, beating/refining, dewatering, sheet formation, pressing, drying and conditioning, some of which affect pulp freeness. A comparison of the paper strength properties reveals that the tear index of the recycled pulp was considerably lower than that of the virgin pulp, which had a value of 16.7 $mN.m^2/g$, indicating the presence of a large long fibre fraction in virgin pulp. The tensile index of MOW pulp, 23.34 N.m/g, was higher than that of the unbeaten softwood kraft pulp.

The data in Table 1 also indicate that the virgin pulp had good physical strength properties, with tensile and burst indices improving after beating/refining of pulp. Paper strength properties are largely a function of fibre length and interfibre bonding. Interfibre bonding increases with specific surface area by fibrillation and the presence of materials that facilitate surface interactions.

Papermaking properties of blends from MOW and virgin pulps

The laboratory handsheet quality was highly dependent on furnish composition, resulting in significant changes in strength properties with the addition of virgin pulp. Production rate is crucial to a commercial operation and thus, the pulp stock drainage rate, as measured by freeness, is of practical importance and has been used as a basis for property comparisons. The effects of blending on the major papermaking characteristics of various formulations are discussed in terms of pulp freeness, sheet density, tensile, burst and tear indices.

Table 1
Characterization of deinked MOW pulp and virgin softwood kraft pulp (unbeaten and beaten)

Particulars	MOW pulp	Virgin pulp				
PFI revolutions, No.	0	0	1000	2000	3000	3500
Freeness, CSF	350	680	610	480	390	320
Apparent density, g/cm^3	0.617	0.614	0.701	0.773	0.790	0.810
Tensile index, N.m/g	23.34	20.45	49.42	64.45	72.19	80.33
Stretch, %	1.90	2.22	3.69	4.00	4.44	3.97
Tensile energy absorption, mJ/g	330	326	1238	1720	2110	2106
Burst index, $kPa.m^2/g$	1.20	1.34	4.10	5.25	6.58	6.44
Tear index, $mN.m^2/g$	3.90	16.66	18.45	12.78	11.24	10.57
Porosity, mL/min	1500	2780	1240	265	60	55

Effect on freeness

The freeness of blended pulps increases with the addition of virgin pulps, when virgin pulp freeness is higher than the freeness of recycled pulp, whereas it decreases, when virgin pulp freeness is lower than that of recycled pulp (Fig. 1). Higher increments in blended pulp freeness are observed with a decreased degree of beating of virgin pulp due to less external and internal fibrillation of virgin pulp. The changes could be explained in terms of the intrinsic properties of the recycled pulp with respect to virgin pulp.

The swelling capacity of the recycled pulp is greatly reduced due to multiple drying-rewetting cycles that the recycled fibres have undergone, resulting in hornified and stiff fibres limiting the water absorption. On addition of lightly or less beaten virgin pulp, whose internal structure largely remains intact, swelling is minimum, resulting in higher freeness increase. It is well known that the increased degree of beating results in an increase of the hydrophilic surface area of fibres and fines, resulting in more water being absorbed, and more swelling and subsequently, a decrease in pulp freeness.

Effect on density

The conformability of individual fibres in the fibrous network and the bonding potential of fibres can be measured in terms of density of paper handsheets. As presented in Figure 2, the density of blended pulps increases with the addition of virgin pulps due to the replacement of more stiff recycled fibres with flexible virgin fibres. The conformability of individual fibres in a handsheet made of only recycled fibres is lower due to hornification of fibres, resulting in lower density or higher bulk. Higher increments in blended pulp density are observed with an increased degree of beating of virgin pulp due to increased flexibility with beating, allowing the fibres to come into closer contact, and thus, more fibres per unit volume.

Effect on tensile index

The tensile index increased with increased virgin pulp content due to the substitution of the passive recycled fibres with the more active fibres of the virgin pulp. The inactivity or passivity of recycled fibres is because of fibres undergoing drying-rewetting processes and subsequent reduction in capability to swell, as explained earlier. The virgin fibres are able to absorb more water and swell to a higher degree compared to the recycled fibres and the degree of swelling increases with increased beating. Swelling is an important factor in the development of paper strength due to increased fibre flexibility with swelling. Upon the addition of 320 CSF freeness virgin pulp, the tensile index improvement of the blended pulp increased from 7.3% to 55.2% as the addition level rose from 5% to 25%.

The tensile index of pulp blends also increased with an increased degree of beating of virgin pulp, as the more flexible the fibres with increased beating, the more their conformation could be altered, resulting in enhanced interfibre bonding between themselves and the recycled fibres, and thus, increased tensile index. The density plots of blended pulps (Fig. 2) also showed that fibres became compacted after blending, which increased their potential to form interfibre bonding with increased degree of beating. Blending with highly beaten virgin pulp had a more pronounced effect due to the increase in bonded area of handsheets with increased internal and external fibrillation during beating.

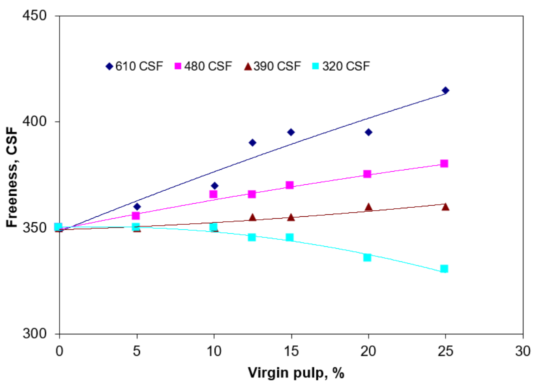

Figure 1: Effect of virgin pulp addition on freeness of MOW pulp blends

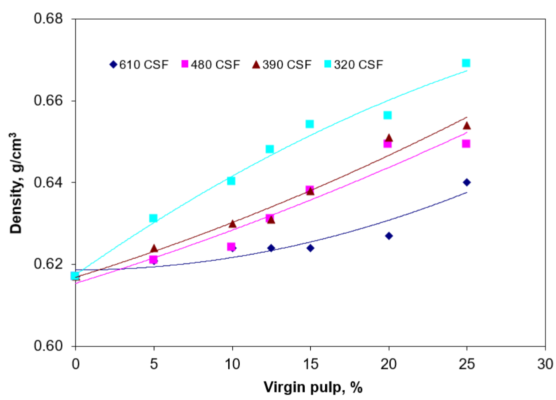

Figure 2: Effect of virgin pulp addition on density of MOW pulp blends

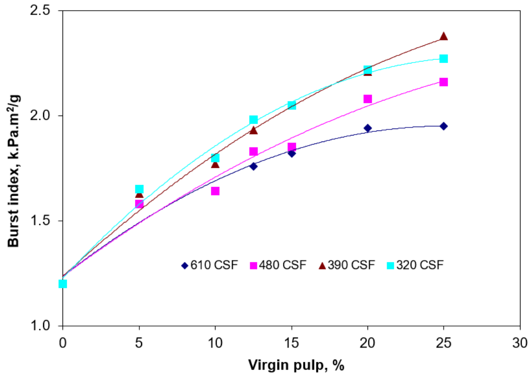

Figure 3: Effect of virgin pulp addition on burst index of MOW pulp blends

Effect on burst index

The observed effects of blending on the burst index of MOW pulp blends are shown in Figure 3. The burst index increased with increased virgin pulp content due to the substitution of the passive recycled fibres with the more active fibres of the virgin pulp. The burst index of pulp blends also increased with increased degree of beating of virgin pulp. The highest improvements in the burst index of blended pulps – 62.5%, 80%, 98.3% and 89.2% – were observed with the addition of 25% softwood pulp at 610, 480, 390, and 320 CSF, respectively.

Effect on tear index

Tear strength is a function of both fibre strength and fibre bonding. The addition of virgin pulp to recycled pulp has caused an increase of both parameters, resulting in an increase in the tear index of the pulp blends. Higher increments in the tear index of the blended pulp are observed with a decreased degree of beating of virgin pulp, at all levels of virgin pulp addition, due to less external and internal fibrillation of virgin pulp. At lower addition of virgin pulp, of 5%, the effect of the degree of beating of virgin pulp on the tear index of the pulp blends was marginal. At a higher degree of beating with high virgin pulp content, the tear index dropped substantially due to fibre cutting and generation of fines. The drop of the blend tear index is due to the drop of the virgin pulp tear index. The highest improvements in the tear index of blended pulps – 142.6%, 110%, 103.8% and 87.9% – were observed with the addition of 25% softwood pulp at 610, 480, 390, and 320 CSF, respectively.

Tensile-tear strength relationship

The tensile-tear strength relationship of MOW pulp blends is shown in Figure 4, which illustrates the relative importance of beating/refining of pulp for tensile strength development of pulp. It is evident from the figure that both tensile index and tear index increase with blending of virgin pulp. However, the improvement in tensile index is marginal at a lower degree of beating of virgin pulp. The tensile index of pulp blends improves as an effect of beating/refining, resulting in higher increments with an increased degree of beating of virgin pulp. However, the improvement in tear index drops with an increased degree of beating.

Tensile strength-density relationship

The MOW pulp blends were also compared in terms of their tensile strength/density relationship. Figure 5 illustrates the tensile strength-density relationship of MOW pulp blends. As can be seen, the MOW pulp blends obtained after the addition of virgin pulp with freeness of 390 CSF tend to have higher tensile index or interfibre bonding than other pulp blends, at a given apparent handsheet density in the range of 27 to 34 N.m/g, when the density ranges from about 0.63 to 0.65 g/cm^3. In other words, the MOW pulp blends obtained after the addition of virgin pulp with the freeness of 390 CSF tend to have higher bulk than other pulp blends at a given tensile index. It is well known in the paper industry that a higher bulk at a given tensile strength is often preferred in many paper/board applications, as has been discussed elsewhere.[39] The MOW pulp blends obtained after addition of virgin pulp with the freeness of 320 CSF tend to have lower bulk or higher density compared to any other pulp blends.

To summarize, the blending of softwood pulp results in significant increases in strength properties and also increases pulp freeness. However, the rise in pulp blend freeness is only in the cases when the virgin pulp has a higher freeness than that of the MOW pulp. The degree of improvement is dependent on the proportion of softwood pulp added. The effect of the addition of different proportions of virgin pulp on the recycled pulp showed that the higher the content of virgin pulp, the higher the increase in strength properties of MOW blended pulp. At the addition of 25% virgin pulp of 320 CSF, the maximum improvement in tensile index and burst index was 55 and 89%, compared to the respective values for recycled pulp. The pulp freeness for the pulp blend dropped to 330 CSF from a value of 350 CSF for recycled pulp. With this addition of virgin pulp, the improvement in tear index was 88%, however, with the addition of 25% virgin pulp of 610 CSF, the maximum improvement of 143% in tear index was achieved with 20% and 63% improvement in tensile index and burst index, respectively, and the pulp freeness improved to 415 CSF. The addition of 20% lightly or less refined (610 CSF) virgin pulp to the MOW pulp also improved tensile index (11%), burst index (62%) and tear index (110%).

Filipova *et al*. reported that the addition of 25% softwood kraft pulp to waste fibres increased the tensile index and burst index by 33% and 49%, respectively, if compared to paper consisting of the waste fibres only.[26] Earlier, it was reported that inferior handsheet properties were observed when using 100% recycled fibres (OCC pulp). The addition of 10 to 30% bagasse pulp to OCC pulp did not significantly enhance the tensile and burst indices of the paper sheets, but the addition of 70% or more of bagasse virgin pulp to OCC pulp resulted in a substantial increase in tensile and burst indices (Sheikhi *et al*.).[33] Based on the data on a pilot-plant paper machine, Horn *et al*. reported that an acceptable newsprint can be produced using a blend of 25% kenaf CTMP and 75% deinked recycled newsprint. The blended paper provided a greater burst and tensile strength than the control furnish of 100% recycled newsprint (Horn *et al*.).[36] Earlier, Sheikhi *et al*. studied the effects of blending 340 mL CSF unbleached bagasse soda pulp to 250-300 mL CSF OCC pulp and reported that an addition of 50% bagasse would improve the tear index, but higher proportions led to lower tear.[33] Nassar *et al*. reported that by blending rice straw and deinked recycled ONP pulps, the properties of paperboard made from mixtures were improved significantly. Tensile strength was increased by increasing the amount of rice straw pulp in the blend from 33.3% to 50%. The virgin nature of rice straw pulp improved the structural and mechanical properties of the blend.[37] Latifah *et al*. studied the effect of blending unbeaten and beaten kenaf pulp to old corrugated containers pulp. The addition of 10, 20 and 30% of beaten kenaf pulp resulted in 37, 42 and 59% increases in the tensile index of old corrugated container pulp, whereas the addition of 20, 30 and 40% virgin kenaf fibres resulted in 15, 30 and 37% increases in the burst index of old corrugated container pulp. The increase in the tensile index and burst index of blended pulps was more pronounced for beaten kenaf as compared to the unbeaten kenaf.[38]

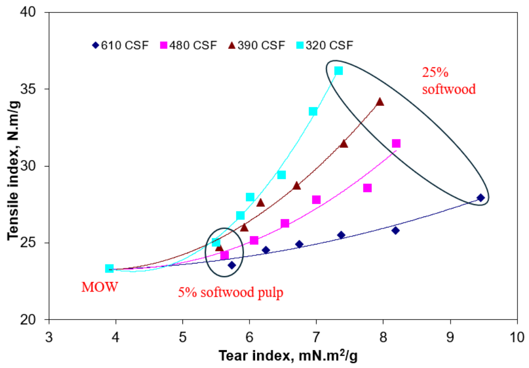

Figure 4: Tensile strength-tear relationship of MOW pulp blends

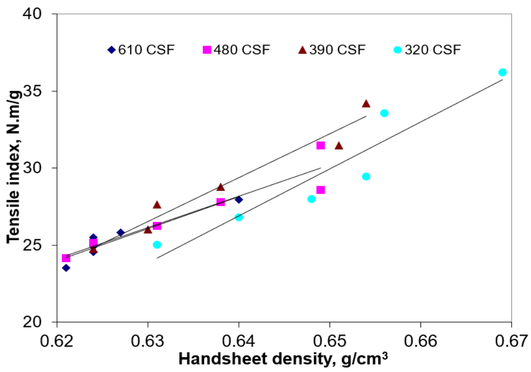

Figure 5: Tensile strength-density relationship of MOW pulp blends

Comparison of measured and calculated properties of blended pulps

The effect of adding up to 25% of the virgin softwood kraft pulp of varying freeness, ranging from 610 CSF to 320 CSF, to MOW pulp on the property of resultant pulp blends, in comparison to the property value calculated from the sum of weighted contributions from their individual components, is shown in Table 2. It is difficult to estimate the physical strength properties of blended pulps based on the properties of individual components. In general, for the addition of different proportions of virgin pulp, the measured density and tensile index values were lower, whereas the burst and tear indices were higher in comparison to the calculated property values, respectively.

The experimental data obtained from the laboratory were also analysed from the graphs and the polynomial regression models were developed. The entire regression models developed and given in Table 3 are very accurate as the regression coefficient, R^2, has values close to unity. The predicted data from the regression equation were plotted against the experimental values in various graphs and percentage errors were also determined. The model predicted data (MPD) and the experimental data (ED) were also compared with the graphs. Figure 6 depicts the relation between experimental values and the model predicted values for the tensile index of different pulp blends. The plot between MPD and ED showed an excellent agreement between the two.
Various comparisons of ED and MPD and residual analysis for different properties of pulp blends are given in Table 4. The level of significance from the data does not exceed about 8.3% and thus statistical analysis predictions claimed to have a reasonable degree of accuracy. Figure 7 examines the behaviour of residuals as a function of MPD for the tensile index of pulp blends. It was found that the plot was structureless and residues were found distributed around zero giving good prediction.

Effect on pulp brightness

The brightness of the pulp blends increased with a higher virgin pulp content, due to the replacement of lower-brightness recycled fibres with the higher-brightness fibres of the virgin pulp. Virgin pulp, being less contaminated and chemically bleached, contributed significantly to an overall brightness improvement in the blend. However, among blends with the same proportion of virgin pulp, brightness decreased slightly with an increasing degree of beating of the virgin pulp.

Table 2
Comparison of properties of MOW pulp blends (measured *versus* calculated)*

Virgin pulp freeness,	Measured property compared to calculated property			
CSF	Density	Tensile	Burst	Tear
610	Lower (0.89)	Lower (6.3)	Higher (11.3)	Higher (21.2)
480	Lower (0.37)	Lower (5.7)	Higher (2.3)	Higher (33.8)
390	Lower (0.77)	Lower (6.2)	Higher (2.1)	Higher (33.9)
320	Higher (1.25)	Lower (7.7)	Higher (3.2)	Higher (32.2)

*(values in parentheses are percentage differences for 15% softwood pulp blends)

Table 3
Second order univariate polynomial model equations and R^2 values for different properties of MOW and virgin pulp blends

S. No.	X, Virgin pulp, %	Y, Properties	2nd order univariate polynomial model	Value of R^2
1	610	Density	$y = 3E\text{-}05x^2 + 4E\text{-}06x + 0.6186$	0.8934
		Tensile index	$y = 0.0046x^2 + 0.0618x + 23.312$	0.9659
		Burst index	$y = -0.0011x^2 + 0.0567x + 1.2355$	0.9696
		Tear index	$y = -0.0008x^2 + 0.2264x + 4.1400$	0.9814
2	480	Density	$y = 1E\text{-}05x^2 + 0.0012x + 0.6154$	0.9347
		Tensile index	$y = 0.0067x^2 + 0.1552x + 23.282$	0.9820
		Burst index	$y = -0.0007x^2 + 0.0538x + 1.2355$	0.9718
		Tear index	$y = -0.0034x^2 + 0.2483x + 4.0705$	0.9812
3	390	Density	$y = 2E\text{-}05x^2 + 0.0012x + 0.6169$	0.9703
		Tensile index	$y = 0.0084x^2 + 0.2313x + 23.298$	0.9968
		Burst index	$y = -0.0014x^2 + 0.0769x + 1.2276$	0.9881
		Tear index	$y = -0.0023x^2 + 0.2103x + 4.1082$	0.9719
4	320	Density	$y = -3E\text{-}05x^2 + 0.0027x + 0.6175$	0.9828
		Tensile index	$y = 0.011x^2 + 0.2554x + 23.324$	0.9932
		Burst index	$y = -0.0009x^2 + 0.0667x + 1.2355$	0.9884
		Tear index	$y = -0.0034x^2 + 0.2113x + 4.1058$	0.9644

Table 4
Residual analysis and % errors in different properties of MOW and virgin pulp blends

S. No.	SW pulp freeness	Properties	Error %	Residual analysis
1	610	Density	-0.59 to +0.40	-0.004 to +0.003
		Tensile index	-2.20 to +0.96	-0.57 to +0.25
		Burst index	-3.20 to +5.60	-0.05 to +0.09
		Tear index	-2.05 to +8.34	-0.17 to +0.48
2	480	Density	-0.71 to +0.86	-0.004 to +0.006
		Tensile index	-1.74 to +2.49	-0.50 to +0.69
		Burst index	-3.87 to +5.89	-0.06 to +0.09
		Tear index	-2.36 to +7.16	-0.14 to +0.40
3	390	Density	-0.83 to +0.32	-0.005 to +0.002
		Tensile index	-1.66 to +0.59	-0.43 to +0.19
		Burst index	-4.89 to +4.41	-0.09 to +0.10
		Tear index	-3.53 to +8.07	-0.22 to +0.45
4	320	Density	-0.53 to +0.42	-0.004 to +0.003
		Tensile index	-1.00 to +2.23	-0.36 to +0.75
		Burst index	-3.11 to +6.27	-0.07 to +0.10
		Tear index	-3.42 to +7.69	-0.21 to +0.42

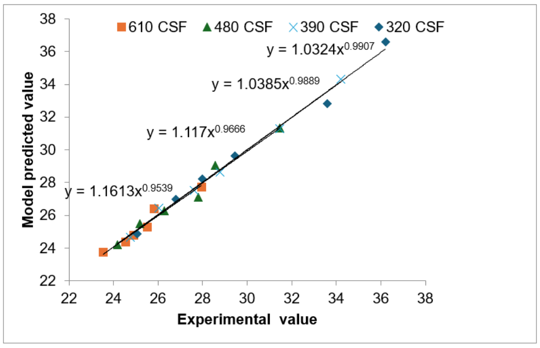

Figure 6: EV and MPV for tensile index of MOW pulp blends

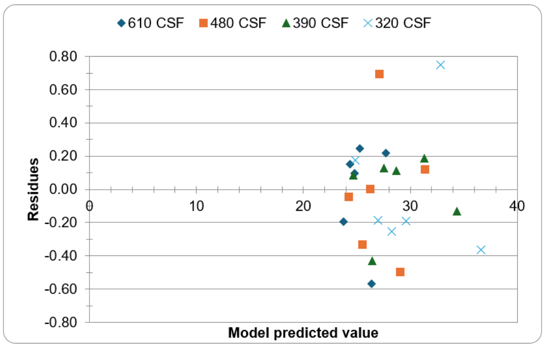

Figure 7: Residuals *versus* MPV for tensile index of MOW pulp blends

The highest brightness of 75.9% ISO was achieved with the addition of 25% softwood kraft pulp beaten to 610 CSF, while a slightly lower brightness of 75.4% ISO was recorded at the same addition level, but with pulp beaten to 320 CSF, highlighting the subtle influence of refining intensity on brightness.

CONCLUSION

The laboratory handsheet quality is highly dependent on furnish composition. For economical production and good product quality using recycled pulp, the addition of virgin pulp is crucial. Smaller increases in strength properties are achieved by the addition of lightly or less beaten virgin pulp, except for the tear index. The higher beating of virgin pulp and subsequent addition result in significant increases in strength properties of recycled MOW pulp, the major mechanism of strength development being the increase of interfibre bonding due to the replacement of inactive recycled fibres with active virgin fibres. The highest improvement in tensile index was 55.2% with the addition of 25% softwood kraft pulp at 320 CSF, whereas the highest improvement in burst index was 98.3% with the addition of 25% softwood kraft pulp at 390 CSF. The developed regression equations agree well with the experimental data with good regression coefficients. Paper with better strength properties can be prepared using suitable blends of MOW and virgin pulps.

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