

Blending impact of softwood pulp with hardwood pulp on different paper properties

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ABSTRACT

This paper discusses the physical and mechanical strength properties of pulp stock paper ($^{\circ}$ SR, tensile, tear, and burst) obtained by blending different proportions of hard wood and softwood fibre pulps. Regression models were developed by the least square technique and various results were tested graphically and by curve fitting. Bleached short fibre mixed hardwood pulp (Eucalyptus and poplar) and long fibre softwood pulp (Pinus roxburghii) was used. The initial $^{\circ}$ SR of the softwood pulp was 25, while the hardwood pulp

was 33 and 46 respectively for two different sample of hardwood. Various hardwood/softwood blends in the proportion of 100:0, 85:15, 70:30, 55:45, 40:60, 25:75, 10:90, 0:100 were prepared and then various pulp and paper properties of these blends were estimated using TAPPI standard procedure.

Results were analysed with the help of the developed linear model and the univariate regression model. This investigation was undertaken to examine the hypothesis whether the pulp blends follow the super position principles of additivity.

Keywords: blending, least square technique, curve fitting, univariate regression.

INTRODUCTION

Paper industries face a high availability of recycled paper, limited hardwood resources (due to their regional distribution) and abundant non-wood resources – all of which require a stronger and longer fibre pulp to be used alongside the indigenous material in order to meet high quality pulp standards. Mixed wood fibres provide the good bulk and smoothness of hardwood fibre, and the greater length and larger surface area for more fibre-fibre bonding of softwood fibre. The softwood pulp is variably mixed with the hardwood pulp to enhance the strength and formation of paper while obtaining the desirable yield. Through the blending of pulps, the regression models were developed on a microscopic level. The multi planner model developed by Görres Amiri et. al.³ assumes that

- (a) Paper is a super imposition of fibre layers,
- (b) The layer mass is a function of fibre width and coarseness and is given in one point when 1% of the network area is covered by fibre crossings,

- (c) The layer structure is described adequately by network statistics,
- (d) Translayer bonding occurs when fibres are deflected by wet pressing, and
- (e) The average fibre properties are sufficient to describe the sheet structure.

Mean fibre properties given by each pulp are weighted by the fraction of total fibre length that the individual pulps contribute to the sheet. Less research has been done in the area of blending of fibres, their effect on $^{\circ}$ SR and the prediction of various properties of pulp and paper on a macroscopic level. Individual fibres in a whole can easily describe the properties that may be additive or counteracting based on their interaction and orientation. Ray *et al*⁷ tried to model the effect

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of blending on optical and surface properties and develop nonlinear regression model to determine the interactions of blend percentage, amount of filler and amount of size added in a blend furnish on the different properties.

$$Y=B_0+B_1.X_1+B_2.X_2+B_3.X_3+B_{12}.X_1.X_2+B_{13}.X_1.X_3+B_{23}.X_1.X_2.X_3$$

BACKGROUND LITERATURE

Developing empirical models of pulp blends ⁴ can help to select pulps and determine the best blend compositions for a particular paper making application. Blending models are either based on principle of property additivity or regression analysis ².

Quality of fibre required for the production of paper

Eucalyptus and Poplar pulps are common raw materials for the manufacture of several grades of paper – each requiring a specific pulp quality that can be dependent on the wood quality, the conversion of wood into pulp (such as viscosity and degradation of cellulose fibre-fibre deformation, individual fibre strengths, surface charge on the fines etc.) or a combination of these two factors.

When blending pulp, the refining is the important process that provides greater surface area to the fibre-fibre bonding. This may lead to fibre flocculation in the refining ⁶, as an increase in the inter-fibre bonding increases the formation of coherent flocs that resist rupture in the flow and changes the randomness in the suspension. At the point of contact between fibres, several types of cohesive forces exist and due to this, fibre properties may differ. For example, fibre length, fibre surface, fibre stiffness and fibrillation action affect the magnitude of mechanical surface linkage and elastic fibre bending ⁵. Different gap widths for the short and long fibre pulps have been reported ⁸, while research shows that chip blending results in a faster decrease of tear index than pulp blending ⁹.

RESULTS AND DISCUSSION

Effect on °SR

Fig 3.1.1 shows the effect of blending on °SR values and compares the influence of initial °SR of softwood pulps. For more clarity, data was subjected to regression

models by least square techniques. In this figure, two regression models are analysed and reveal that the slopes of two linear lines are different. The slopes of the pulp blends with higher °SR value are steeper, verifying that an increase in the percentage of softwood pulp means a decrease in the °SR. The behaviour is expected to be influenced by the property of additivity.

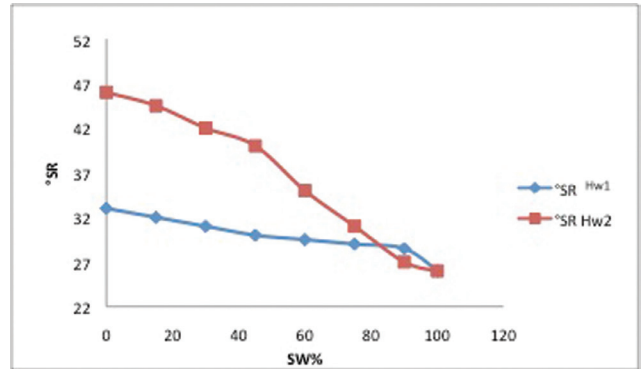


Fig 3.1.1: Comparison between °SR vs. % of Sw in the blend of SwHw1 and SwHw2

Effect on tensile strength

Fig 3.1.2 compares two types of hand sheets to show the effect of blending on tensile index values as experimentally determined. In this figure, it is clearly shown that the values of the tensile index are higher for high °SR pulp due to the presence of a higher surface availability for strong fibre bonding.

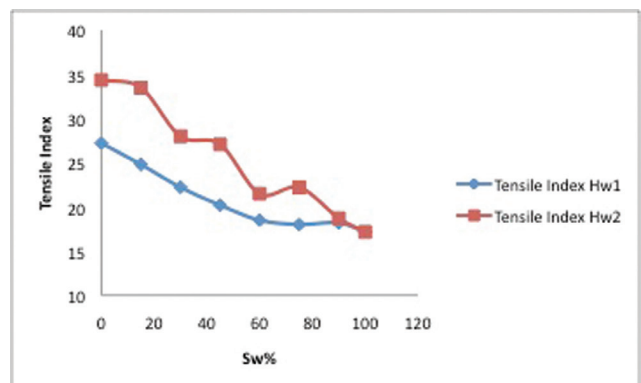


Fig 3.1.2: Comparison between Tensile Index vs. % of Sw in the blend of SwHw1 and SwHw2

3.1.3. Effect of blending on tear index

Fig 3.1.3 shows the effect of blending on tear index values as experimentally determined. Results show that the values of the tear index are higher for high °SR pulp than °SR low pulp, due to the degree of refining

of the fibres. It is evident that with an increase in the percentage of softwood pulp in the blend, and the related increase in the °SR of the blend, the tear index values also increase.

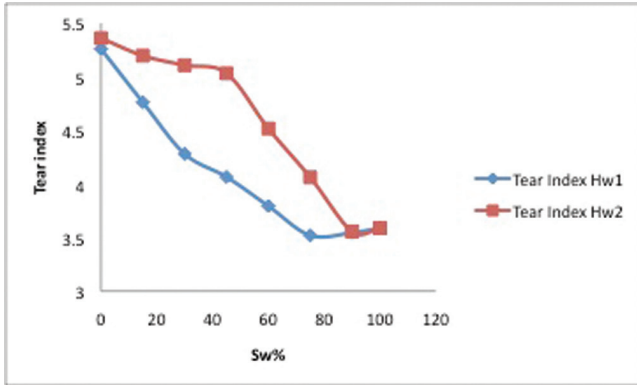


Fig 3.1.3: Comparison between Tear Index vs. % of Sw in the blend of SwHw1 and SwHw2

3.1.4. Effect of blending on burst index

Fig 3.1.4 shows the effect of blending on burst index values as experimentally. Results show that burst index values are higher for high °SR pulp. However, with an increased percentage of softwood pulp in the blend (and an increase in the blend's °SR), the burst index values decreases due to an increase in the refining and distribution of fibres.

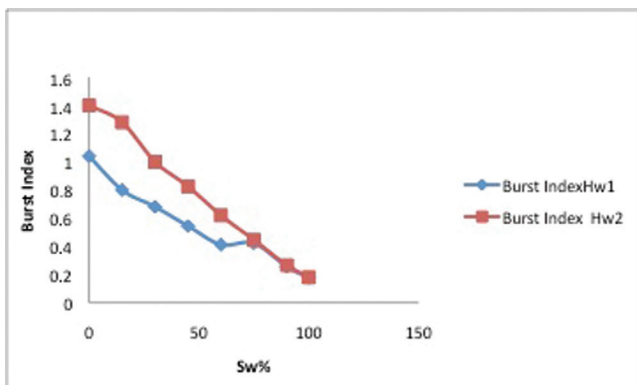


Fig 3.1.4: Comparison between Burst Index vs. % of Sw in the blend of SwHw1 and SwHw2

STATISTICAL INTERPRETATION OF DATA

Experimental data obtained from the laboratory was analysed and the regression model was developed with the help of the least square technique. For simplicity, the linear and regression have been used for analysis according to the applicability of the data.

$$\text{Percentage error} = \frac{(\text{e.v.} - \text{m.p.v.})}{(\text{e.v.})} * 100$$

Where e.v.= experimental value.

m.p.v. =model predicted value.

There is a high rate of accuracy in all of the regression models developed, as the regression coefficient (R2) is close two unity on avg. of 0.9351, percentage error does not exceed ±10.7% and the residues are found in between -1.9 to +2.1. The model predicted data (MPD) and the experimental data (ED) are compared with the graphs. The plot between MPD vs. ED shows approximately less than 10% of error between the two graphs.

From these observations, we can say that the fibre length as well as surface area play an important role in the bond formation with and within the fibres by providing a large surface area and surface charge for binding, resulting in a higher number of bonds.

Residuals and MPD

If the model is correct and if the assumptions are satisfied, the residuals should be unrelated to any other variable - including the predicted response. A simple check is to plot the residues versus MPD. For results, the residuals are almost distributed around zero.

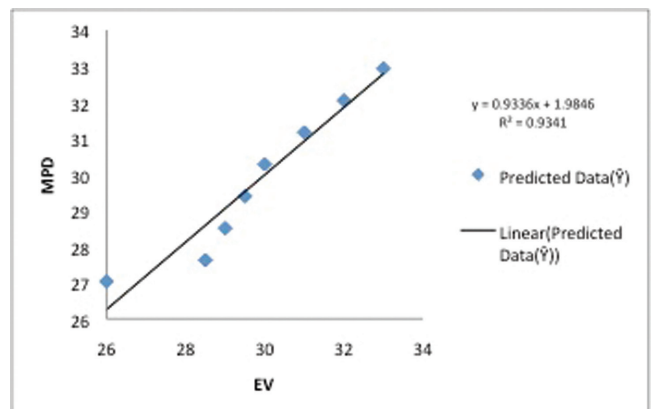


Fig 3.2.1: The EV Vs. MPD for pulp blend SwHw1 (°SR)

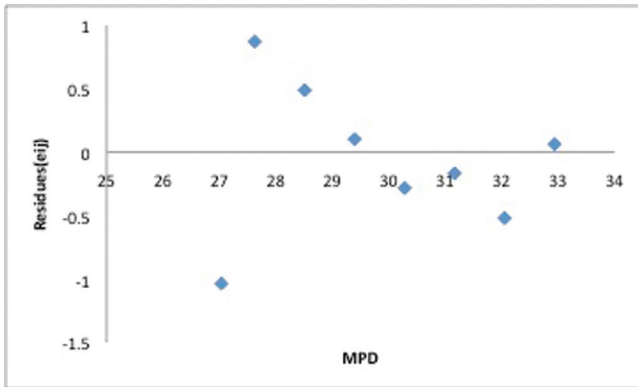


Fig 3.2.2: Residuals vs. MPD for pulp blend SwHw1 (°SR)

CONCLUSIONS

From the detailed analysis of data and their interpolations through graphs, the following conclusions can be made:

- ▶ The linearity of in the graph of °SR vs. the percentage of softwood shows the property of additivity.
- ▶ The increase in the amount of the softwood fibre:
 - decreases the blend tensile index of paper is due to higher refining of hardwood fibre,
 - increases the tear index of paper due to the longer length of softwood fibre,
 - decreases the burst index of paper
- ▶ Regression equations correspond with the experimental data with regression coefficient tends towards unity. From residuals analysis the unstructured plots obtained are very close towards zero.

SW%	°SR	Tensile Index	Tear index	Burst Index
0	33	27.22	3.442	1.04
15	32	24.8	3.545	0.8
30	31	22.22	3.62	0.68
45	30	20.2	3.794	0.544
60	29.5	18.5	4.065	0.412
75	29	18.02	4.281	0.422
90	28.5	18.2	4.862	0.254
100	26	17.18	5.22	0.18

TABLE 1: Various properties of blend SwHw1

EXPERIMENTAL DESIGN

The experimental procedure carried out in the laboratory was as follows:

1. Pulp samples

The long fibre pulp was treated in the Valley beater mill at 1.5% consistency to attain °SR of 25 (Sw). For short fibre pulp, a refined mixed hardwood pulp of °SR of 33 and °SR of 46 was used (sample Hw).

2. Evaluation of pulp and pulp blending

The two pulps were blended in several softwood-hardwood proportions, always mixing the samples Sw and Hw1, and Sw and Hw2, respectively, as shown in Table 1 and Table2. Slurries of each blend were prepared. The slurries were well stirred to ensure a uniform distribution of the fibres of the two mixed pulps. The various readings for the freeness of all the blends were measured and also subjected to statistical regression in relation to the proportion of soft wood used.

3. Handsheet forming and paper testing

In all experiments, standard handsheets with a grammage of 78 (avg) gsm were made on a British sheet mould according to Tappi standard T-205 cm-80. The blended handsheets were subsequently tested for physical properties after conditioning at 27±2 0C and 65±2 % relative humidity.

SW%	°SR	Tensile Index	Tear Index	Burst Index
0	46	34.36	3.742	1.4
15	44.5	33.48	3.832	1.28
30	42	27.99	4.062	1
45	40	27.08	4.517	0.825
60	35	21.5	5.032	0.62
75	31	22.21	5.108	0.445
90	27	18.72	5.197	0.266
100	26	17.18	5.22	0.18

TABLE 2: Various properties of blend SwHw2

S.N.	X, blend of	Y, properties	Regression equations	R2	Error	Residues (i,j)
1	SwHw1	°SR	$y = -0.059x + 32.937$	$R^2 = 0.9341$	-3.0,+2.0	-1.1,+1.0
2	Do	Tensile Index	$y = -0.0965x + 25.801$	$R^2 = 0.9018$	-6.4,+6.0	-1.6,+1.5
3	Do	Tear Index	$y = -0.0172x + 3.2104$	$R^2 = 0.9041$	-5.2,+7	-0.2,+0.3
4	Do	Burst Index	$y = -0.0075x + 0.9394$	$R^2 = 0.9475$	±10.7	-0.6,+0.2

Table 3: Various Linear Regression equations and Regressions coefficients, R2 as a functions of different parameters for blend between SwHw1 %

S.N.	X, blend of	Y, properties	Regression equations	R2	Error	Residues (i,j)
1	SwHw2	°SR	$y = -0.2167x + 47.68$	$R^2 = 0.978$	-4.4,+5.2	-1.7,+2.1
2	Do	Tensile Index	$y = -0.1773x + 34.515$	$R^2 = 0.9616$	-8.8,+4.9	-1.9,+1.7
3	Do	Tear Index	$y = -0.0171x + 3.7015$	$R^2 = 0.9325$	-3.8,+6.1	-0.2,+0.35
4	Do	Burst Index	$y = -0.0123x + 1.3956$	$R^2 = 0.9856$	-8.5,+8.0	-0.06,+0.03

Table 4: Various Linear Regression equations and Regressions coefficients, R2 as functions of different parameters for blend between SwHw2 %

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