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SIMULATION AND DEVELOPMENT OF LEAST COST BLENDS

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Abstract:

Shortages in fibrous raw material supply will force the industry to use a wide variety of raw materials and depend more on agricultural residues and annual plants. Blending of various raw materials and pulps will be attempted to get finish properties of desired qualities at least cost. The paper discusses a simple linear programming technique based on modified simplex method. The constraint equations are developed and tested on available data. With the informations on relative costs of different pulps least cost furnishes and propertions of constitutent pulps for the desirable property demands are predicted.

The Indian Paper Industry is facing an acture shortage of fibrous raw materials, particularly those from forest sources. The situation is likely to be worsened with an increase in capacity, decrease in forest cover and increase in environmental awareness. This will force the Industry to look at annual plants/agrucultural residues like rice straw, wheat straw and bagasse. The agricultural residues in general are short fibered in nature besides being seasonal. The difficult raw material situation will lead to lesser dependence on forest based superior fibres like bamboo and hardwood and greater dependence on agricultural residue fibers. Blending perforce will have to be adopted to meet the quality requirements and raw material position. It may be necessary to import costly long fibered raw materials/pulps/waste papers and add them to the indigenous forest/agriresidue pulps as reinforcing components. The most pertinent question therefore in today's context is how to choose a blend which will not only satisfy one property requirements in the finished paper but also be least costly.

The paper presents a simple and realistic solution to a complex problem faced in blending different refined pulps in a ratio which is minimum in terms of cost while satisfying the property requirements in the finished paper. The method of solution involves reducing blending into mathematically precise operations which are then solved for most efficient use of available resources. The basis is the assumption that the pulp produced from any species has its own physical and chemical characteristics.

The method of solution involves reducing the blending decisions into mathematically precise operations which are then solved for most efficient use of available resources. Linear programming can be used to obtain a solution to any types of mixing operation, whether it is mixing various raw materials for pulp or blending various pulps for a specific pulps.

In devising the problem it must be ensured that the basis or criterion chosen for optimising the operation most effectively measures or responds to optimality. Further the constraints within which optimisation is to be carried out must be set down. The objective and the constraints can be expressed mathematically as linear functions. The general form of the formulated linear programming problem is shown in Table (I).

Solution of this general type of linear programming problem is too tedious a job without fast computers especially when blending of more than three pulps are to be optimised. So, for different furnishes containing 2 to 6 different pulps each, problems were formulated and least cost blends were found out using software of modified simplex method on a supermini computer. The objective of the blending problem may be to maximise any specific property of a given paper or the contribution to profit and

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TABLE - I

Objective Function : $Z = C1 * X1 + C2 * X2 + \ldots Cn * Xn$

Z : Total relative cost of the furnish of pulp no. 1, pulp no. 2 etc.
n : Number of pulps taken for blending.
C1, C2 .... Cn : Reltive costs of pulp no. 1, pulp no. 2 etc.
X1 X2 .... X : Proportional amounts of pulp no. 1, pulp no. 2 etc.

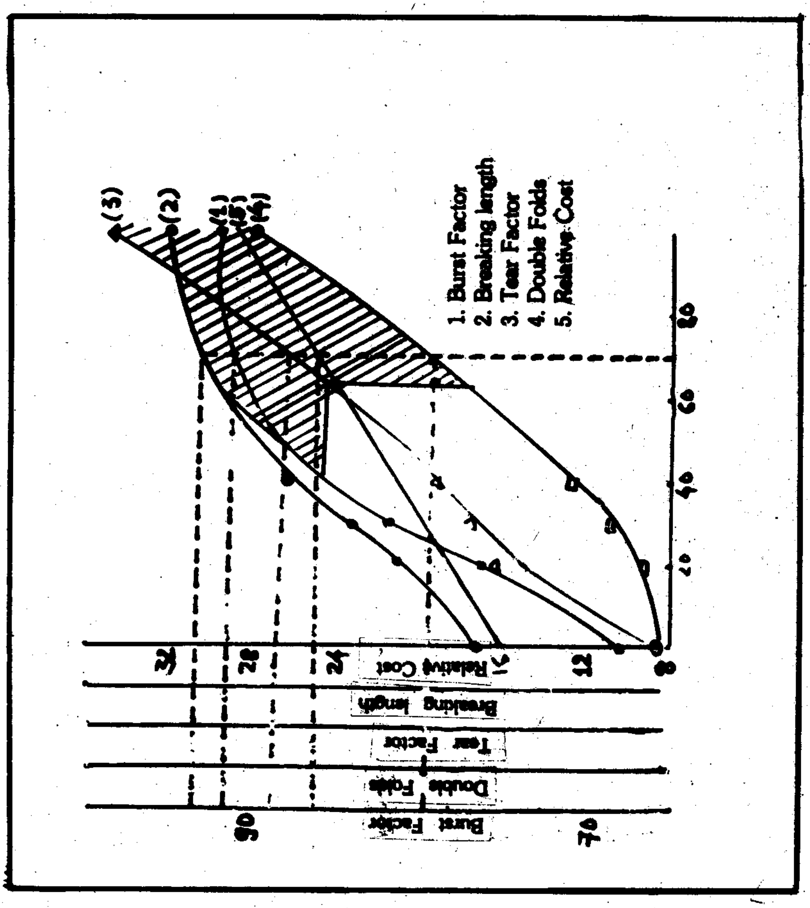
Constraints :
$X1 * D1 + X2 * D2 \ldots Xn * Dn \geq D$ mix (Minimum density requirement)
$X1 * B1 + X2 * B2 \ldots Xn * Bn \geq B$ mix (Minimum burst requirement)
$X1 * T1 + X2 * T2 \ldots Xn * Tn \geq T$ mix (Minimum tear requirement)
$X1 * S1 + X2 * S2 \ldots Xn * Sn \geq S$ mix (Minimum smoothness requirement)
$X1 * O1 + X2 * O2 \ldots Xn * On \geq O$ mix (Minimum opacity requirement)
$X1 * N1 + X2 * N2 \ldots Xn * Nn \geq N$ mix (Minimum tensile requirement)
$X1 + X2 \ldots Xn = 1.0$

The final equality constraint is necessary to assure that the sum of the proportions indicated in the solution equals unity.

TABLE - II

PROPERTIES OF THE BLEND OF BAMBOO (KRAFT) AND RICE STRAW (KRAFT) (1)

RICE STRAW	100	90	80	70	60	50	—
BAMBOO	—	10	20	30	40	50	100
Breaking length (metres)	2360	2840	3250	3840	4600	5100	6050
Burst Factor	10.5	13.5	17.6	21.6	25.0	27.4	30.0
Tear Factor	32.0	40.0	51.0	54.0	58.0	61.0	97.0
Double folds	2	2	3	7	12	14	50



1. Burst Factor
2. Breaking length
3. Tear Factor
4. Double Folds
5. Relative Cost
Relative Cost
Breaking length
Tear Factor
Double Folds
Burst Factor

TABLE - III

OPTIMAL LEAST COST BLEND AND THE PREDICTED PROPERTIES

OPTIMUM RATIO OF MIXING FOR LEAST COST BLEND

Bamboo = **71.8%** **Rice straw** = 28.2%

Properties	Predicted values	Experimentally obtained values
Burst Factor	24.50	29.2
Breaking length	5009.42	5600
Tear Factor	78.67	78.0
Double Folds	36.46	28.0

TABLE - IV

PROPERTIES OF THE BLEND BAMBOO, BAGASSE AND RICE STRAW (2)

	Free ness (ml.	Tensile Index CSF)Nm/g	Burst Index kpa.m^3/g	Tear Index mN.m^2/g	App. Density g/m^3	Drainage Time (Secs.)
Bamboo (Kraft)	300	55.0	4.0	11.2	0.66	6.75
Bagasse (Kraft)	115	57.5	4.1	4.65	0.89	27.2
Rice straw (Soda)	145	37.0	2.6	5.0	0.70	15.45

OPTIMAL LEAST COST BLEND AND THE PREDICTED PROPERTIES

Bamboo = 37.2% Bagasse = 42.6% Rice straw = 20.2%

Properties		Predicted values
Freeness	(ml. CSF)	189.88
Tensile Index	(Nm/g)	52.43
Burst Index	(Kpa.m3/g)	3.76
Tear Index	(mN.m2/g)	7.157
Apparent Density	(g/m3)	0.766
Drainage Time	(secs.)	17.29

TABLE - V

PROPERTIES OF THE BLEND OF BAMBOO, HARDWOOD, KENAF AND RICE STRAW (3)

	Freeness (ml. CSF)	Tensile Index Nm/g	Burst Index Kpa.m3/g	Tear Index mN.m2/g	App. Density g/m3	Drainage Time (secs.)
Kenaf (kraft)	275	97.5	6.3	10.0	0.79	13.32
Bamboo (kraft)	150	70.0	6.15	14.0	0.64	14.54
Hardwood (kraft)	185	69.5	4.25	7.54	0.72	10.29
Rice straw (soda)	175	34.0	1.85	3.90	1.85	14.12

OPTIMAL LEAST COST BLEND AND THE PREDICTED PROPERTIES

Bamboo = 28.6% Hardwood = 30.5% Rice straw = 21.5% Kenaf = 19.4%

Properties		Predicted values
Freeness	(ml. CSF)	190.3
Tensile Index	(Nm/g)	67.44
Burst Index	(Kpa.m3/g)	4.68
Tear Index	(mN.m2/g)	9.08
Apparent Density	(g/m3)	0.953
Drainage Time	(secs.)	12.92

overhead from a particular product line; or it may be to minimise production cost. The limitations may be of a minimum nature, such as a minimum acceptable characteristic of the resulting blend. The model assumes that a property of a paper made by blending several pulps will be strictly proportional to the amounts and properties of each pulp used. For many of paper properties, this may be approximately true, but some of the properties follow a nonproportional or curvilinear relationship. If these curvilinear relations ships are precisely known, they can be described mathematically as a series of segments. The accuracy of this description is controlled by the number of segments. One specific example is intended to demonstrate the linear programming method of decision making for a blending problem. The data reported for blending of bamboo and rice in different ratios were used (3); problems were formulated and these mathematically stated constraints and the objective function were processed in a computer. The properties of the optimal least cost blend were found to be fairly comparable to the experimentally obtained values for that blend (table 2). If the assumptions of linear related interactions were true, the predictions would be accurate. However if an interaction relationship proves to be linear, the curved relationship would then be segmented and the data obtained can be used for another computer solution.

Conclusions:

The primary objective in this paper was to demonstrate that Linear programming can be used to obtain the blends of least cost and minimum acceptable properties. this approach may not yield the accurate results if the cost factors entered are not true indicators of the actual cost of the pulps. In such cases the computer solution may yield a false optimum. Further it is possible that the properties under consideration might not respond in a linear manner over the entire range of weight fractions of individual pulps in the blend. In such cases it is required to find out the linear range in these properties and carry out the analysis in these regions. Another way would be to divide the nonlinear curve depicting the relationship into several linear regions and find out the optimal costs in each region and finally compare all the individual optimum solutions to find out the best among them.

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