Fiber Fractionation – A Unique Technique for making Quality Paper from Indigenous Raw Materials

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ABSTRACT

Fibre fractionation process utilizes maximum potential of the fibres and produces better quality paper by separating the fibres according to different fibre properties like fibre length, fibre coarseness, flexibility etc. This offers various options to produce paper with optimum properties for a specific application. This study covers the two major segments of the Indian paper industry, one which manufactures paper using hardwoods as a major raw material and another using agro residues. In both cases, the fiber fractionation followed by selective processing of each fraction proved to be a better option to produce paper of improved quality in terms of strength, optical and printing properties. Multilayer paper produced after fractionation of hardwood and agro residues pulp showed better surface strength properties. By using fiber fractionation process , it is possible to separate pulp fiber into several fractions of different fiber strength, fiber length, curl and kink indicies. This helps in using different fiber fraction of different grades of paper

Introduction

The production of paper, paperboard and newsprint in India as per estimates is expected to be around 22 million tonnes by 2025 from present production of 10.11 million tonnes. For a highly fragmented industry consisting of small, medium and large sized paper mills and constrained raw material availability, it seems a challenging task for the industry to meet the future paper demand. Since the availability of quality raw materials, especially wood and agro residues is a challenge, therefore effective utilisation of pulp fibers may offer option for better utilisation of the raw materials. Fractionation of pulps into long and short fractions has been reported as a good opportunity for wood and agro based mills to utilise their fibres properly (1-3). The present paper highlights the results of laboratory studies carried out at Central Pulp and Paper Research Institute, Saharanpur on the furnish collected from hardwood and agro based mills to explore the possibilities of better utilisation of raw materials after fractionation.

Fibre Fractionation A Unique Technique

The term " fractionation " is generally extended to ensure the separation of a fibre suspension into fractions according to any average property, including cell wall thickness, specific surface, bonding potential etc. Fibre fractionation is a specific application of screening with different objectives. It uses screen plates either with slots or holes combined with specific conditions suitable for fractionation, so that long fibers concentrate in feed side while short fibres are passed through the openings. The purpose of fractionation is to generate two pulp fractions with clearly differentiated qualities such as fiber length distribution or shive content. Fractionation of pulps, therefore separates the fibres according to different fibre properties like fibre length, fibre coarseness, flexibility etc. and offers the paper maker better options to produce paper with optimum properties for a specific application by controlling the refining conditions, use of additives, dewatering conditions at the wet end and draws in the dryer section. This concept is extensively employed in developed countries for wood pulps for making better quality paper.

The paper properties are dependent on fibre properties and it has been demonstrated qualitatively by several experimental studies (4-7) that fractionation can be used to separate different fibres and hence manufacture paper with improved characteristics. By fractionation it becomes possible to use better fraction for making improved quality paper. Fractionation prior to papermaking is the common practice abroad for paper manufacture from waste paper furnishes (8-9). Fractionation is an integral part of producing multilayer paperboard and corrugated containers from secondary fibre. In multilayer paper board manufacture, fractionation is used to produce a sheet that can be altered to fit the required properties (10-11) The short fraction can be used as filler in the centre of the sheet, while the long fraction can be used as liner stock. Adjustments may be made in the properties of long and short fractions to obtain desired characteristics. Similarly, in corrugated container, the short fraction is used as corrugating medium, while stronger long fraction is used for the liner (12).

Since the process of fibre fractionation followed by selective refining results in reduced energy consumption, improved strength and reduced fines generation, fractionation studies on hardwood and agro residue pulps, which are common furnish components in Indian paper mills, were evaluated systematically in this study to address quality related problems.

Experimental Methodology

Bleached pulp samples were collected

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from hardwood and agro residue based mills. The fiber furnish of hardwood based mill comprised of 70-80% mixed hardwood and 20-30%. bamboo pulp. Bleached pulp sample from agro based mill contained 90% wheat straw and bagasse pulp (mixed in the ratio of 60:40) along with 10% imported softwood pulp, which is a typical furnish of medium sized agro paper mills in India. The fiber fractionation of the pulps was carried out on laboratory Bauer McNett fiber classifier. The pulps were beaten in PFI mill as per ISO 5264/2-1979 (E) method. The handsheets, prepared on British handsheet former according to **ISO 5269-1** method, were conditioned (temp, ±271°C; relative humidity, 652%) prior to testing. The following tests were carried out as per standard methods: (i) Thickness, ISO 534:1988 (E); (ii) Tensile strength index, ISO 1924-2:1994 (E); (iii)Tearing strength index, ISO 1974:1994 (E); (iv) Burst strength index, ISO 2758; (v) Specific scattering coefficient, SCAN C 27-69; (vi) Folding endurance, ISO 5626:1993(E); (vii) Fiber rising test, using Fiber Rising Tester; (viii) Fiber strength index, using Pulmac short span tensile tester; (ix) Kink index, using Fiber quality analyzer; and (xi) Curl index, using Fiber quality analyzer.

Results and Discussion

1. Selection of Fiber fraction of Hard wood & Agro Residue Pulps Using Baur McNett Fiber Classifier

For hardwood/bamboo pulp Bauer McNett classification indicated that +50 fraction (mesh opening 0.297 mm) in this pulp mixture is about 45% and +30 fraction (mesh opening 0.595 mm) is about 20%. The amount of fines (passing 200 mesh) in whole pulp is about 20 - 25%. Based on Baur McNett results, the pulp was separated into following two groups of fractions: (i) Retained on +50 mesh and passing 50 mesh (ii) Retained on +30 mesh and passing 30 mesh for further studies.

For agro residue pulp, Bauer McNett fibre classification indicated that +50 fraction in such pulp is about 40%. Typically +50 mesh retains fibres of average length 1.23 mm which is a typical range of straw and bagasse fibres. In fractionation, the mesh size is preferred to be selected in such a way that two fractions obtained are in about equal quantities. Thus to study the behaviour of agro residues pulps the pulp was separated into two fractions (*i.e.* retained on +50 mesh and passing -50 mesh) on Bauer McNett fibre classifier for further studies.

2. Studies on the strength improvement of fractionated pulp

(i) For pulp collected from hardwood based paper mill

(a) +50 and -50 Fraction:

The pulp fractions collected after fractionation of +50 and -50 fractions were subjected to PFI beating and hand sheet making in the laboratory. Evaluation of handsheets showed that the development of bonding strength characteristics (tensile, bursting strength) on beating at a particular apparent density level is more for +50 fractions than -50 fractions (Figs. 1, 2). The behavior of the tearing strength also showed the same trend (Fig 3). Specific scattering co-efficient, which is an important property for printing grade paper, as it affects opacity and print through, is also improved if pulp is fractionated and treated separately (Fig 4). This is probably due to a better refining action received by the fibers when refined separately after fractionation in comparison to the refining of the both fraction as a mixture in one pulp.

(b) +30 and -30 Fraction:

Similar Studies were carried out on + 30 and -30 fractions of mixed hardwood pulp. Results show that similar to +50 and -50 fractions, the development of tensile strength and bursting strength on beating is more for +30 fraction. However, it is interesting to note that the trend of tearing strength of +30

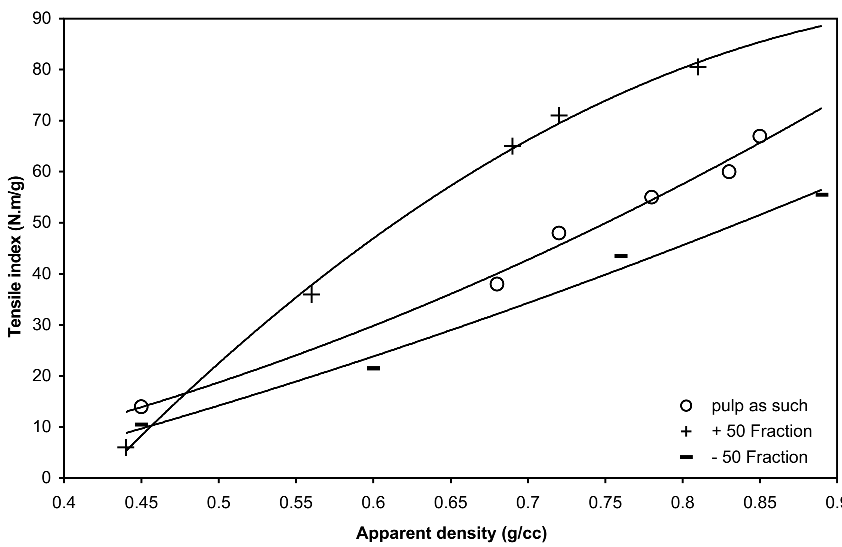

Fig 1: Development of tensile index on beating of as such and different fractions of pulp containing 70-80% hard wood pulp and bamboo 20-30%

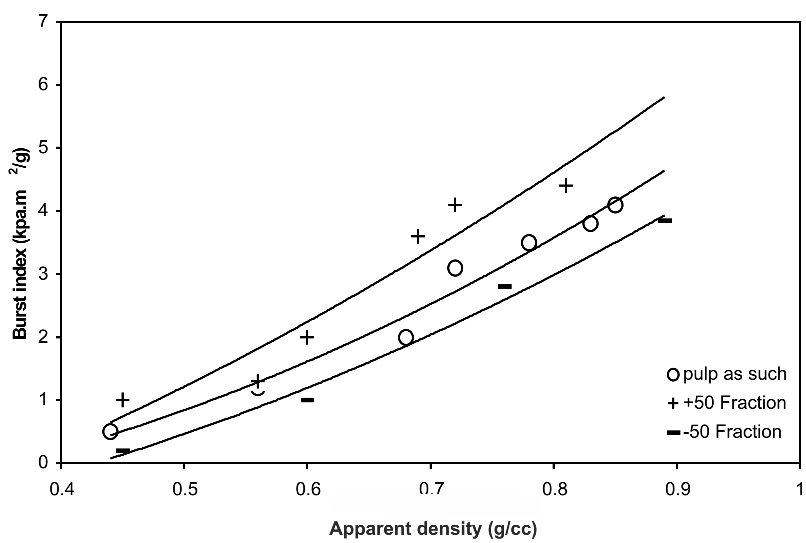

Fig 2: Development of burst index on beating of as such and different fractions of pulp containing 70-80% hard wood pulp and bamboo 20-30%

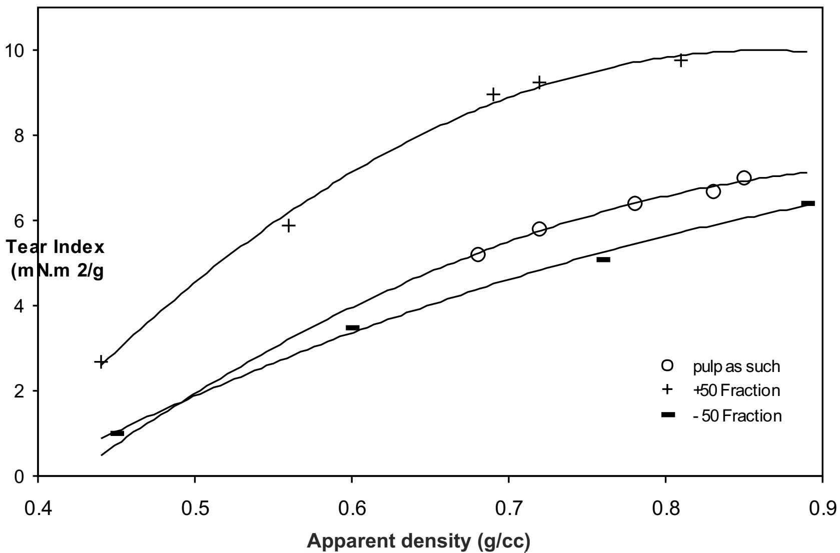

Fig 3: Development of tear index on beating of as such and different fractions of pulp (+50 & -50) containing 70-80% hard wood pulp and bamboo 20-30%

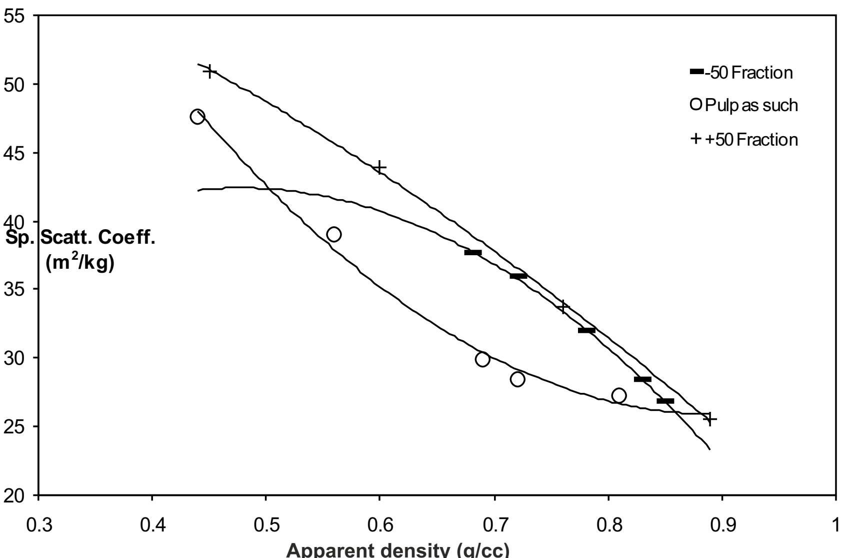

Fig 4: Effect on sp. Scatt. Co-eff. with beating of as such and different fractions (+50 &-50) of pulp containing 70-80% hard wood pulp and bamboo 20-30%

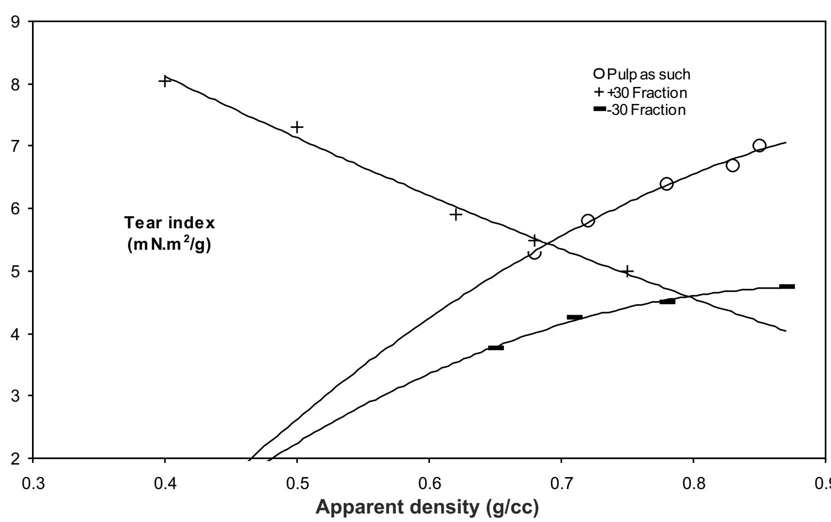

Fig 5: Development of tear index on beating of as such and different fractions (+30 & -30) of pulp containing 70-80% hard wood pulp and bamboo 20-30%

fraction is entirely different than that observed for +50 fraction. The behavior is similar to softwood pulp (Fig.5). This indicates that such fractionation would only be useful for producing packaging grade of paper where tearing strength and tensile energy absorption properties are important. However, the amount of + 30 fraction is only 20% in the pulp furnish, so it is advisable for pulps furnish containing hardwood /bamboo, to fractionate into +50/50 fractions which is more feasible compared to +30/30 fractions. The effect on specific scattering co-efficient reduction on beating was found to be relatively lower in case of +30 fractions than other wood pulps.

(ii) For pulp collected from agro residue based paper mill

(a) +50 and -50 Fraction:

The analysis of results of hand sheet prepared for +50, -50 Fraction of agro residue pulp also indicated that the development of bonding strength characteristics (tensile, bursting strength), tear strength and specific scattering co-efficient on beating at a particular apparent density level was more for +50 fraction than -50 fraction. This is probably due to a different impact of refining action on the fibres when treated separately than as a mixture. The non-fibrous component which is more in (-50) fraction has little contribution to specific light scattering co-efficient.

3. Studies on handsheets made using unfractionated pulp and fractionated components

(a) For pulp collected from hardwood based paper mill

In order to improve the quality of paper, studies were conducted to prepare handsheets using un-fractionated and fractionated components of pulp in different combinations and refining action .Two possibilities of making paper from the fractionated pulp were selected. One is refining the two fractionated fractions separately and then mixing to form a paper sheet. The second approach, which is generally preferred, is to make different grades of papers on different paper machines. For the first approach following three possibilities were examined: (i) Sheet prepared using as such pulp; (ii) Sheet prepared using +50 fractions beaten to 450 CSF and –50 fraction beaten to 300 CSF and mixing to get blend around 350 CSF; and (iii) Multilayered sheets prepared using +50 and -50 fractions. The –50 fraction was kept between two

Table 1 Characteristics of handsheets refined as such and after fractionation (+50/-50) and blending for bleached pulps (hardwood/bamboo and agro residue)

Characteristics	Hand sheets from Wood/Bamboo pulp			Hand sheets from agro pulp	
	As such (Hand sheet made from unfractionated pulp)	After fractionation		As such	After fractionation
		Single layered sheet	Multi layered sheet	Hand sheet made from unfractionated pulp	Triple layered hand sheet*
Freeness, CSF, ml	370	390	390	320	320
Specific scattering coefficient, m^2/kg	28.4	29.9	29.2	29.0	30.0
Apparent density, cm^3/g	0.83	0.80	0.81	0.81	0.78
Tensile index, N.m/g	57.0	66.0	67.0	42.5	47.5
Tear index, $mN.m^2/g$	6.50	7.50	7.55	4.50	4.80
Burst index, $kPa.m^2/g$	3.80	4.00	4.10	2.50	3.10
Porosity, Bendtsen, ml/min	430	450	410	118	167
Double fold, Nos.	62	69	72	12	20
Vessels pick No, No. per 2000 mm^2	20	10	5	45	15
Fiber Rising Test					
LRC, mm/m	2.647	1.668	0.998	6.831	1.040
TRA, mm^2/m	0.87	0.27	0.17	1.210	0.355

N.B.:*Triple layered hand sheet was formed by sandwiching (-50) fraction between two layers of (+50) fraction

layers of +50 fractions.

The results in Table-1 indicate that the better paper characteristics are obtained when sheet is prepared using last two approaches. There is an increase in tensile index (15%), tear index (15%) and burst index (5%) of single layered sheet prepared after recombining the +50 and 50 fractions as compared to unfractionated pulp. Similarly, multilayered sheets, formed by keeping shorter fraction between two layers of longer fractions showed increase in tensile index (17.5%), tear index (16.2%) and burst index (8%) in comparison to unfractionated pulp. This indicated that better strength packaging grade paper could be produced from fractionated pulp. During the fractionation of pulp, the vessels pick number and fiber rising characteristics, which are indicative of fluff problems on paper machine dryers and on printing press, were reduced. Thus lower vessel pick number and fiber rising characteristics indicated the possibilities of reducing the fluff problem on papermaking dryers and on printing presses. The second approach can be utilized in making different grades of paper on different machines. e.g it can enable paper makers to produce paper with higher surface strength like lithographic grades on one machine and paper like copier and other printing grades which comparatively have low surface strength on another machine.

(iii) For pulp collected from agro residue based paper mill

Similar to hardwood pulps, trials were taken on un-fractionated and fractionated pulp fractions of agro residue pulp for the manufacturing of quality paper. The hand sheets were made using the following approach.

- Making single layered sheet from unfractionated pulp as such with mild refining to 350 ml CSF
- Refining the (+50) fraction only and making triple layered sheet with unrefined short (-50) fraction

In triple layered sheet, the unrefined short (-50) fraction which was rich in fines content was sandwiched between two long (+50) fraction layers. Handsheets so formed on testing indicated that bonding properties (*i.e.* tensile index, burst index, folding endurance) were improved when triple layered sheet formation was adopted (Table-1).

In offset printing, the major problem observed with papers containing agricultural residues pulps is loosely bonded fibres getting picked out or raised form the sheet matrix. This is generally graded by vessel pick number and fibre rising number which includes long rising component (LRC) and total rising area (TRA) of fibres. The lower values of these are preferred for good printing. The vessels pick number and fibre rising values *i.e.* LRC and TRA got reduced appreciably in triple layered sheet (Table-1). This indicated that paper having better printing quality could be made using this approach.

4. Characteristics of different pulp fractions and their suitability for different grades

The curl index, which indicates about the curvature of fibers, is the ratio of the true contour fiber length divided by the projected length of fiber minus one. The kink index indicates the abrupt change in fiber curvature. The fractionation of the pulp has helped in getting the pulp components having different fiber length, kink index and curl index. The different pulp fractions obtained from fiber fractionation were studied for different fiber characteristics like curl index, kink index, fiber length and Fiber Strength Index. The results for hardwood pulp and agro residue pulps are tabulated in Table-2. Results in Table-2 indicate that it is possible to make paper of different grades using different fractions of mixed hardwood furnish. Generally pulps with high curl and kink indices produce paper of high tear strength, bulk, wet web stretch, porosity and absorbency. However, high curl and kink give paper of lower tensile strength, bursting strength and bending stiffness.

Similarly, for agro residue pulps, the different fractions of pulp were analyzed for fibre characteristics, fibre strength index and presence of vessel and parenchyma elements (Table-2). The fibre strength index, which is indicative of intrinsic strength of fibres, was more in +50 fraction (12.0 km) than –50 fraction (6.0 km). This indicates that paper having high tear strength could be manufactured using longer +50 fraction. The vessel and

Table 2 Fiber Characteristics of unfractionated and fractionated pulp samples of bamboo/hardwood and agro residue pulps

Pulp/fraction		Fiber length (mm)	Fiber width (µm)	Fines Content (%)	Kink Index (1/mm)	Curl Index	Fiber Strength Index (Km)	Paren-chyma and vessel elements
Unfraction-ated pulp	HW/ bamboo	1.47	16.0	15.3	1.50	0.13	11.1	-
	Agro residue	1.10	15.5	24.0	2.83	0.19	8.0	-
Long fraction (+50)	HW/ bamboo	1.55	16.0	14.3	1.60	0.14	10.2	-
	Agro residue	1.37	17.1	1.8	3.09	0.24	12.0	Little
Short fraction (-50)	HW/ bamboo	1.43	15.5	16.5	1.20	0.11	8.5	-
	Agro residue	0.70	16.3	31.3	2.88	0.17	6.0	Excessive

parenchyma elements were relatively lower in the case of +50 fraction as compared to -50 fraction. The +50 fraction was observed to have high curl and kink indices as compared to -50 fraction. The high curl and kink indices generally have positive influence on the bonding of fines and fibres

Conclusions

Fiber fractionation followed by selective processing of each fraction for hardwood/bamboo furnish is a better option to produce paper of improved quality in terms of strength, optical and printing properties. Paper of better surface strength can be prepared if multi layered sheet is prepared keeping short fraction between two layers of longer fraction. The short fraction showed lower vessels pick number and fiber rising tendency. This indicated less fluff-generating tendency at paper machine dryers and printing press. The behavior of +30 fraction from such furnish is similar to softwood pulp indicating that better tensile energy absorption and tearing strength properties can be attained which are the requirement of good quality packaging paper. The separations of above furnish into fractions of +50 (mesh opening 0.297 mm) and 50 should be preferred to +30 (mesh opening 0.595 mm) if the mill is interested to manufacture writing and printing grade paper. By fractionation, the development in bonding strength characteristics (tensile, bursting) at particular apparent density level can be improved. This is due to separation of fibers having different fiber length, curl and kink index.

For ago residue pulps , fibre fractionation followed by triple layered paper formation with longer fraction sandwiching the fines rich fraction in between, is an option to produce paper of improved quality from agricultural residue pulps. Paper of better tensile strength, tear strength, bulk, stiffness and surface strength can be prepared using the proposed technique

References

1. Sood Y. V., Tyagi Sanjay, Payra, I; Neeti Kumar, Tyagi Renu, Kr. Ashwani & Kulkarni, A.G., " Fiber Fractionation as a tool for making better quality paper from agricultural residue pulp", *Cellulose Chemistry & Technology*, 41(1), 79-85, (2007).
2. Sood Y.V. Pande P.C, Tyagi Sanjay, Payara I, Nisha and Kulkarni A.G., " Quality Improvement of paper from bamboo and hardwood furnish through fiber fractionation", *Journal of Scientific and Industrial Research* (NISCIR), Vol 64, April 2005.
3. Seth, R. S., 'Fiber quality factor in paper making' The importance of fiber length and strength, materials interactions relevant to the pulp, paper and wood industries." Caulfiels, Passasett, Sobezyriski (ed) Research Society symposium proceedings, San Fransisco, California USA, Vol 197 (1990).
4. Paavilainen, L., 'Influence of fiber morphology and processing on the softwood sulphate pulp fiber and paper properties' Doctoral thesis, Laboratory of Pulping Technology, Helsinki University of Technology, Helsinki, p 155 (1993)
5. Seth, R, Jantunen. J, Mass. C., 'The effect of grammage on sheet properties', *Appita* 42, p 42 48 (1989)
6. Selfa, P and Long, K. J., *Tappi* 57(10), p 69 (1974)
7. Bliss, T.I., 'A study of fiber fractionation using centrifugal cleaners' M.S. thesis Miami University, Oxford OH, (1983).
8. Mureselmam, W., *Pulp and Paper* 57(8), p125(1983).
9. Bliss, T.L., *Pulp and Paper* 61(2), p104 (1987).
10. Kostka, A., Carsky, M., 'Trends in improving mechanical and optical properties of secondary fibers', Proceedingof Conference on secondary fiber utilization, Bristol, British Paper and board Ind. , Feb (1977).
11. Behera, N. C., Basu, S., 'Studies on the improvement of pulp strength by fiber fractionation and blending technique., *Appita* 34, No. 6, p485 - 491 (1981).
12. Clark, B., Eastwod, F. G., Voss, G. P., ' Laboratory upgrading of waste paper by fractionation either alone or in combination with chemical and mechanical treatment., Pira Report, PB 13 (R); 1978/PM 4837(1978).