PEER-REVIEWED FRACTIONATION

OCC pulp fractionation–A comparative study of fractionated and unfractionated stock

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ABSTRACT

This study sought to determine the optimum conditions required for a operating laboratory pressure screen in the fractionation of old corrugated container (OCC) pulp and then applied the findings. The long fiber fraction was refined with a laboratory scale refiner and re-mixed with the short fiber fraction. The resulting furnish was termed "recombined stock." The strength properties of the recombined stock (fractionated stock) were measured and compared with those of refined feed stock (unfractionated stock). We observed that the overall strength properties of refined feed stock are higher compared to the recombined stock. However, separate refining has brought savings in refining energy.

This paper discusses the papermaking potential of different fractions of OCC pulp in general, with a focus on detailed comparisons of between recombined and refined feed stocks.

Application: Mills could save raw material, energy and capital by using this information.

Key words: Fractionation, recombined stock, refined feed stock, accept fraction, reject fraction, strength properties, energy, refining, fines

Linerboard is produced with various top plies and from various raw materials. If it is produced from virgin fibers is usually called kraft liner, whereas recycled fiber containing linerboard is called test liner. The medium is a single-ply product. The medium is formed into a fluted (wavy) structure and sandwiched between two plies of linerboard to form the corrugated board for boxes. The corrugated container has had a high degree of recycling for many years. The major problem with recycling of old corrugated container (OCC) is loss of its strength properties. Fractionation has potential to upgrade the fiber supply and to enable the production of higher value paper grades provided that the correct formulation has been found. One process in fractionation of OCC pulp is to fractionate the OCC pulp into long and short fiber fractions. Once fractionated, the long fiber fraction is refined and recombined with the short fiber fraction to produce a new stock. Findings of different laboratories on papermaking quality of the recombined stock are, however, contradictory [1-3].

Musselmann [1] reported gain in strength, freeness, and energy for separate refining of long fiber fraction and recombining with short fiber fraction. Observations of Nazhad and Awadel-Karim [2] and Sloane and Weinberg [3], up to a certain degree, are inconsistent with the results reported by Musselmann [1]. The authors [2-3] reported that the gain in strength was the highest for the refined feed stock compared to the recombined stock (i.e., the refined long fiber fraction and mixed with short fiber fraction).

A major focus of the work presented here is to assist in settling the on-going debate about whether refined feed stock or recombined stock provides better strength properties for OCC pulp. The issue was addressed by comparing strength properties of the two processes.

MATERIALS AND METHODS

Materials

Raw material for this experiment was 100% European OCC. The pulps were collected from the thickener before the thickening stage. The consistency of the pulp at the thickener was 4%.

Methods

The objective of the experimentation was to compare the papermaking quality of the recombined stock with the refined feed stock. However, the pulp characteristics and papermaking potential of each fraction were tested and compared with feed stock as well. In addition, the fiber length distribution and fines content of the stock at each stage of experimentation was measured and compared for two reasons: a) to evaluate the fractionation potential of the laboratory pressure screen; b) to estimate the amount of fines generated in separate processing of OCC pulp. The details of the experimentation plan are reported in Appendix A.

Fractionation

The pulps were fractionated with a Valmet pressure screen (TPA031) to separate the fibers into short and long fiber fractions. The fraction retained on the screen plate and that passed into the reject stream is called long fiber fraction (LF) or reject fraction. The part passing through the screen plate is called short fiber fraction (SF) or accept fraction. We followed the optimum operational conditions for laboratory presure screens reported by Sodtivarakul [4]. In summary, the author [4] reported that at 0.2-mm slot width, the screen performed better (i.e., without plugging) when the consistency, reject rate, and RPM were set at 0.9%, 50%, and 960 RPM, respectively.

Handsheet formation

Handsheets were made from six groups of pulps. Those included feed stock (inlet pulps), short fiber fractions, long fiber fractions, refined long fiber fractions, refined feed stock, and recombined stock (i.e., refined long fiber fraction that was remixed with short fiber fraction). Handsheets with a basis weight of 125 g/m^2 were made using a laboratory Finnish handsheet former, then pressed and dried according to SCAN-C 26:76.

Pulp and paper properties

The pulp was refined in the PFI mill according to SCAN-C 24:67 standard. The target freeness to compare the recombined stock with the refined feed stock was set to be 300 mL (CSF). The fiber length was measured using a Kajaani FS-200. The average coarseness was measured with a new process [Appendix B] using the Kajaani FS-200 The pulp was fractionated using a Bauer McNett fractionator according to SCAN-M 6:69 standard.

All paper properties were measured according to SCAN standards. Burst, tensile, tear, ring crush, short span compression, and roughness were measured according to SCAN-P 24:77, SCAN-P 16:76., SCAN-P 11:73, SCAN-P 34:71, SCAN-P 46:83 and SCAN-P 21:67 standards, respectively. The data were analyzed using SPSS statistical software.

RESULTS

Characteristics of feed stock

Table I shows the characteristics of the feed stock (OCC pulp). The length weighted average, the average coarseness, and the freeness of the feed stock are 1.10 mm, 0.17 mg/m, and 490 mL (CSF), respectively. Table I includes the fiber distribution of the OCC pulp.

Table I. Characteristics of feed stock (European OCC).

Feed Stock	Length Weighted Average [mm]	Coarseness [mg/m]	Freeness [CSF]	Fines Content [%]
European OCC	1.10	0.171	490	18
Length distribution of European OCC pulp using Bauer McNett (%) Fractionator				
R30	R50	R100	R200	P200
37.8	22.5	11.5	10.2	18

R: retained on the screen; P: passed through the screen

Effect of fractionation on pulp properties

Table II shows the pulp characteristics of the fractions. The freeness and fiber length of reject fractions were higher than those of feed stock by about 16% and 21%, respectively. The mass split ratio of accept to reject was 28:72.

Table II. Screening conditions and fractionation results.

	Feed Stock	Accept (SF)	Reject (LF)
Slot Width [mm]	0.2		
Reject Rate [%]	50		
Rotor Speed [RPM]	960		
Consistency [%]	0.90	0.56	1.22
Freeness [CSF]	490	190	570
Fiber Length [mm]	1.10	0.87	1.33
Volume [mL]	-	39,142.8	46,710.3
Weight [g]	-	219.2	569.9
Mass Split Ratio	-	28	72

Figure 1 shows fiber distributions of accept and reject fractions compared to original feed stock. The screen with 30 mesh shows that almost half of the reject stream (47%) was retained on the screen (Fig. 1). The share of the accept is minimal, almost 13% compared to feed or reject. For the rest of the screens, except for the fines fraction, the distribution was almost the same (Fig. 1). For the fines fraction, the fines content of the accept stream is the highest (about 40%). The fines content of the accept fraction is almost three times higher than the reject fraction (Fig. 1). This observation indicates that the laboratory pressure screen is capable of separating pulp into long and short fiber fractions.

Effect of fractionation on strength properties

If OCC pulp is separated into two components, the reject fraction generally has higher freeness and contains long fibers, the accept fraction has low freeness and contains short fibers. Fractionation causes a decrease in strength properties of the reject fraction, excluding tear strength (Table II). Unlike the reject fraction, the handsheets made from the accept fraction showed higher density, higher strength (except for tear), and higher smoothness (**Table III**).

Table III. Comparison of strength properties of feed stock and accept and reject fractions.

Properties	Unit	Feed Stock	Accept (SF)	Reject (LF)
Fiber Length	[mm]	1.1	0.87	1.33
Coarseness	[mg/m]	0.171	0.137	0.182
Freeness	[CSF]	490	190	570
Refining @ 30 g.	[Rev.]	-	-	-
Density	[kg/m^3]	539	610	507
Burst Index	[kPa m^2/g]	3.01	3.03	2.91
Tensile Index	[Nm/g]	30.1	33.6	29.3
Elongation @ Break	[mm]	2.8	3.3	2.2
Stiffness Index	[MNm/kg]	3.2	3.4	3.6
Ring Crush	[N]	136	160	126
Tear Index	[Nm^2/kg]	6.95	4.72	7.81
Scott Bond	[J/m^2]	211	377	172
SCT Index	[Nm/g]	14.7	18.2	13.6
Roughness	[mL/min]	2442	1800	2552

Figure 2 compares the strength properties of accept and reject handsheets. Accept handsheet were 20% higher in density, 4% higher in burst index, 15% higher in tensile index, 27% higher in RCT, and 50% higher in Scott bond than reject handsheets. The tear index for the reject fraction was almost 40% higher than the accept fraction. A similar trend was observed earlier [5].

The higher strength properties for the accept fraction might be related to the separation process by pressure screen. The accept population is probably comprised of short but flexible and finer fibers, which all contribute on development of the paper strength, while the reject fraction should be composed of long but stiff and coarse fibers. The higher percentage of fines component in the accept fraction should be another reason for higher strength of the accept fraction. Morgan [6] reported that the particulate fines found its way in the reject stream, while the fibrillar fines joined the accept stream during the fractionation process. The author [6] observed that the fibrillar fines increase the strength, but the particulate fines reduce strength. The influence of the size and shape of fines on strength properties of paper was also highlighted by Retulainen et al. [7].

Effect of refining on strength properties of feed stock and reject fraction

Recycled fibers are usually stiff, less flexible, and lower in bonding potential, which results in lower strength properties. Refining is one of the options to improve strength properties if loss in pulp drainage due to refining is tolerated. **Figure 3** shows the increase in strength properties for feed stock and reject fraction after refining. The reject fraction is refined to 340 mL (CSF), the feed stock to 300 mL (CSF).

All the strength properties for the feed or reject were increased after refining except for tearing resistance. In general, the reject fraction has higher papermaking quality than the feed stock after refining. This indicates that the reject fraction of the OCC pulp has potential to produce higher grade products at higher freeness, provided that a suitable application was recommended for the short fiber fraction. This observation has been reported earlier, as well [5].

Papermaking potential of recombined stock

The recombining process means that the reject fraction was refined and mixed with accept fraction at the same mass split ratio (reject/accept: 72/28). Then, the papermaking properties of the recombined stock were compared at the same freeness value (300 CSF). The summary of the differences in performance of both stocks are reported in Appendix C.

Fiber chararacteristics of the recombined stock

Figure 4 shows fiber distribution of the recombined pulp and refined feed stock. The fines content of recombined pulp is about 9% lower than that of refined feed stock. Except for the fraction R30, the rest of the fractions show higher fiber content (Fig. 4). Figure 4 suggests that the two pulps are different in two important properties: fiber length distribution and fines content.

Burst index of recombined stock

Burst strength is an important requirement for corrugated container. Burst strenght indicates resistance of a container to external and internal mechanical stresses. **Figure 5** shows the development of burst index for refined feed stock and recombined stock. The burst index of refined feed stock is slightly higher than that of the recombined stock. It confirms that the burst strength does not benefit from separate processing. Figure 5 also indicates that there is no difference in burst strength between the accept and the reject fraction before refining, except that the freeness for the reject fraction is 3 times higher than the accept fraction (Fig. 5).

The increase in burst strength for the refined long fiber fraction is not significant compared to the refined feed stock (Fig. 5). However, the refined reject fraction has higher freeness than the recombined or refined feed stock. Therefore, the refined reject fraction has potential to be developed further, depending on the requirements of the end products.

Tensile index of recombined stock

Tensile strength is used widely to characterize the mechanical properties of paper and board, although it has no direct significance. Paper and board are seldom loaded to tensile failure. In assessment of board strength, it is barely relevant, but it is customary to report because of its bearing on compressive strength and its easy measurement procedure.

The tensile strength for refined feed stock is slightly higher than the recombined stock. The refined reject fraction is barely different from refined feed stock, but it has potential to be refined further because of its higher freeness. (**Fig. 6**). Similar observations were previously reported [3]. Figure 6 also demonstrate that the unrefined accept fraction has higher strength than the unrefined reject fraction.

Ring crush test of recombined stock

Fiberboard shipping containers are frequently subjected to loads, which are resisted by compression strength, making this property an important measure of the performance of corrugated board. Since edgewise compression strength can be estimated by a summation of the ring crush values of the liner and medium, then this test becomes an informative test for containerboard-makers. **Figure 7** shows that the compressive strength for the refined feed stock is slightly higher than the recombined stock and the refined reject fraction (i.e., about 3%). Although the difference is not significant, it shows that the recombined stock has no visible advantages if the product requires a higher compressive strength. The accept fraction demonstrates significant gain due to fractionation per se (Fig. 7).

Short span compressive strength of recombined stock

There is a considerable difference between the short span compression test (SCT) and other compression tests. The samples in testers such as RCT fail because of the combined effect of buckling and compression, while the sample failure in the SCT occurs only because of compression. This is owing to the fact that the SCT tester is capable of using a span length as short as 0.7 mm. **Figure 8** shows the influence of fractionation on compressive strength using the SCT tester.

Similar to the RCT results, fractionation did not improve compressive strength as measured using the SCT (Fig. 8). The refined feed stock is slightly (i.e., about 7%) higher in compressive strength, compared with the recombined stock The compressive strength of refined feed stock is the same as the refined long fiber fraction, except that the refined reject fraction is higher in freeness (Figure 8).

Scott bond of recombined stock

Scott bond measures the ability of paper or board to withstand tensile stress in the z-direction. In board manufacture, the importance of z-direction strength was always highlighted. For this reason, the z-direction strength was quite often reported as an indicator of the container board strength quality. Higher z-direction strength is highly appreciated in offset printing and in core products. **Figure 9** shows the effect of fractionation on z-direction strength of the OCC pulp.

The z-direction strength was considerably higher (i.e., about 14%) for the refined feed stock compared with the recombined stock. It also competes with z-directional strength of the refined long fiber fraction (Fig. 9). Similar to other strength properties, except for tear, the z-direction strength was higher for the accept fraction than that of the reject prior to refining (Fig. 9).

Tear index of recombined stock

Tearing resistance is traditionally used as an indicator of paper runnability, even though no valid correlation between tearing resistance and frequency of web break has been reported. **Figure 10** shows the development of tear index after fractionation and refining. The tear strength for the recombined stock is not different from the refined feed stock. However, the strength of the reject fraction is significantly higher than either the recombined or refined feed stock (Fig. 10).

Overview of the recombined stock performance compared with refined feed stock

Figure 11 shows the overall quality performance of recombined stock compared to the refined feed stock. In general, the strength properties of the recombined stock are lower than those of the refined feed stock, except for the tear strength (Fig. 11).

Based on the experimental conditions practiced in this investigation, the present observations confirm that the recombined process is not a viable practice and hardly could be recommended for paper or board makers as an option for upgrading OCC pulp.

Energy consumption for separated refining compared with full-stream refining

One of the advantages of fractionation, which has been frequenly reported [1, 8], is its energy savings potential. The net specific energy consumed for refining the feed stock and reject fraction was calculated using the power consumption curve for the PFI mill [9]. Net refining energy required for fractionated pulp was 207 kWh/ton and that of the feed stock was 256 kWh/ton. Therefore, fractionation has brought about a 20% savings in energy. The gain in energy has not been corrected for the energy consumed in the process of fractionation. Therefore, it is inferred that the real savings in energy should be less than the calculated value. It could even be a complete trade-off with the energy consumed for the fractionation process. A similar cautious approach in evaluating the energy cost was also recommended by earlier researchers [3].

Fines content of recombined stock compared with the refined feed stock

Figure 12 compares the fines content of the refined reject fraction and refined feed stock before and after refining. The fines produced from refining were almost 8% more for the feed stock compared to the reject fraction. This observation is opposite of what has previously been reported on the influence of two different processes on fines generation [2].

The reason for this might be sought in the refiner type. The laboratory PFI mill refiner works at medium consistency. At this consistency, especially with the specifications of PFI mill, we would expect that the fibers, regardless to their length, receive almost the same share of refining.

DISCUSSION

The major focus of this study was to compare and contrast the strength properties of the recombined stock (i.e., refined long fiber fraction mixed with short fiber fraction) with the refined feed stock. The observations, in general, suggest that the refined feed stock yields better quality products (i.e., strength quality). In other words, the recombining process has no gain compared to the refined feed stock (Fig. 11). Nazhad and Awadel-Karim [2] reported similar observation using a Bauver McNett fractionator and Valley beater in preparation of the recombined stock. Both of the experiments were conducted at the laboratory scale, but using different factionators (laboratory pressure screen vs Bauver McNett) and different refiners (Valley beater vs PFI mill). In spite of the differences in the mode of action of the fractionators or the refiners, the results display similar trends. Sloane and Weinberg [3] used a laboratory Packer screen and an Escher Wyss refiner for producing recombined stock. Their observations were similar to the findings of the present work. Using different accept-to-reject ratios (i.e., 78/22; 63/37; 51/49) to produce the recombined stock did not alter the trend [3]. Therefore, it is plausible to assume that the recombined stock has no gain in strength compared to the refined feed stock. However, the observations reported by Musselmann [1] is inconsistent with the findings of the present work. The author [1] conducted a project at the laboratory scale as well, using Bauer McNett and Jorko refiners.

The savings in energy, before its correction for the energy required in fractionation, was about 20%. However, the net energy might be less significant after correction for the energy consumed in fractionation. In addition, the energy savings should be a function of the reject-to-accept ratio in fractionation. The energy savings is expected to be the highest for the lowest reject-to-accept ratio.

The refined feed stock generated more fines compared to the recombined stock (Figure 12). This is opposite to what has previously been reported [2]. The differences in the observations were attributed to the differences in consistencies required for the refiners and the mode of action of the refiners. The pulp in a PFI mill is refined at 10% consistency. We would expect the pulp refined with a PFI mill to receive more a homogeneous refining effect than the pulp refined by Valley beater. The required consistency for a Valley beater is about 1.5%. At low consistency, the refining effect on the pulp happens through the flocs. The flocs are expected to be governed by longer fibers. Therefore, the longer fibers experience more refining than the fines. Therefore, it is plausible to assume that the differences in generation of fines, in the process of refining, might be related to both consistency of refining and mode of action of the refiners.

Fiber fractionation provides a renewed fiber resources and new challenges for a better use of the new products. The better strength and smoothness (Fig. 2 and Table III) for the accept fraction, compared to the reject fraction or the feed stock prior to refining, make it suitable for products that require better smoothness or printability. The reject fraction, due to its higher drainage, has potential to be improved to a higher quality pulp. However, a better use of these renewed resources also requires multiple production lines, which allows shunting of different grades between lines depending on the requirements of the products. Therefore, implementing fiber fractionation in the process is realistic if the mill is producing multiple grades on multiple production lines.

CONCLUSION

The pressure screen is able to produce a pulp with different characteristics compared to the original pulp. The accept fraction was higher in strength properties compared with the reject fraction, except for tear strength Refining of the long fiber fraction improved overall strength properties, except for tear. We inferred that long fiber fraction could be upgraded and used in higher grade paper products, and the accept fraction could be used in products for which smoothness or printability are major requirements.

Refined feed stock was stronger in all strength properties than the recombined stock. We concluded that fractionation with the goal of producing pulp superior in quality to the original pulp is not a promising prospect. However, separate processing has potential to bring about savings in energy and generate pulps with different characteristics.

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AUTHOR INSIGHTS

We chose this research topic, in part, because three major packaging companies recommended the topic. The work complements previous findings, with one exception.

Attaining a realistic fractionation ratio with the pressure screen was the difficult part of the study; it was overcome with monitoring the consistency of each fraction. Among the more interesting findings was the realization that, for better use of the raw material, fractionation per se could not be a target, fractionation should be a means to better use of raw materials.

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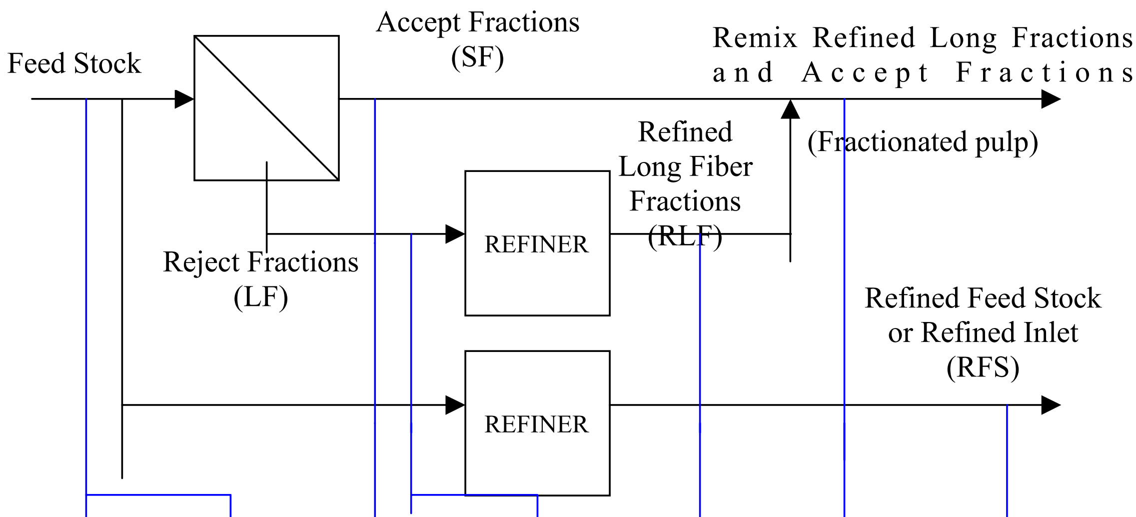
Appendix A



Fiber and Paper Analysis	Feed Stock	Accept (SF)	Reject(LF)	RLF	RLF&SF	RFS
Fiber Length	T	T	T			
Coarseness	T	T	T			
Fiber Length Distribution and Fines Content	T	T	T	T	T	T
Freeness	T	T	T	T	300	300
Handsheet	M	M	M	M	M	M
Burst Strength	T	T	T	T	T	T
Tensile Strength	T	T	T	T	T	T
Tear Resistance	T	T	T	T	T	T
Ring Crush Test	T	T	T	T	T	T
Scott Bond	T	T	T	T	T	T
Short Span Compression Test	T	T	T	T	T	T
Smoothness	T	T	T	T	T	T

LF: Long fiber fraction; SF: short fiber fraction; RLF: Refined long fiber fraction; RLF&FS: Refined long fiber fraction and mixed with short fiber fraction; RFS: Refined feed stock; T: To be tested; M: To be made; Target Freeness was set to be: 300 ml CSF

Figure A1. Brief overview of the experimentation.

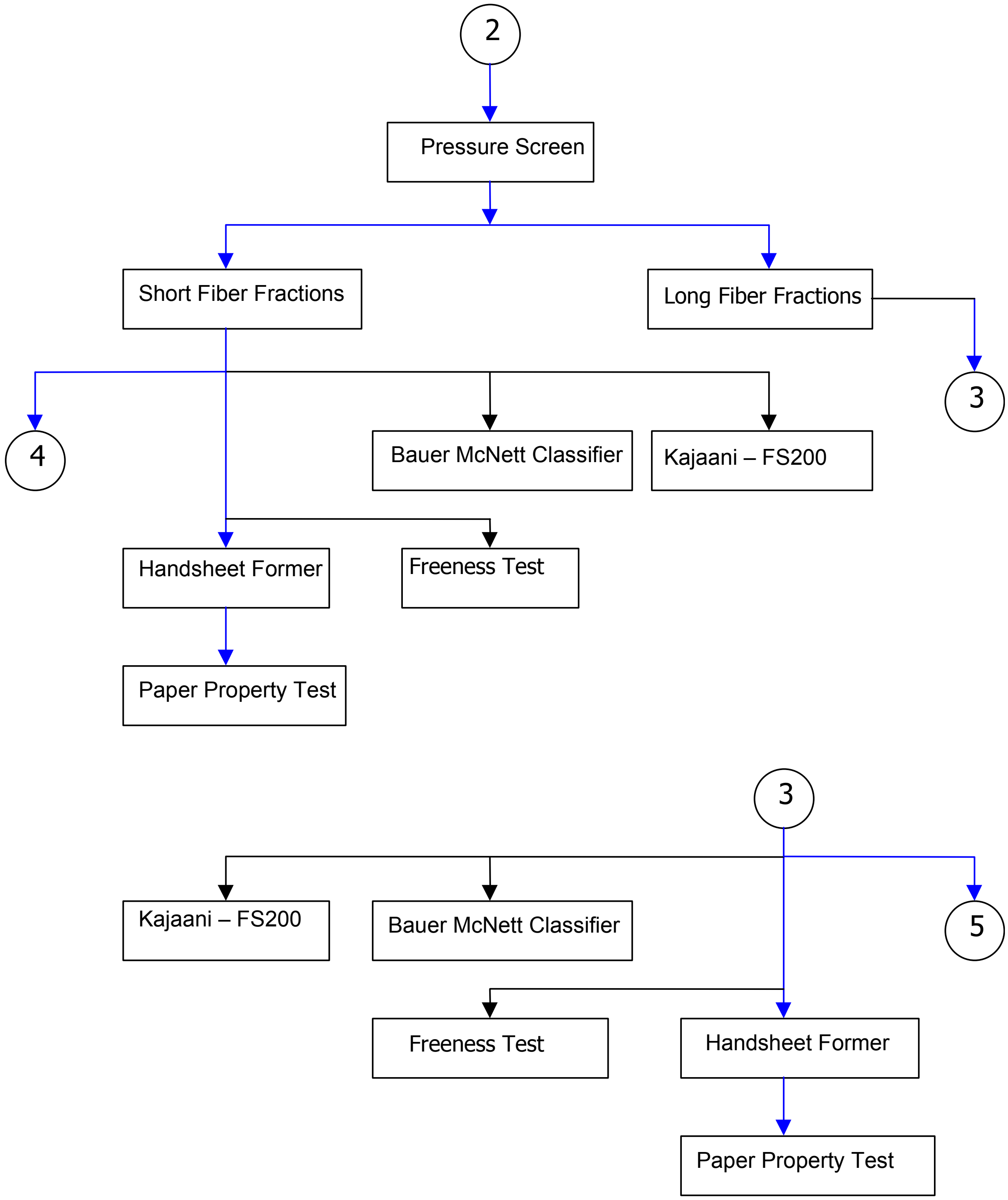


Figure A2. Experiment flowchart (continued).

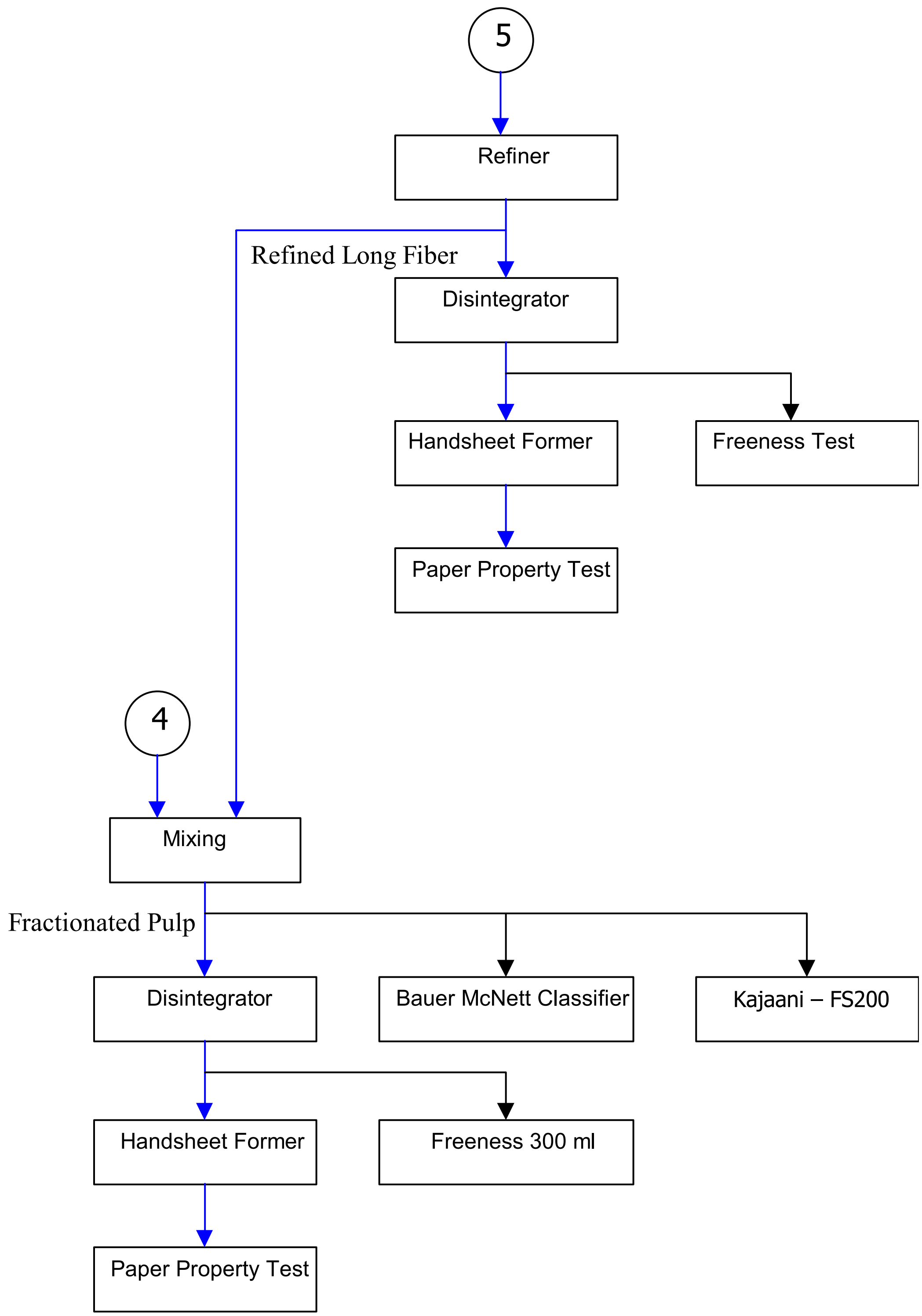


Figure A2. Experiment flowchart (continued).

APPENDIX B

Coarseness Measurement

Scope

Measuring the average coarseness by Kajaani-FS-200 requires an accurate sample weight. To obtain a reliable sample weight, we used the following device.

Apparatus

Figure B1 shows a sketch of the device. The main body is made from Plexiglas, with metal bars on its sides. The dimensions of the device are specified in Fig. B1.

Procedure

Insert a Plexiglas device (similar to Fig. B1) into the Finnish handsheet former. Add a fines-free suspension into the former and follow the standard sheetmaking procedure for agitation. Drain the water and let the mini-sheets form. Remove the device carefully from the former and collect three of the mini-sheets (A1, A2, A3) into a Petri dish with a known weight, then measure its oven-dry weight. The oven-dry weight of A1-A3 sheets would be the oven-dry weight of A4-A6 sheets as well. Use wet mini-sheets (i.e., A4, A5, and A6) for coarseness measurement.

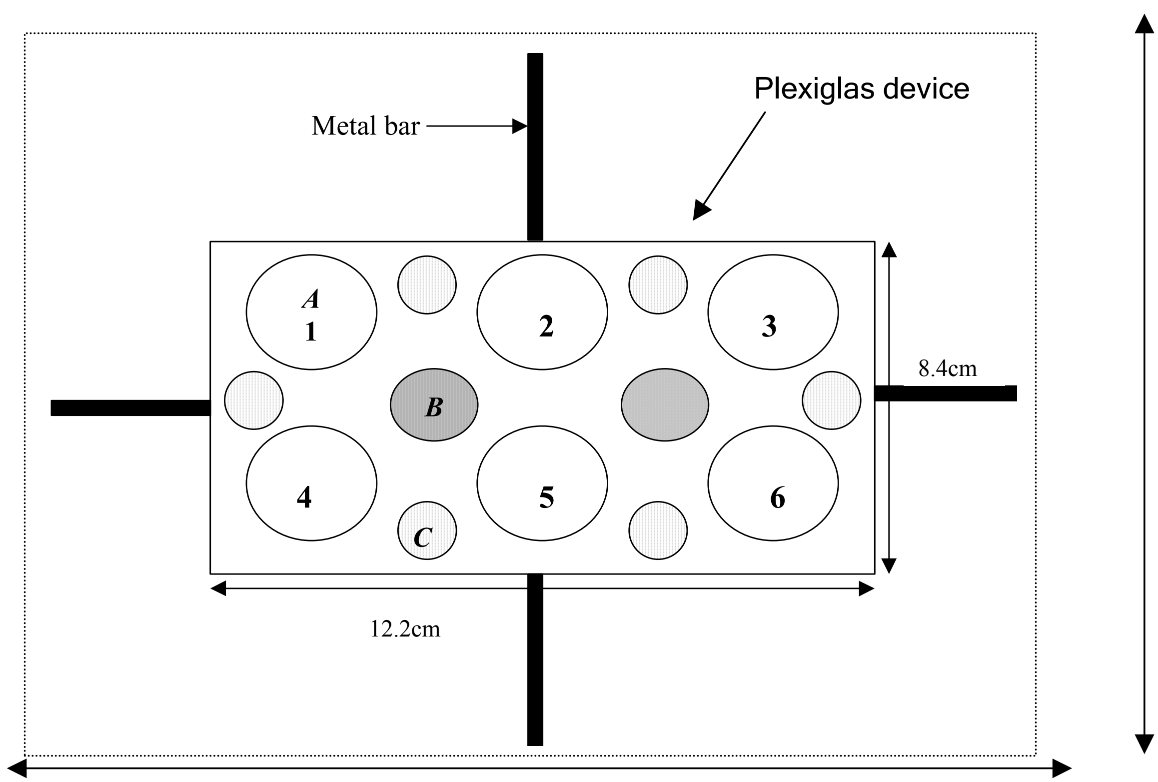
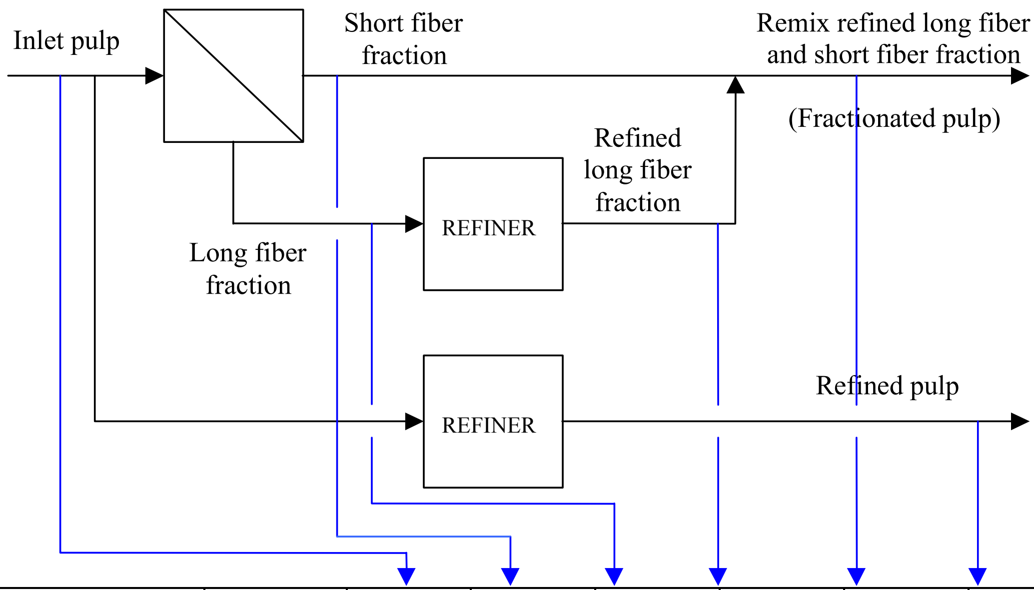


Figure B1. Mini handsheet former [10] for coarseness measurement (diameter of the holes are: *A*: 27 mm, *B*: 16 mm, *C*: 7.14 mm).

Appendix C



Properties	Unit	Feed Stock	Accept (SF)	Reject (LF)	RLF	F	RI
Fiber Length	[mm]	1.1	0.87	1.33	-	-	-
Coarseness	[mg/m]	0.171	0.137	0.182			
Freeness	[CSF]	490	190	570	340	300	300
Refining @ 30 g.	[Rev.]	-	-	-	2250	-	2000
Density	[kg/m^3]	539	610	507	637	612	648
Burst Index	[kPa m^2/g]	3.01	3.03	2.91	4.82	4.44	4.65
Tensile Index	[Nm/g]	30.1	33.6	29.3	49.3	45.1	46.7
Elongation @ Break	[mm]	2.8	3.3	2.2	3.3	3.5	3.6
Stiffness Index	[MNm/kg]	3.2	3.4	3.6	4.6	4.1	4.1
Ring Crush	[N]	136	160	126	169	168	173
Tear Index	[N m^2/kg]	6.95	4.72	7.81	7.49	7.13	6.86
Scott Bond	[J/m^2]	211	377	172	441	390	455
SCT Index	[Nm/g]	14.7	18.2	13.6	22.5	20.5	22.2
Roughness	[mL/min]	2442	1800	2552	2336	2114	2130
+30 B. McNett	[%]	37.8	13.2	46.8	33.5	28.4	28.9
+50	[%]	22.5	21.9	20.4	23.1	22.5	18.4
+100	[%]	11.5	12.9	11.6	12.8	12.6	9.7
+200	[%]	10.2	12.2	7.9	7.7	10.4	7.6
FINES	[%]	18	39.8	13.3	22.9	26.1	35.4

Figure C1. Strength properties of fractionated and unfractionated pulps at differing conditions.

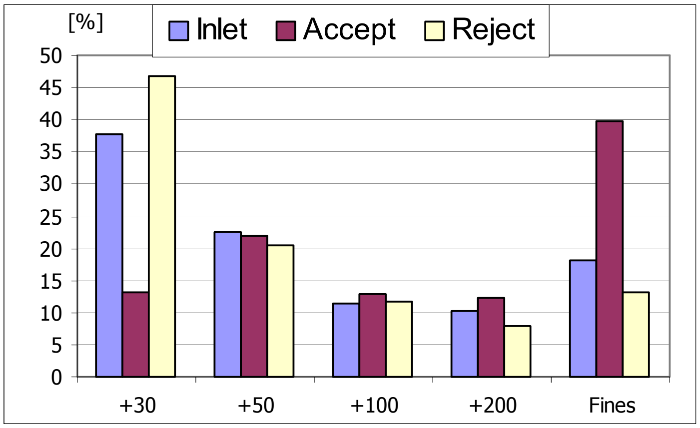


Figure 1. Fiber distribution of accept and reject fractions compared to original feed stock (inlet).

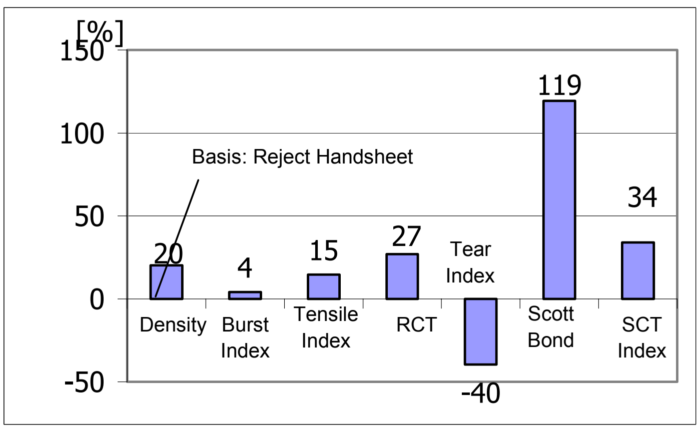


Figure 2. Comparison of accept and reject handsheet; percentage difference in strength properties.

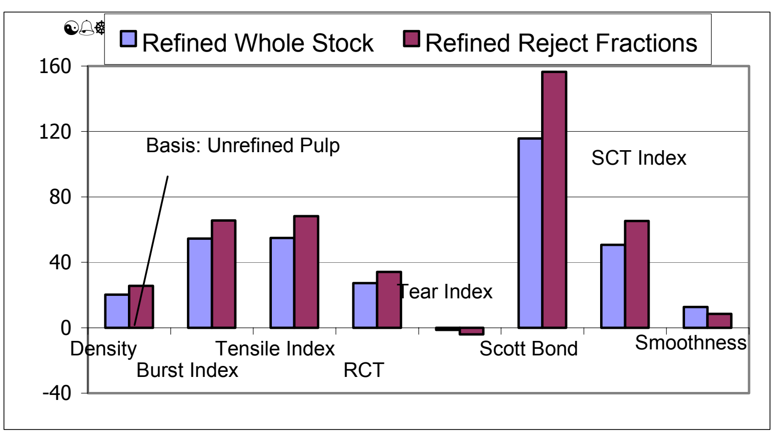


Figure 3. Strength of refined feed stock (refined unfractionated stock) compared with refined reject fraction.

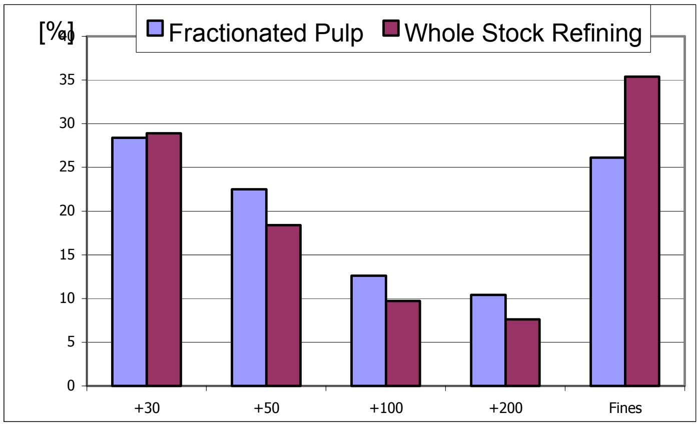


Figure 4. Fiber distributions of recombined stock (fractionated pulp) compared with refined feed stock (refined unfractionated stock).

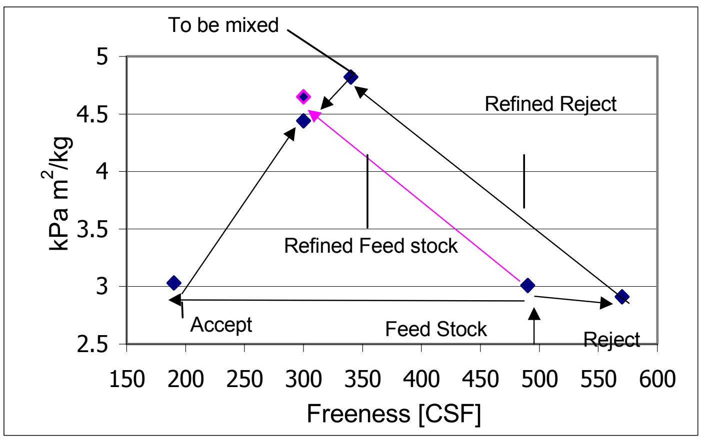


Figure 5. Burst index of recombined stock compared with refined feed stock.

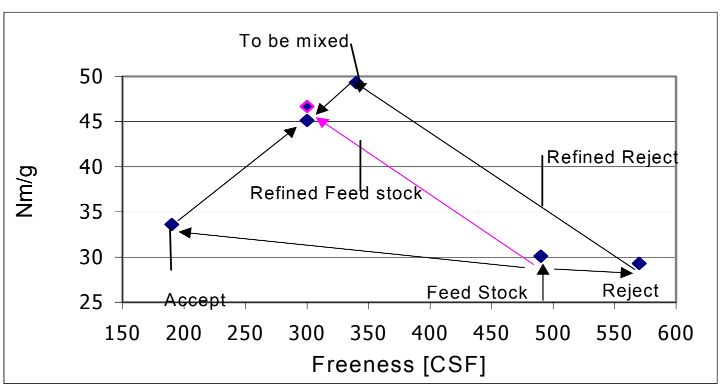


Figure 6. Tensile index of recombined stock compared with refined feed stock.

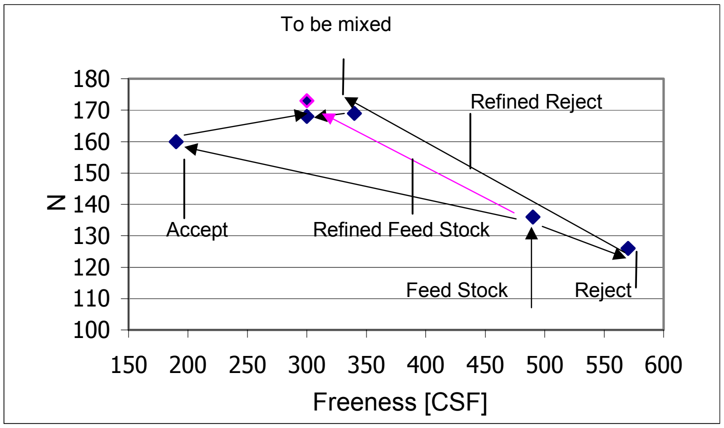


Figure 7. Compressive strength of recombined stock compared with refined feed stock.

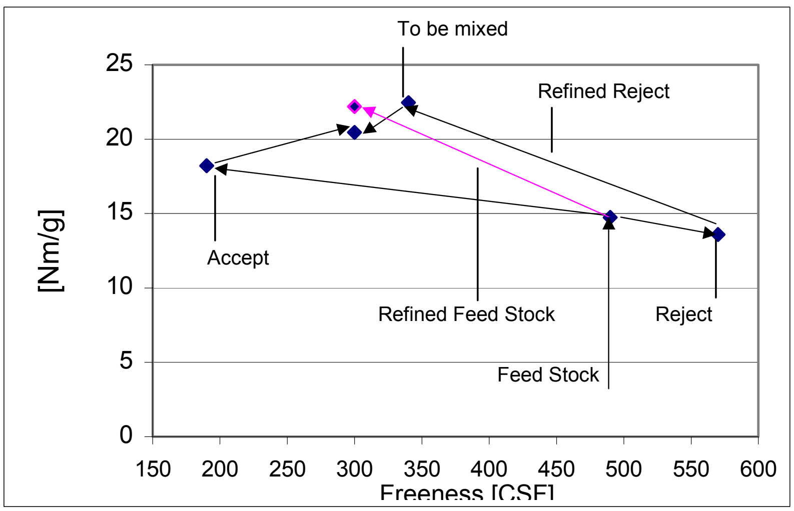


Figure 8. Compressive strength of recombined stock compared with refined feed stock..

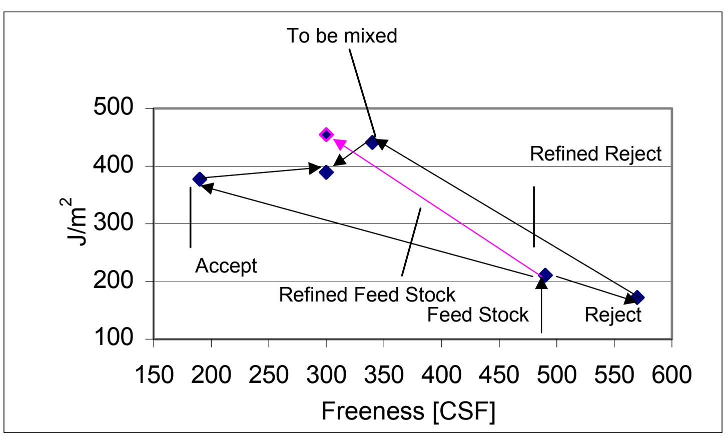


Figure 9. Scott Bond of Re-combined Stock Compared with Refined Feed Stock.

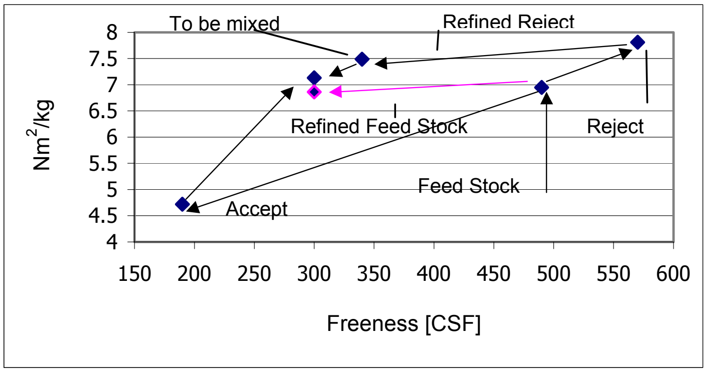


Figure 10. Tear index of recombined stock compared with refined feed stock.

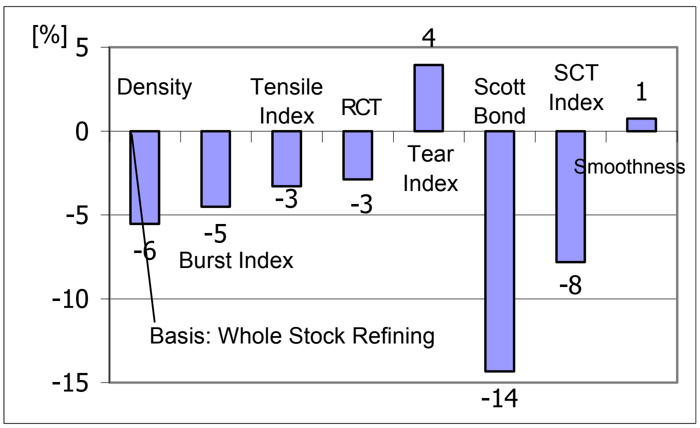


Figure 11 Comparison between recombined stock and refined feed stock (refined unfractionated stock).

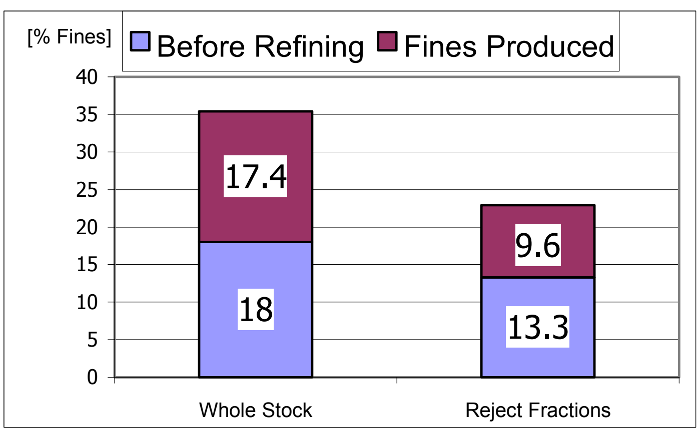


Figure 12. Fines generated by refining of the feed stock (unfractionated stock) vs. fines generated by refining of the reject fraction.