Impact Refining
Relative importance of different refining action

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Introduction :

In the article titled 'Impact Refining' part I published in IPPTA Vol 2, No. 4, December 1990 the effect of different impact variables on fibers and paper properties was explained. The second phase of the exprimental work consisted of the study of relative importance of internal fibrillation, external fibrillation and fines on the pulp and paper properties. The pulp used throughout these experimentations was bleached kraft pulp of Southern USA pine, supplied by M/S IIT Rayonier Inc.

Impacting variables were optimize for maximum strength development. Similary fibers were abraded in an abrasion refiner to get external fibrillation and fines were generated by beating. Different blends of impacted, abraded, fines and unrefined fibers were studied and analyzed.

Impact Refining :

After analyzing the test result of Impact Refining, the impacting variables were fixed as follows :

a) Number of Impacts.....40
b) Impact Weight.....9 65 Kg.
c) Sheet Basis Weight.....120 gm/m²
d) Number of Sheet (s).....ONE
e) Intermittent Reslushing.....NO

A sufficient amount of fibers were impacted at these conditions for subsequent experimentation.

Abrasion Refining :

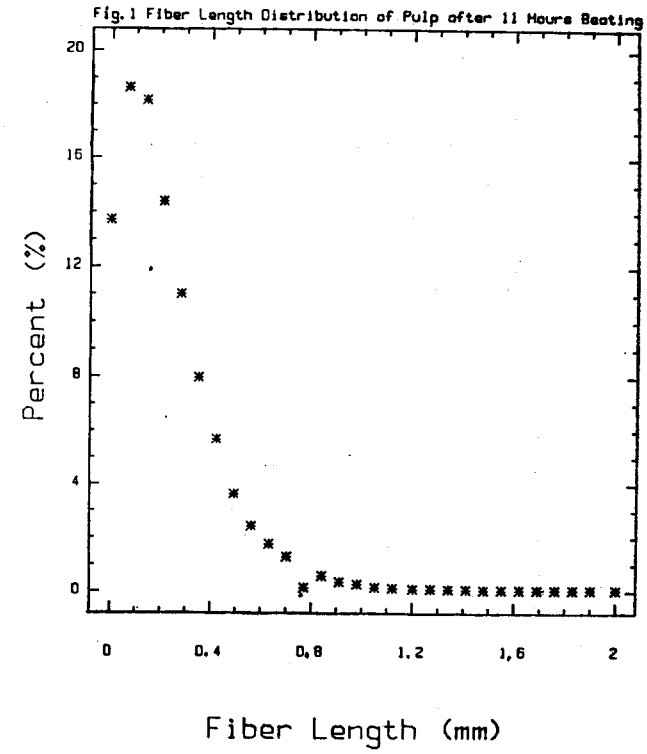
The external fibrillation of the fibers was achieved by treating the pulp in an Abrasion Refiner. The Abrasion Refiner was designed and fabricated at Western Michigan University,
Kalamazoo, Michigan (USA). A brief description of the equipment is given in Appendix B.

The dry lap of the pulp was soaked overnight in water and disintegrated in a standard British Disintegrator for 15 minutes or 45,000 revolutions at 3% consistency. One gram of the pulp was refined at a time in abrasion refiner for 5.0 minutes at 1000 revolution per minutes. The impacted fibers were also abraded to study the effect of abrasion after impacting.

Fines Generation :

The fines were generated by treating the pulp in a Valley Beater for 11.0 Hours using full load of 5.5 Kg. Fiber analysis was performed at different intervals of times, using Kajaani Fiber Analyzer. Fig. 1 shows the fiber length distribution of the terminal pulp.

Fig. 1 Fiber Length Distribution of Pulp after 11 Hours Beating



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Experimentation :

Different percentage of fines were mixed with unrefined fibers, impacted fibers, abraded fibers and impacted abraded fibers. The fraction of impacted and abraded fibers was changed at different levels of fine addition. The pulp and paper sheet were tested for the following properties.

1) Canadian Standard Freeness
2) Drainage Time
3) Density
4) Tensile Strength
5) Bursting Strength
6) Tear Resistance and
7) Scattering Co-efficient

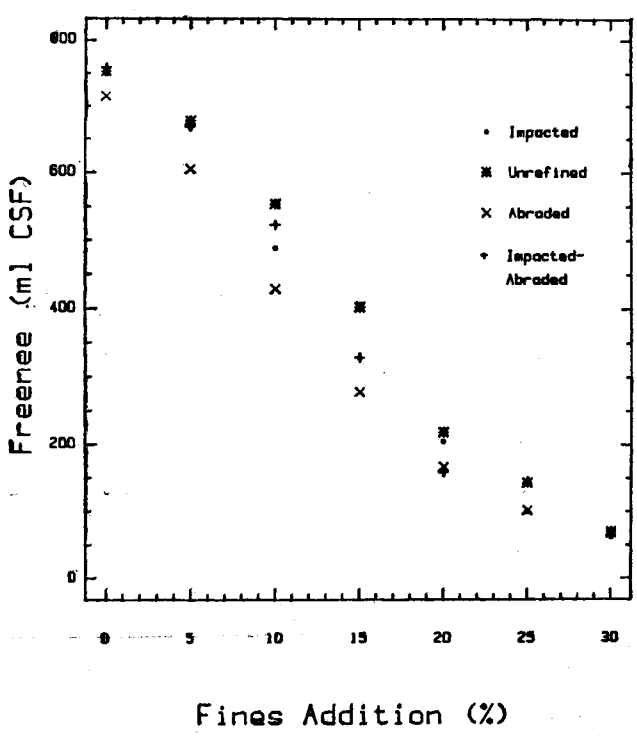
Another sample of the original pulp was beaten in a Valley beater at standard conditions to compare the test result with different furnishes made by mixing of impacted and/or abraded fibers and fines.

1. Effect of Addition of Fines on :

1.1. Freeness ;

Fig. 2 shows the effect of the addition of fines on pulp freeness for impacted, abraded, impacted-abraded and unrefined fibers. The drop in freeness is highest for abraded fibers and least for unrefined fibers. The higher freeness drop in case of abraded fibers may be due to the creation of external surface by abrasion.

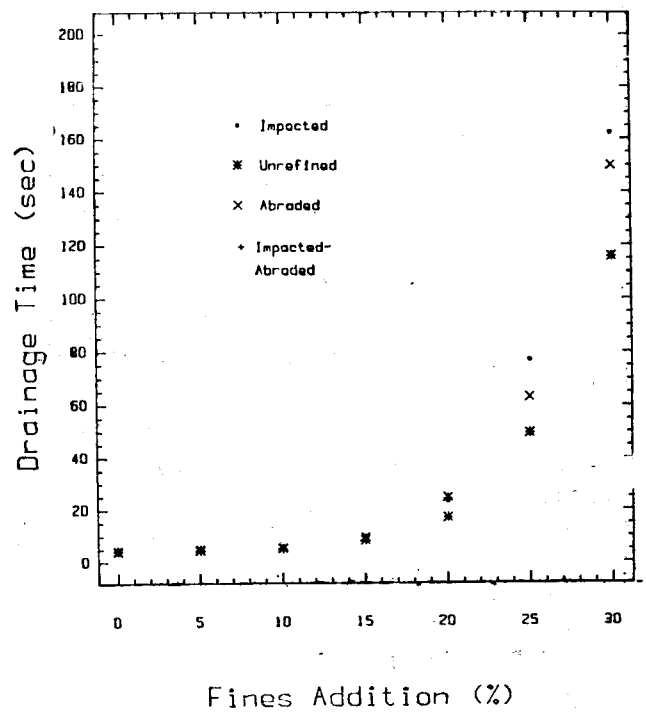
Fig. 2 Effect of Addition of Fines on Freeness in Impacted, Abraded, Unrefined and Impacted-Abraded Fibers.



1.2. Drainage Time ;

Fig. 3 shows the effect of addition of fines on drainage time for impacted, abraded, impacted-abraded, and unrefined fibers.

Fig. 3 Effect of Addition of Fines on Drainage Time in Abraded, Impacted, Unrefined and Impacted-Abraded Fibers.



Drainage time shows only a marginal increase up to 15% fines addition, but after that the increase is very steep. Impacted fibers showed minimum increase while the unrefined fibers showed maximum increase in drainage time at all levels of fines addition.

Density

Fig. 4 shows the relationship between the addition of fines in the pulp furnish with impacted, abraded, impacted-abraded and unrefined fibers and sheet density.

The Figure shows an increase in sheet density on increasing fines addition. The increase in the density may be contributed by the increase in compactness of the sheet due to the filling of voids between the

Fig. 4 Effect of Addition of Fines on Density in Impacted, Abraded, Unrefined and Impacted and Abraded Fibers.

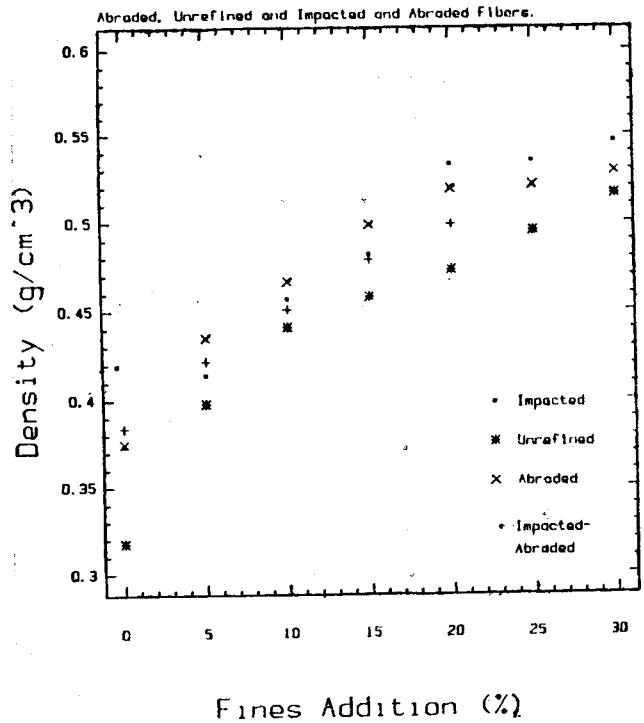
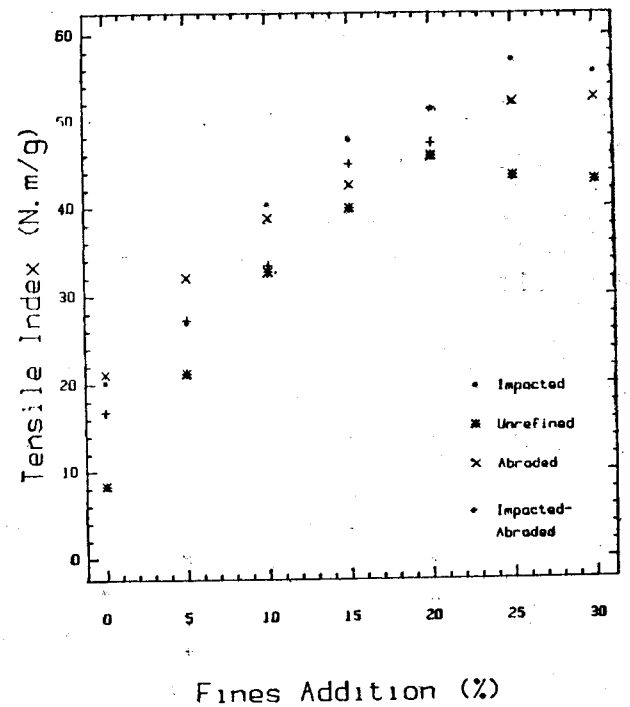


Fig. 5 Effect of Addition of Fines on Tensile Index in Impacted, Abraded, Unrefined and Imported Abraded Fibers.



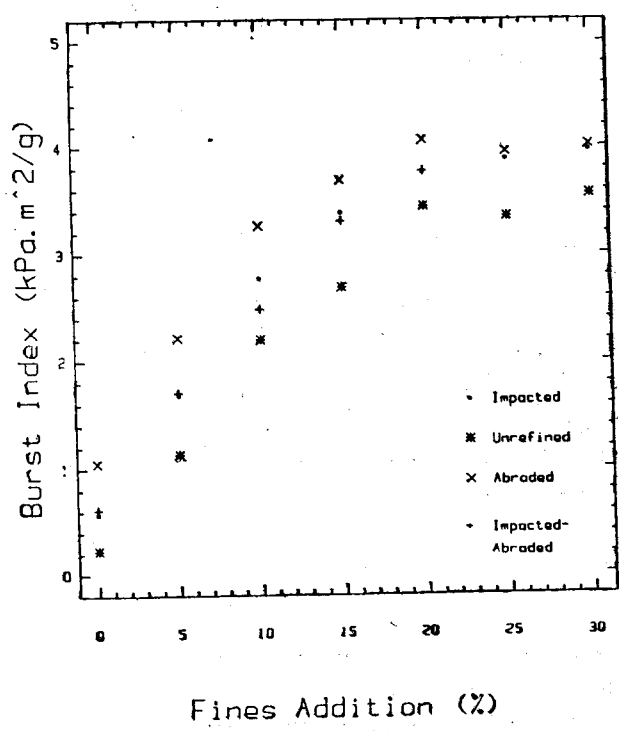
fibers by fines. The increase in the density at higher levels of fines addition is marginal as voids in the sheet are progressively filled.

Tensile Strength

The fig:5 shows the relationship between the addition of fines in abraded, impacted, impacted-abraded and unrefined fibers, and tensile index. There is an increase in tensile index with increasing fine content in the furnish.

The unrefined fibers show the least improvement in the tensile strength. Initially abraded fibers exhibit higher increase in strength as compared to impacted fibers but the trend is reversed at higher level of fines addition. The impacted-abraded fibers show lesser increase in strength compared to impacted or abraded fibers. This may be due to the fact that fibers are damaged by abrasion after impacting. The increase in tensile strength may be due to increase in bonding between fibers and fines. Fines provide very large external surface for bonding. The bonding between fibers and fines may be fiber-fine–fiber, fiber - fine or fine-fine types. Though the addition of fines increases numbers of bonds and bond strength but intrinsic strength of the fibers decrease with decrease in fiber length. Figure also shows a trend of decrease in strength after reaching a maximum.

Fig.6 Effect of Addition of Fines on Burst Index in Impacted, Abraded, Unrefined and Impacted-Abraded Fibers.



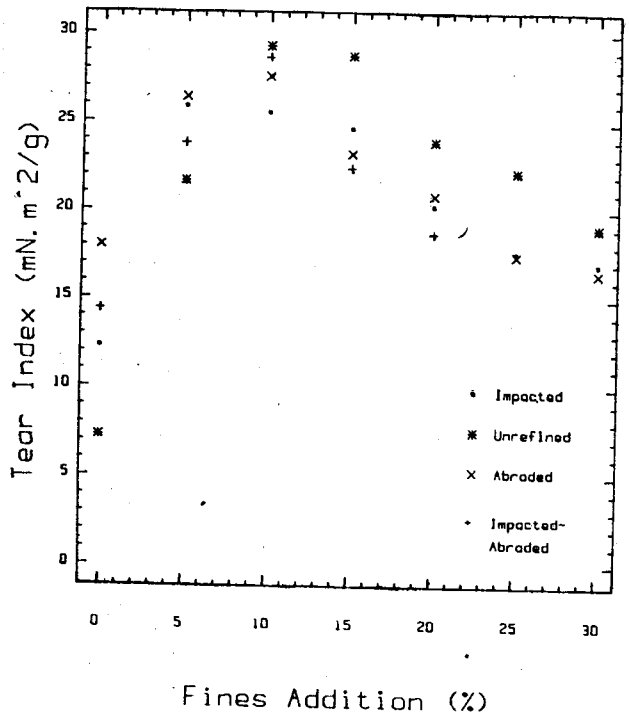
Bursting Strength

Bursting strength shows almost same trend as exhibited by tensile strength. Fig. 6 shows the relationship between amount of fines and burst index for differently treated fibers.

Tear Resistance

Fig. 7 shows the effect of addition of fines on tear index for impacted, abraded, impacted - abraded and unrefined fibers.

Fig. 7 Effect of Addition of Fines on Tear Index in Impacted, Abraded, Unrefined and Impacted-Abraded Fibers.

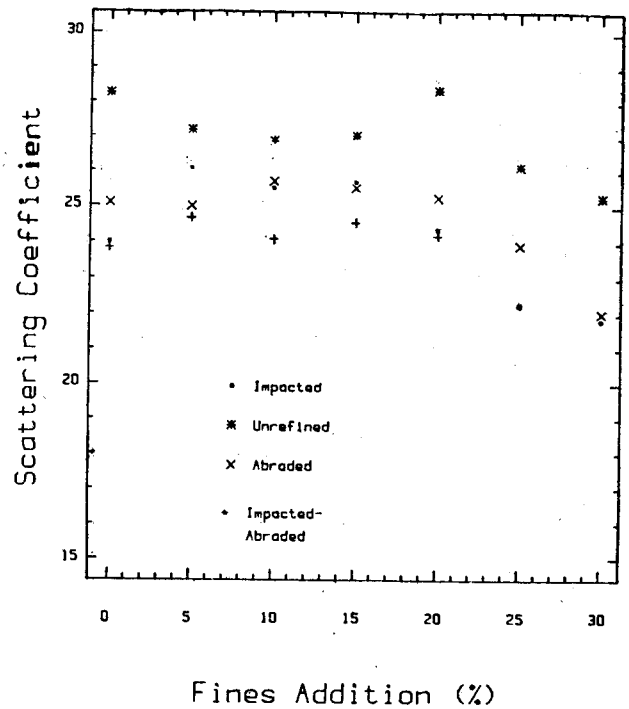


Initially the tear index with increasing fine content sharply reaches to a maximum at 10 to 15% fines level and start decreasing. The unrefined fiber shows the highest development in tear index though started at a lower level. The tear strength is more fiber strength dependent than fiber bonding This peculiar nature of tear index is exhibited on beating pulp in valley beater also.

Scattering Coefficient

The scattering coefficient does not exhibit any significant change with increasing fines addition to impacted, abraded, impacted-abraded or unrefined fibers. Fig. 8 supports this statement.

Fig. 8 Effect of Addition of Fines on Scattering Coefficient in Impacted, Abraded, Unrefined and Impacted-Abraded Fibers.



Relative Contribution of impacted and Abraded Fibers in Pulp Furnish at Various Level of Fines

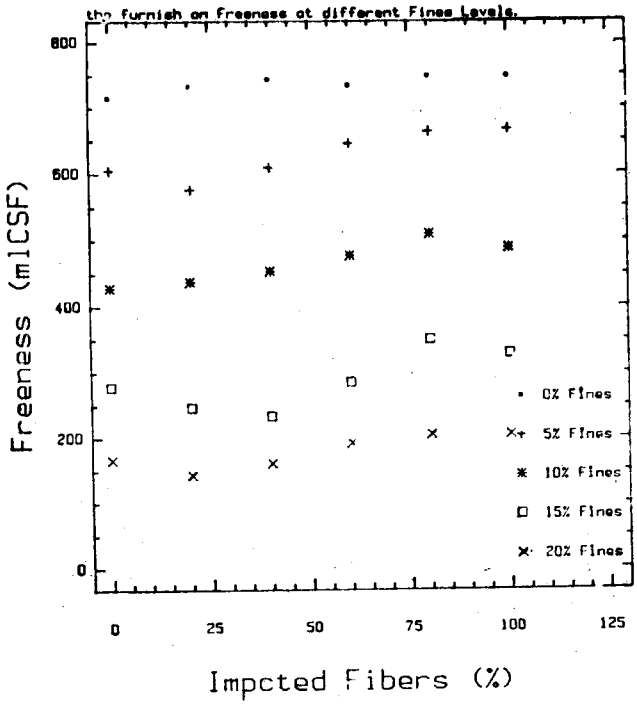
Figure 9 to figure 14 shows the relative effect of impacted and abraded fibers on freeness, drainage time density, tensile, burst and tear indices respectively at different levels of fines addition. The percent abraded fibers is 100 minus percent impacted fibers. All figures show that the level of fines in the furnish is the largest contributing factor in the property development. The trend for relative contribution of impacted and abraded fibers is not clear from the figure since the points are scattered. No fair conclusion can be drawn in this regard.

The details of statistical analysis is not given to avoid the complicity, Some of the resulting regression equations are given below.

1. Freeness = 710.6-29.1 (Fines%) + 0.74 (impacted Fiber%)

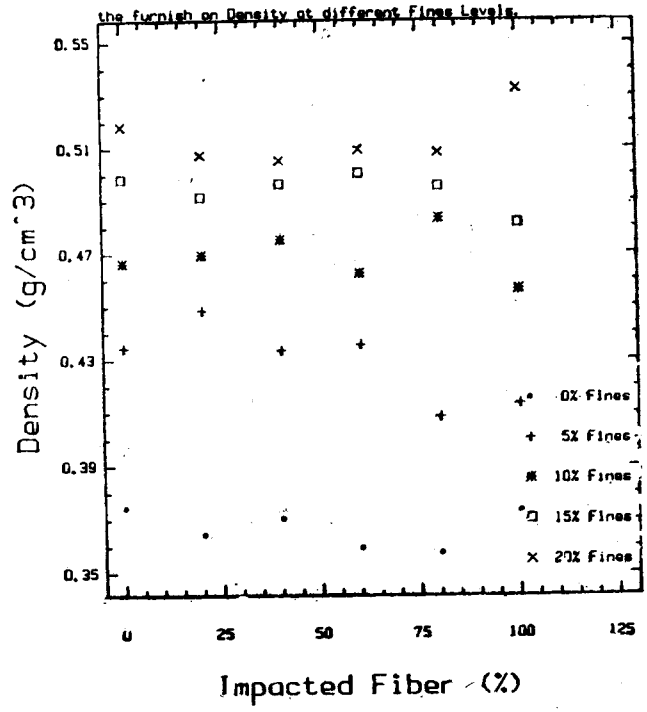
2. Density = 0.364 + 0.013(Fines%) — 0.0003 (Fines%)2

Fig. 9 Relative Effect of Impacted and Abraded Fibers in the furnish on Freeness at different Fines Levels.



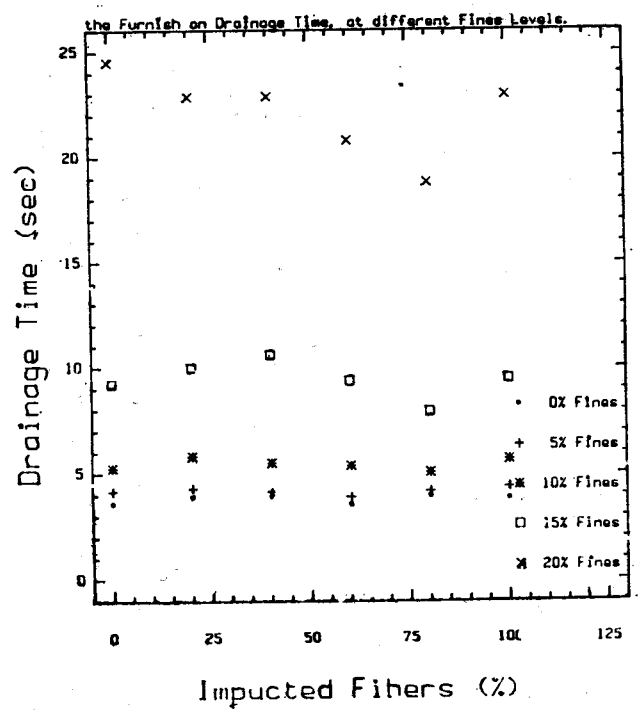
Abraded Fibers % = 100 - Impacted Fibers %

Fig. 11 Relative Effect of Impacted and Abraded Fibers in the furnish on Density at different Fines Levels.



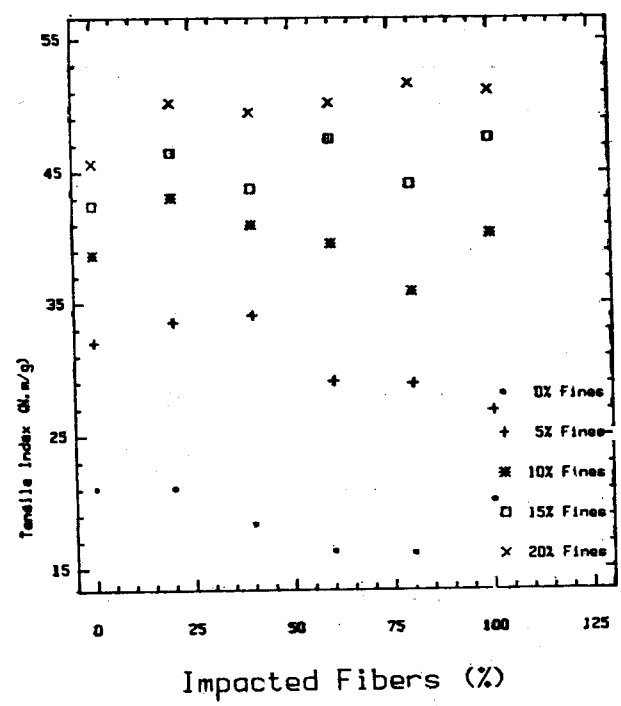
Abraded Fiber % = 100 - Impacted Fibers %

Fig. 10 Relative Effect of Impacted and Abraded Fibers in the Furnish on Drainage Time, at different Fines Levels.



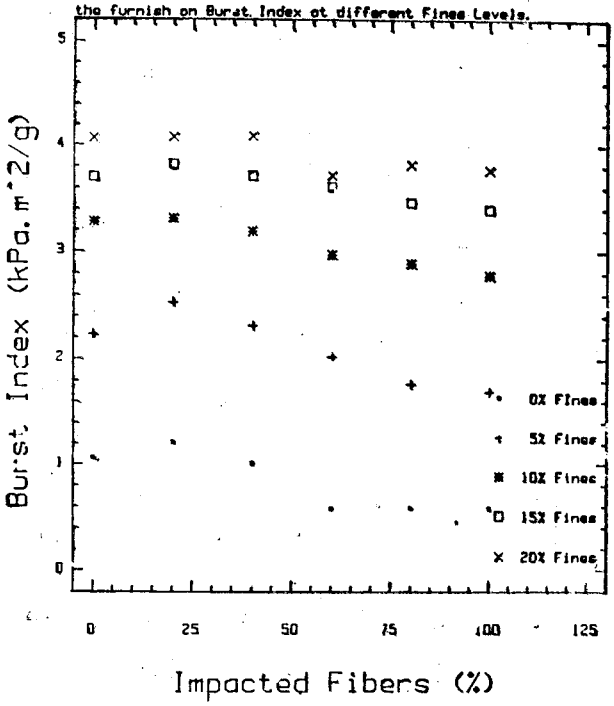
Abraded Fibers % = 100 - Impacted Fibers %

Fig. 12 Relative Effect of Impacted and Abraded Fibers in the furnish on Tensile Index at different Fines Level.



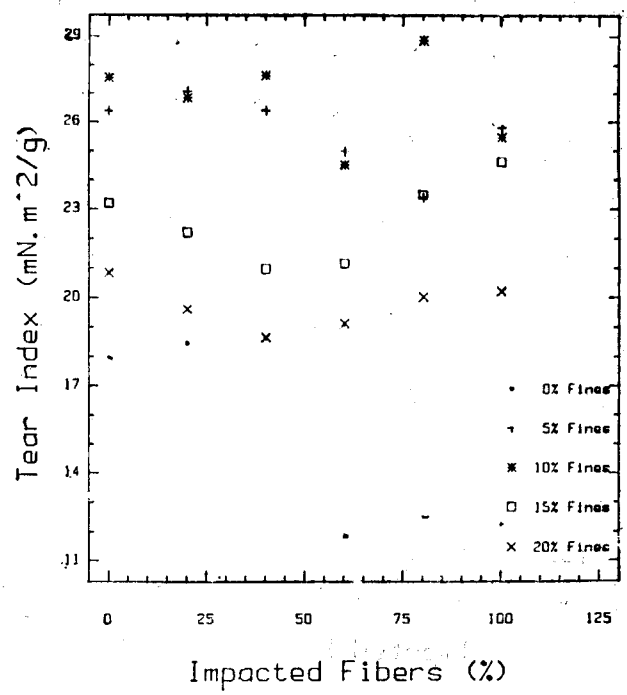
Abraded Fiber % = 100 - Impacted Fibers %

Fig. 13 Relative Effect of Impacted and Abraded Fibers in the furnish on Burst Index at different Fines Levels.



Abraded Fibers % = 100 - Impacted Fibers %

Fig. 14 Relative Effect of Impacted and Abraded Fibers in the furnish on Tear Index at different Fines Levels.



Abraded Fibers % = 100 - Impacted Fibers %

3. Tensile Index = 18.9 + 2.6 (Fines%) — 0.53 (Fines%)2

4. Burst Index = 1.06 + 0.28 (Fines%) — 0.007 (Fines%)2 — 0.0001 (Impacted Fibers%)2

All the equations shows that the fines percentage is most important in determining the properties.

Comparison of Fines, Impacted, Abraded, impacted-Abraded and Unrefined furnish with Pulp Treated in Valley Beater

The following table gives the comparative properties development for differently treated fibers, their blends and Valley beaten pulp.

Proper — ties	Unrefined Fibers	Abraded Fibers	Impacted Fibers	30% Fines Impacted Fibers	Addition Abraded Fibers	Pulp After 75 Minutes Beating
Freeness (ml CSF)	750	708	750	58	65	167
Density (g/m³)	0.317	0.374	0.373	0.545	0.528	0.583
Tensile Index N.m/g)	8.11	20.92	19.97	53.74	52.35	78.87
Burst Index (KPa.m²/g)	0.219	1.04	0.558	3.95	4.00	6.20
Maximum Tear Index	7.16	18.91	12.18	25.74*	26.33*	24.24**

*5% Fines Addition, **5 Minutes Beating.

Table shows that the impacted and abraded fibers could reach only 20% of the tensile index of pulp beaten for 75 minutes. A blend of impacted of abraded fibers with 30% fines could get only about 66% of the tensile index of 75 minutes beaten pulp. Dr. Hartman (1) could also achieve only 75% of the maximum achievable strength by roller refining. Though Dr. Hartman by blending roll refined fibers and 20% fines could get maximum achievable tensile strength by beating. The effect of fines when blended with impacted, abraded or even with unrefined fibers, on properties development is very profound. But Hartman did not observe the same effect. Either the abrasion or impaction of fibers was not very effectivte or fines were produced by roll refining also but could not be detected. The method and equipment used in these experiments for fines determinations were different and more precise as used by Dr. Hartman.

Conclusions

1. In a blend of impacted fibers, abraded fibers and fines, the fines are the most influential factor to reduce Canadian Standard Freeness and to increase tensile and bursting strength.
2. The strength properties developed by beating the pulp in a Valley Beater were higher than all the blends of impacted, abraded and fines tested.

Questions for Future Study

A number of interesting questions have arisen from the results of this study which may be used as guidelines for the future study.

Sheet properties can be developed by impaction of the fibers. But why did these properties reach an upper limit and then start decreasing ? Was it becauset of the fibers got damaged after certain energy inpu or loosening of the fibers internally did not contribute to bonding any more ? If the fiber got damaged with increased energy input, why did paper show higher strength at higher impact intensities ? Was it because the higher impact intensity loosen the fiber more deeply? Will the changing of duration of impact pulse, by changing backing material, change the fiber properties ? Was there any change in water retention value of impacted fibers ?

When the fines were added to the impacted and abraded fibers, was the increase in strength due to the increase in fiber-fine or fiber-fine-fiber bonding ? Will the fines from different sources show the same development in properties ?

Reference

1) Hartman, R.R., Mechanical Treatment of pulp Fiber for property Development, Ph.D Thesis, Institute of Paper Chemistry, Appleton, Wisconsin, June 1984.

APPENDIX B

Abrasion Refiner

Abrasive wear occurs when a rough and hard surface moves against a softer surface and plows fragments from it. For abrasive wear to occur in pulp suspension flows, fibers must make contact with the abrading surfaces and move relative to it when contact is made. A schematic of the experimental apparatus used to achieve the abrasive effect in pulp fiber is shown in Fig. B-1.

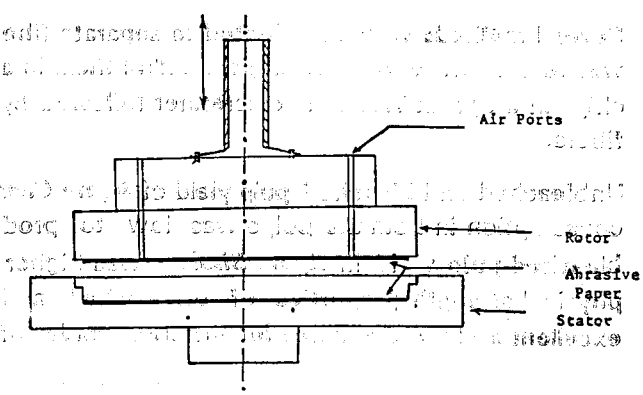


Fig. B-1 Schematic Diagram of Abrasion Refiner.

Both rotor and stator were made of plastic. The internal diameter of stator was 102 mm. Wet dry silicon carbide sand paper of 120 grit was glued on the workiing surfaces of rotor and stator. The distance between two surfaces was 4.0 mm. Teflon rings were applied to the rotor and staror contacting surfaces to reduce the friction. The rotor was driven by a variable speed motor. The rotor could move vertically up and down. One gram pulp at 3% consistency was abraded at 1000 rpm for 5 minutes each time.