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AN INVESTIGATION OF HOW FIBER CLASSIFICATION AND STRENGTH INDEXES COMPARE WITH MACHINE PULP STRENGTH EVALUATIONS

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INTRODUCTION

Due to the fact that paper made with double lined kraft corrugated cuttings as its main components of strength will vary in strength along with the different strengths of various shipments of cuttings, it is important that a method of evaluation be found. A method of evaluating the strength of various shipments prior to their use on a machine could eliminate off grade paper due to low strength and assure a more uniform strength of the finished sheet.

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LITERATURE SURVEY

The literature I surveyed pointed out the fact that pulp can be classified quite well with the present classifiers, that different size fibers give different strength products, and that a product of either burst and tear or tensile and tear will give an index to paper strength.

Classifiers

In all fiber classifiers the fiber length of the different fractions will overlap (1), but this overlapping is of little consequence because a very small portion of the total fiber in a given fraction will fall in the overlapping portion. Average fiber length is the main line of separation.

It was found by C. E. Murray (2) that fibers retained on 14 and 28 mesh screens are whole fibers and that fibers retained on 48 and 100 mesh screens are fragments and fines. This study showed that the length of time a classifier runs and the consistency of fibers being classified will determine where a given fraction of the pulp will be retained. Long running periods and low consistency of fibers will cause a larger percentage of the whole fibers to be retained on a 28 mesh screen than will reverse conditions. These conditions will also shift the percentage of fragments and fines being retained on the 100 mesh screen. It was shown that the total retention on the 14 and 28 mesh screens and the total on the 48 and 100 mesh screens were not affected by these variables.

Sheet Strength

In this paper, tensile is being used as a measure of sheet strength, but a product of tensile and tear is used as a measure of potential or total strength.

Shortening of fibers in itself does not appear to affect tensile. By comparing the tensile strength of a pulp at different rates of swelling with a nonshortening and a shortening refiner, it was shown that tensile was affected by the swelling and not the shortening of the fibers (3). This appears to be due to the fact that fiber to fiber bonding gives tensile, whereas fiber strength is secondary (4). This has been further emphasized by experiments which show that sheet tensile strength is about 40% of the actual strength of the fibers that make up the sheet (5). Photographs of the rupture which occurs when running tensile show that the initial rupture causes the final rupture and that the initial rupture is usually the weakest spot in the sheet. The photographs further show that fiber to fiber bonds were usually the initiators. James d'A Clark (6) has found that the tensile strength that fibers give to a sheet is not affected by fiber length but by fiber width or weight-per-unit length. The cutting of whole fibers with a sharp blade and comparing the resultant sheet strength with that of sheets made of fibers of equal length but smaller width showed the theory to be true. But it must be remembered that prior to mechanical cutting the fiber length is in proportion to the width, so a fiber classification prior to cutting the fibers will separate fibers to some extent by weight-per-unit length.

Pulp Strength Index

Experimental work (7) on pulp strength index has shown that total strength can be measured by either a product of burst and tear or a product of tensile and tear. Burst or tensile measures fiber to fiber bond strength and tear measures internal fiber strength (4). The product index can be used to compare two samples, but it should not be used to predict final strength when the two pulps are going to be refined on different types of refiners. A strength product can be altered by the type of refiner used to develop the final strength (4). In general, a noncutting or wide clearance refiner will retain or increase the strength product, whereas a cutting or close clearance refiner tends to decrease a strength product.

Apparently a lot of work has been done on fiber classifiers, the effect of fiber dimensions on strength properties, and the ability to index pulp strengths by strength products, but it appears that no one has correlated these different works.

In view of what has been done, this thesis is concerned with taking samples of "strong" and "weak" raw materials (waste new double lined kraft corrugated cuttings) and comparing the percent fiber retained in different classified fractions, fraction sheet strengths, and fraction strength indexes. The samples got their "strong" or "weak" rating directly from the results they were giving during the normal production of a board machine. Samples were taken when the board strength was good and when it was poor.

The reason for this work was to see if the above machine evaluations could be substantiated by any one or a combination of the above procedures.

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EXPERIMENTAL DESIGN

I investigated how fiber classification and strength indexes compare with machine pulp strength evaluation because of the difficulty encountered when one tries to rate pulps in the laboratory by fiber classification only. This problem is most troublesome when the difference in percent fiber retained on adjacent screens is quite large. By comparing both the percentage of fiber retained and the strength index of each fraction, I hoped to find a combination which would substantiate the results found during regular production.

Representative samples of three "strong" and three "weak" waste new double lined kraft shipments were taken.

Ten batches of each sample were classified in the Bauer-McNett classifier. The preparation for fiber classification consisted of soaking (16 hours) and disintegrating 20 grams of (O.D.) pulp in the TAPPI Disintegrator for 75,000 revolutions. Six batches of each sample were disintegrated and composited for fiber classifications. Five sheets were made from the unclassified composites. Nine 10-gram (O.D.) samples were classified for 20 minutes with 12, 20, 28, and 48 mesh screens. The fraction that went through the 48 mesh screen was considered a classified fraction. The 10 batches of each classified fraction were composited before making Noble and Wood handsheets.

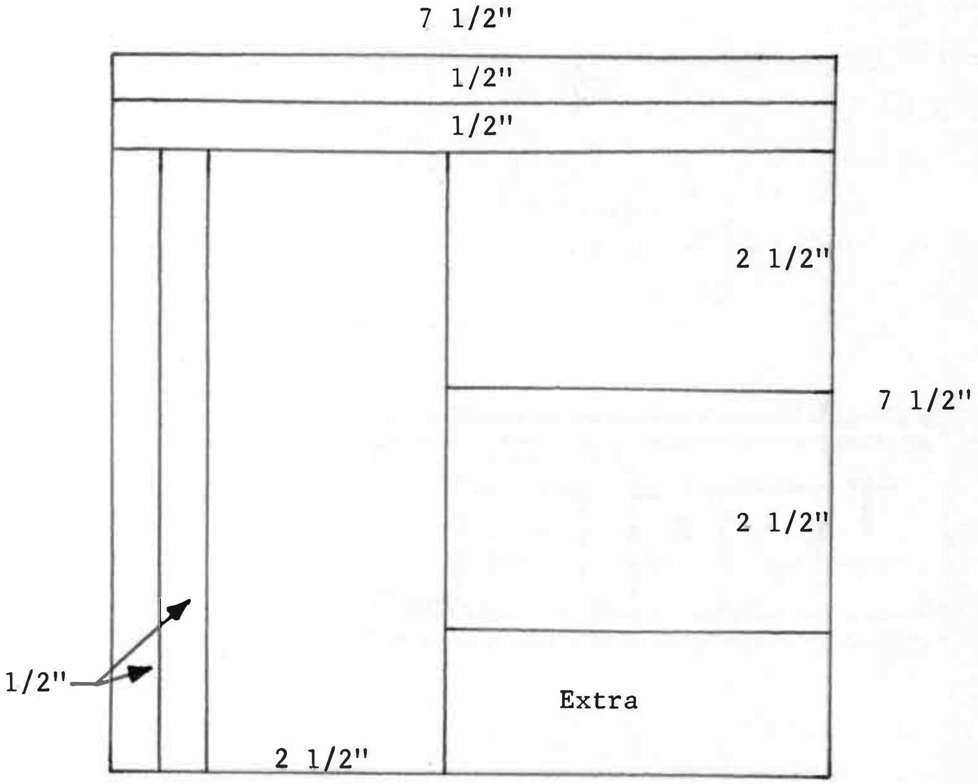
The fraction that went through the last screen (48 mesh) will be referred to as fines. This fraction was collected by catching all the water that passed through the classifier and settling out the fibers with the aid of alum; 20 cc. of saturated solution were used per 55-gallon drum.

The percent retention of each fraction was assumed to be the total weight of handsheets made from that fraction.

TAPPI standard sheet weights of 60 grams per meter were attempted in all cases except for the sheets made from the fines which went through the 48 mesh final screen. With the exception of the sheets made from fines, sheets were pressed and dryed on a Noble and Wood sheet mold. The fines were not pressed but floated off the sheet forming wires prior to drying because of the difficulty of removing these sheets from the forming wire when properly pressed before drying. Sheet weights of about 75 grams per meter were also used to aid in the removal of these sheets.

All sheets were TAPPI conditioned, weighed, and tested for tensile and tear strength. Four tensile tests (two in each direction) and three tear tests (in a combination of directions) were run per sheet. Conditioned sheets were assumed to have 10% moisture.

Position of Test Specimens



RESULTS

The samples were fractionated to determine differences in fiber length distribution and then the different fiber length fractions were made into handsheets for evaluation of strength potentials. The strength potentials are the product of tear times tensile.

Test sheets were conditioned at 72°F. and 50% relative humidity for a minimum of 24 hours. Sheets were then weighed in grams to three decimal places. Conditioned sheets were assumed to have 10% moisture.

Sheets were cut according to the diagram shown in the experimental design section of this report.

Tensile tests were made on 1/2-inch strips with the Schopper Tensile Tester with the jaws 4 inches apart and the machine running on low speed. Results were taken on the low scale and converted to pounds per inch-strip by multiplying the readings by two.

Tear tests were made on four sheets with the Elmendorf Tear Tester. The results were converted to tearing strength per 16 sheets by multiplying the readings by four.

Tensile and tear strength results were corrected to standard TAPPI sheet weights by dividing the standard sheet weight (2.752 grams per 8 x 8 sheet with 10% moisture) by the actual weight of the tested sheets.

Retention of each fraction of the fractionated samples was obtained by assuming that the total weight of each fraction's test sheets was that fraction's total weight retained. There was no allowance for loss of fiber during preparation of test sheets.

The machine evaluation of the samples put them in this order: (1) strong #1, (2) strong #2, (3) strong #3, (4) weak #1, (5) weak #2, and (6) weak #3.

TABLE I

Fraction	Schopper Tensile (Lb./In.)*	Elmendorf Tear (G. Force/16 Sheets)*	Product of Tensile x Tear	% Retention	Weighted Product of Tensile x Tear (Tensile x Tear x % Retention)
Strong #1 New Double Lined Kraft Corrugated Cutting					
Composite	13.4	93	1,330		
12 Mesh	5.6	84	484	31.0	150
20 Mesh	7.3	72	569	28.2	160
28 Mesh	8.0	47	410	17.5	72
48 Mesh	8.5	40	350	11.9	42
Fines**	6.1	8	46	11.7	5
Total					429
Strong #2 New Double Lined Kraft Corrugated Cutting					
Composite	12.5	89	1,114		
12 Mesh	5.0	90	447	24.8	111
20 Mesh	7.6	81	621	23.3	145
28 Mesh	8.0	56	446	14.6	65
48 Mesh	7.5	36	269	18.3	49
Fines**	6.8	25	166	20.1	33
Total					403
Strong #3 New Double Lined Kraft Corrugated Cutting					
Composite	12.5	95	1,191		
12 Mesh	5.2	84	433	23.5	102
20 Mesh	7.2	86	622	22.7	141
28 Mesh	7.8	57	442	13.9	61
48 Mesh	6.6	43	280	17.5	59
Fines**	7.9	18	145	22.4	32
Total					385

* Test results were basis weight corrected to a TAPPI standard sheet weight of 60 grams per meter.

** Due to the need of a technique in collection of fines and the forming of sheets from this fraction, it should be noted that the samples were run in this order: strong #1, weak #2, weak #3, weak #1, strong #2, strong #3.

The samples are listed in order of machine evaluation--strong #1 strongest and weak #3 weakest.

TABLE II

Fraction	Schopper Tensile (Lb./In.)*	Elmendorf Tear (G. Force/16 Sheets)*	Product of Tensile x Tear	% Retention	Weighted Product of Tensile x Tear (Tensile x Tear x % Retention)
		Weak #1 New Double Lined Kraft Corrugated Cutting			
Composite	12.1	84	1,012		
12 Mesh	4.8	83	402	21.4	86
20 Mesh	7.3	76	555	21.3	118
28 Mesh	7.3	59	424	14.3	61
48 Mesh	8.4	36	304	20.8	63
Fines**	5.8	27	154	21.2	33
Total					361
		Weak #2 New Double Lined Kraft Corrugated Cutting			
Composite	11.8	84	1,112		
12 Mesh	5.5	81	464	30.7	142
20 Mesh	7.0	73	557	19.0	106
28 Mesh	7.2	42	333	17.2	57
48 Mesh	7.4	21	226	17.0	38
Fines**	3.8	9	53	16.1	9
Total					352
		Weak #3 New Double Lined Kraft Corrugated Cutting			
Composite	12.1	82	1,116		
12 Mesh	5.4	78	417	28.5	119
20 Mesh	6.6	61	411	20.7	85
28 Mesh	6.8	44	307	16.0	49
48 Mesh	7.4	30	229	18.0	41
Fines**	5.1	14	78	16.8	13
Total					307

* Test results were basis weight corrected to a TAPPI standard sheet weight of 60 grams per meter.

** Due to the need of a technique in collection of fines and the forming of sheets from this fraction, it should be noted that the samples were run in this order: strong #1, weak #2, weak #3, weak #1, strong #2, strong #3.

The samples are listed in order of machine evaluation--strong #1 strongest and weak #3 weakest.

DISCUSSION OF RESULTS

All discussion of results is based on data presented in Tables I and II.

Tensile

1. Tensile strength generally increased with the decrease in fiber length until the very short fibers of the fines were reached.
2. There was a big increase in tensile strength from the fraction retained on the 12 mesh screen to the fraction retained on the 20 mesh screen.
3. The tensile strength of the 20, 28, and 48 mesh screen fractions was in the same range in all cases.

Tear

1. Tear decreased with the decrease in fiber length.
2. The large drops in tear were from the 20 mesh fraction to the 28 mesh fraction and from the 48 mesh fraction to the fines fraction.

Product of Tensile Times Tear

1. Due to the increase in tensile strength from the 12 mesh fraction to the 20 mesh fraction and no corresponding decrease in tearing strength, the 20 mesh fraction has the best product of tensile times tear.
2. The product of tensile times tear decreases from the 20 mesh fraction through the fines.

Retention

1. Retention was generally highest on the 12 and 20 mesh fractions and varied somewhat on the remaining fractions.

Weighted Product of Tensile Times Tear
(Tensile Times Tear Product Times Percent Retention)

1. The 12 and 20 mesh fractions were generally highest, with a general decline from the 20 mesh fraction down through the fines fraction.

Total of Weighted Tensile Times Tear Products

1. The total of weighted tensile times tear products for each sample agrees with the machine evaluation of the samples.

Composite

1. As can be seen in Tables I and II, the product of tensile times tear of the composite sample is somewhat of an indicator of the sample's total strength.
2. It should be noted in Tables I and II that the tear of composite is no stronger than the tear of the strongest fraction, but the tensile of the composite is much better than that of the strongest fraction.

12 Mesh Fraction

1. This fraction has maximum tear but possibly more tensile could be developed without too much loss in tear. This fraction may have more potential than what is shown.

20 Mesh Fraction

1. This fraction has good tear and tensile and appears to be the most important indicator of the sample's strength.
2. Because this fraction generally has the highest product of tensile times tear and its retention is high, this fraction seems to also line up the samples with the machine evaluation. This can be seen in Graph I. Graph I is a bar graph of weighted tensile times tear products according to fractions.

28 Mesh Fraction

1. This fraction has very good tensile but has lower tear than the longer fractions.

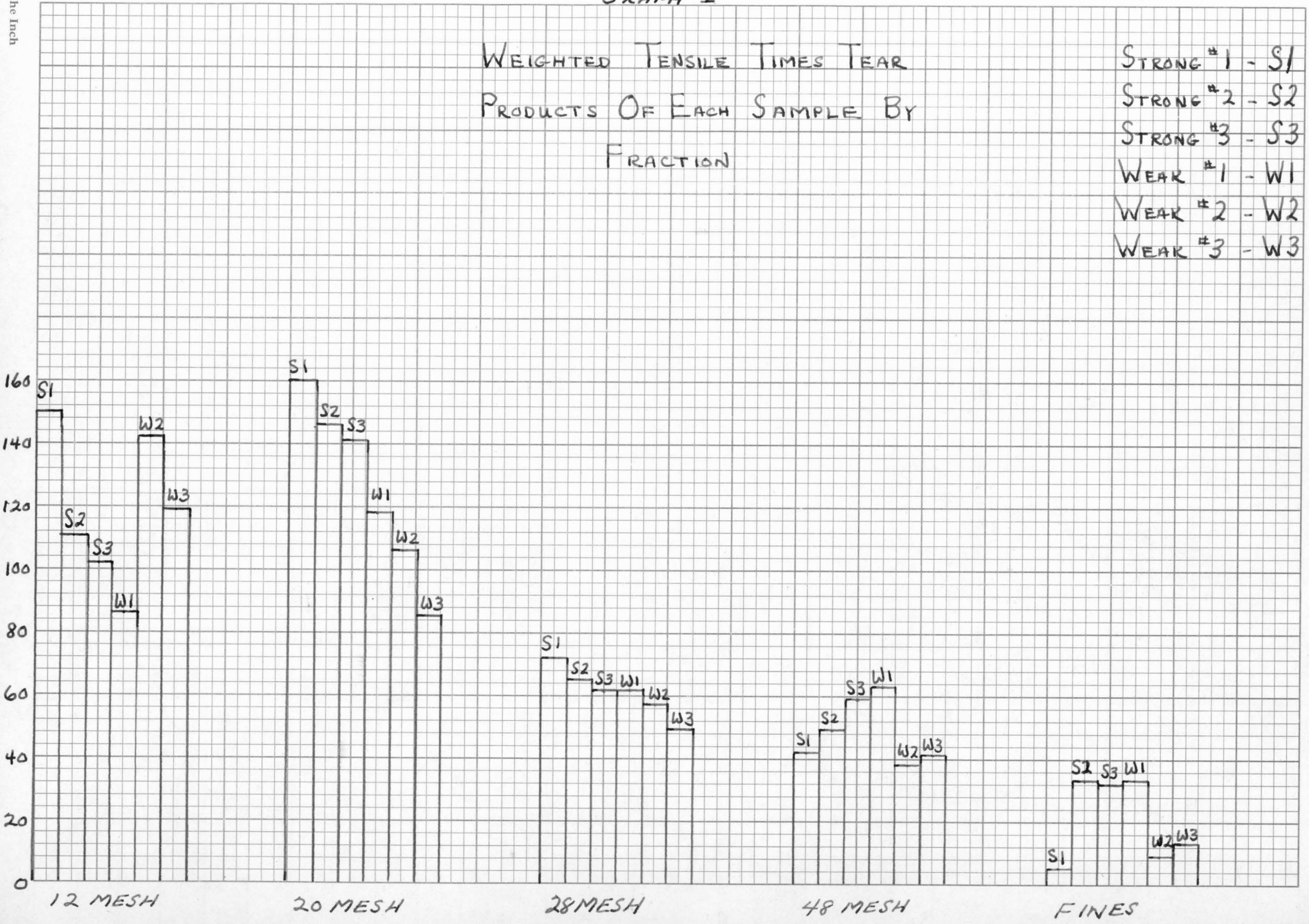
48 Mesh Fraction

1. This fraction also has very good tensile strength but the tearing strength is low.

Fines
(Through 48 Mesh Screen)

1. The tensile and tear of this fraction show that there is very little fiber strength left, but there is good bonding. This fraction could be important as a bonding agent in the total sample.

GRAPH I


WEIGHTED TENSILE TIMES TEAR
PRODUCTS OF EACH SAMPLE BY
FRACTION
STRONG #1 - S1
STRONG #2 - S2
STRONG #3 - S3
WEAK #1 - W1
WEAK #2 - W2
WEAK #3 - W3
160
140
120
100
80
60
40
20
0
S1
S2
S3
W1
W2
W3
12 MESH
20 MESH
28 MESH
48 MESH
FINES

CONCLUSION

Weighted tensile times tear products does correlate with machine evaluation of double lined kraft corrugated cutting shipments.