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Separate Refining Versus Mixed Refining of an “Easy” and “Hard” Refining Pulp

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SEPARATE REFINING VERSUS MIXED REFINING OF AN "EASY" AND "HARD" REFINING PULP

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ABSTRACT

A study of the strength development (mullen and tear) of mixtures of "easy" and "hard" refining pulp, in which the pulps were refined as a mixture with that in which they were separately refined, and then mixed, reveals that separate refining develops mullen to the same extent as does mixed refining, but that a higher tearing resistance at the same freeness and mullen can be obtained with separate refining.

INTRODUCTION

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A great amount of work has been done since the turn of the century on the mechanism of refining, the development of strength with beating and the relationship between fiber bonding and "hydration" of a fibrous mass during the beating cycle. In industry, most refining is done on relatively "easy" and "hard" refining pulps. This investigation was done to see if there were any advantages to be gained by refining pulp separately and then mixing rather than refining them as a mixture.

The foundations for the most generally accepted theory of beating, were contributed by James d'A. Clark (1) and Boyd W. Campbell (2). They will readily admit that some of the ideas which they expanded can be attributed to earlier workers in this area, but the experimental verification and, or, the logical explanation of strength development upon beating, loss of freeness with time of beating, and the nature of the cellulose bond in the sheet of paper was given by these two men.

Recent work by J. E. Ayer (4), H.G. Higgins (5), A.W. McKenzie (5), and K.J. Harrington (5) has either furthured the present knowledge on the subject or added still more conclusive evidence to the theories advanced by Campbell and Clark.

LITERATURE SURVEY

MECHANISM OF BEATING

During the chemical and mechanical treatment involved in the preparation of pulp, the primary wall of the fiber, which is permeable to, but is not swollen by water, is partially cracked, rubbed loose, or removed. Soon after these fibers are put into water, they imbide nearly all of the water necessary to saturate them. It is essential for good results in stock preparation that the fibers be well saturated and swollen before they are subjected to the mechanical action of beating (1). If this is not the case, then the interior fiber structure is brittle and easily damaged. This may result in complete or partial fracture of the fiber.

As soon as the water enters the secondary wall, the fibers swell. At the same time mechanical rubbing gives a suspension of cellulosic material in water at the surfaces of the secondary wall which are in contact with water. All of the cellulose surfaces become covered with a layer of cellulose in partial solution and these will unite if brought into contact by crystallizing action of the cellulose upon evaporation of the water (2).

In the unbeaten state, the greater part of the surfaces of the fiber are sheathed with the cambium layer, and adjacent fibers in a wet web of paper are prevented from ad-

hering well upon drying. This inhibition according to Clark (1), is due to the following reasons:

1. The absence of the suspension of the surface of the sheathed parts.

2. The large diameters present as compared to the relatively small diameters of the fibrillae which are produced by subsequent beating.

When a sheet is made from fibrous material having relatively large diameters and devoid of fibrillation, there is relatively small surface tension compressing effect as the water is removed on drying. This results in poor bonding, as the essential action for strength development is fibrillation (2), and that the surface tension compressing effects leads to better bonding upon drying (1).

As beating proceeds, a coarse fibrillation occurs. This exposes the inner cellulosic material and a new surface colloidal solution forms on the new surfaces. The concentration of this material is inversely dependent upon the degree of polymerization of the exposed surfaces (1). The presence of hemi-cellulose material lowers the degree of polymerization of the exposed surfaces.

The mechanical rubbing increases the concentration of the surface solution, and much of the fibrillated material is rubbed off the surface. This serves as an adhesive filler between the interstices of the larger fibers and bonding is facilitated (1). The internal structure of the fiber is also disrupted to some extent, and the pulps become more flexible resulting in a denser and hence, a more stronger sheet.

As beating proceeds the fibers become mashed up and shortened still further. The fibers are therefore made more flexible, more debris binder is produced, and the external specific surface of the pulp is greatly increased. These strengthening characteristics are offset by the shortening and weakening of the mashed fiber (1). From now on the sheet becomes progressively more dense, more translucent and less porous as beating continues.

FREENESS

While the object of stock preparation is the development of physical strength properties in the finished sheet, the progress of the treatment is marked by a loss of freeness and tear. The loss of freeness and tear may be described by such terms as increase in wetness, increase in drainage time or drainage resistance, or increase of "hydration". According to Campbell (2), the latter term is quite improper as the term hydration implies water held in a more or less combined state. To say that beating increases the proportion of water attached to the cellulose is wrong. This simply does not take place and has been proven by Campbell (2). The wetness or slowness development that occurs with beating is attributed to the production of debris, decrease in fiber length, and increase in wet flexibility and especially by the formation of the colloidal surface of solution of cellulose and allied material on the exposed surfaces (1,2).

James E. Ayer has done work which indicates a mathematical relationship between freeness of the stocks blended and the composite freeness of the blend (3). He also found that heterogeneity of pulp mixtures, (these blends were composed of the same pulp beaten to different freeness values) represented by blending of fibers beaten to different degrees of freeness, influenced freeness and the physical strength of the blend. The burst factor was increased when plotted against percentage stock of different freeness, while the tensile strength decreased. The maximum burst and tensile development, according to Ayer, is experienced when the entire pulp charge has been beaten to the time or freeness desired.

The bulk values and tear factor were influenced in the opposite manner. Pulps of a particular freeness reached by blending pulps of different freeness values exhibit a higher tear resistance and bulk than a pulp at the same freeness which has been developed in its entirety to the same extent.

An important result of this work is that freeness appears to be insensitive to the changes in fiber mass which influences the physical properties of the paper made from this mass.

The influence of hydration was studied by Ayer and the following results were noted (4):

1. Hydration of a pulp is a physical sorption rather than a chemical hydration in which bonding is in definite molecular proportions.

2. It appears that there is not a significant increase in hydroxyl groups available for the adsorption of water in beaten pulps.

3. Increased slowness of beaten pulps alter drainage properties, decrease drying rate and perhaps changes in physicomechanical properties are due to physical attrition and the accompanying increase in water, bound as a secondary hydrate during the beating or refining process.

FIBER BONDING AND HYDRATION

James d'A. Clark (1) adds support to Campbell's theory of partial solubility which states that the molecules of cellulose, on the surface of a fiber in water, are endowed with a freedom which enabled the molecules of adjoining fibers to orient themselves in such a manner that, upon drying, many of the hydroxyl groups could bond together (5). Clark also showed that as water is removed on drying, surface tension causes large compacting forces to be brought into play, which also serve to increase the surfaces in contact. In 1947, Campbell's work disclosed the following (2):

1. "All cellulose surfaces are covered with a layer of cellulose in partial solution and that these unite by the crystallizing action of the cellulose on evaporation of the water if brought into contact."

2. "The essential action for strength development is fibrillation and that this action does not create new surfaces, but exposes new surfaces which already exist."

3. "Slow drainage is due to increase of external solid surface which increases frictional flow."

4. "Sheet density increase is due to increased capillary force."

Recent work accomplished by Higgins, McKenzie and Harrington on the structure and properties of paper show that fiber bonding is a combination of (6):

1. "Frictional effect due to mechanical interaction of the fibers."

2. "The swelling effect. The greater the effect in the medium, the greater is the bonded area and sheet density after pressing. Swelling therefore increases the potentialities for 3."

3. "The hydrogen bonding effect. This is the principal ultimate mechanism of paper strength, and is dependent on the chemical state of the fiber and the swelling effect."

4. "Even though the hydroxyl content of a pulp is unchanged on beating, the increase in swelling capacity leads to an increase in interfiber bound concentration."

5. "Fibrillati n could account for the initial increase in bonding; reduction in length the decrease."

6. "Acetylated fines will not, in most cases, contribute to strength increases as do normal fines."

7. "The surface available for interfiber bonding can be increased by chemical treatment, even after the fibers have undergone a moderate amount of beating. However, this increase is much smaller in the range between unbeaten and highly beaten fibers."

The hypothesis that the strength of the sheets depends largely on the capacity of a fiber to swell is supported by these experiments. They also show that swelling is dependent on the extent to which the whole fiber is opened by light substitution, and that strength depends upon the condition of the surface region of the fibers.

EXPERIMENTAL DESIGN

The objective of this work was to compare the strength development (mullen and tear) of mixtures of "easy" and "hard" refining pulps in which the pulps were refined as a mixture with that in which the pulps were separately refined before mixing.

The initial investigation consisted of beater runs on the pulps chosen for this investigation in which the pulps were beaten in a Niagra beater according to TAPPI Standard (T-200, m-45). Five 35 gram (o. d.) samples at various freeness values were taken from the beater. Each sample was put in the TAPPI disintegrator for 600 revolutions. Three grams of each sample were used in getting a Canadian Standard freeness. The other 27 grams were placed in the mixing chamber of a Noble and Wood sheet machine, and a weight sheet was made. The machine was then adjusted to make handsheets of 2.6 grams. Six handsheets were made and five of them were evaluated. The handsheets were conditioned for at least twenty-four hours at 72° F. and 52% R.H. before testing. The handsheets were then tested for basis weight, caliper, bursting strength, and tearing strength according to TAPPI Standard (T-220, m-46).

The pulps chosen for this evaluation were bleached Southern Pine Kraft ("hard " refining) and unbleached Mitscherlich Sulphite ("easy" refining). All of the mixtures contained 75% kraft and 25% sulphite.

The final experimental design was as follows:

1. Experimental work was confined to bleached coniferous sulphate pulp and unbleached Mitscherlich sulphite pulp.

2. Experimental work with these pulps was at 75% kraft and 25% sulphite mixtures.

3. Samples of sulphite pulp were made for blending by refining in the Niagara beater using a 5500 gram weight on the beater roll. A total of 360 grams O.D. pulp were put in the beater at 1.6% consistency. Ninety grams of O.D. pulp were taken out for each sample. After two samples were removed 11 1/4 liters of water were added to the beater reducing the consistency to 0.8%. The refining was continued, and two more samples were made. A Canadian Standard freeness was taken on each of the four samples made per beater run. The freeness of the samples used was 627, 606, 536, 451, 363, 280, 194, 186, and 120.

4. Samples of Kraft pulp were made for blending using the same procedure. The freeness of these samples was 642, 614, 600, 586, 555, 548, 492, 476, 442, 422, 364, and 295.

5. The samples ofDKraft and sulphite were blended together in a TAPPI disintegrator for 600 revolutions. The blends were made from Kraft pulp of a constant freeness and sulphite pulp of a variable freeness, for each series. A resultant Canadian Standard freeness was run on each blend in the series. Handsheets were made and tested.

6. The freeness range of the blends covered in this work was from 620 to 250. This was done to see if the product of mullen and tear would remain constant, increase, or decrease with a decrease in freeness.

7. The two pulps were refined as a mixture in a Niagra using a total of 360 grams O.D. pulp at 1.6% consistency.

8. Five 35 gram O.D. samples were taken from the beater at successive beating times, and they were run through the TAPPI disintegrator for 600 revolutions. A Canadian Standard freeness was run on each sample.

9. Handsheets were made and tested from each sample.

DISCUSSION OF RESULTS

The results of the work done are as follows:

1. The product of mullen and tear of the pulps refined as a mixture is constant.

2. The product of mullen and tear of the pulps separately refined and then mixed is also constant over a range of freeness values, but the bursting strength of these pulps is developed to the extent that it is by mixed refining, and the tearing resistance is higher than it is in the pulps refined as a mixture.

3. This means that mullen can be developed in a mixture by putting most of the power into refining the "easy" refining pulp and just brushing the "hard" refining pulp. This would give higher tear resistances at the same freeness and mullen and could be done faster and more economically.

4. The results in table three were not duplicated by the results in tables one and two. In view of the fact that the tearing resistance of these sheets was run on a different tear instrument than that which was used in obtaining the results of tables one and two, I have chosen to disregard this part of my work in my conclusions. The rejection of these results is further substantiated by the following:

> Part A of table three contains results which are duplicated by the results in tables one and two. These results are from handsheets made from the same pulp used in making the sheets whose results are not duplicated, but were tested on the tear instrument used on the sheets whose results appear on tables one and two.

CONCLUSIONS

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The following conclusions are based on this work:

1. The strength development as measured by mullen and tear is enhanced by separate refining.

2. The bursting strength can be developed with separate refining to the extent that it can be developed at the same freeness with mixed refining.

3. A higher tearing resistance for the same mullen and at the same freeness can be obtained with separate refining of the two pulps used in the mixture.

TABLE ONE

Two Pulps Refined Seperately

Sulphite Freeness	627	536	363	186	120	280
			Kraft Freeness-614			
Result.						
Freeness	616	565	507	482	437	
Tear	126	138.5	140	128	134.2	
Mullen	46.6	47.4	49.4	49	49.6	
Product	5800	6550	6900	6260	6600	
			Kraft Freeness-586			
Result.	555	530	454	366	411	
Freeness						
Tear	125	135	127	124	118	
Mullen	45.2	48.4	49.4	53	50.4	
Product	5640	6540	6250	6570	5950	
Result.			Kraft Freeness-548			
Result.						
Freeness	524	490	419	275	348	
Tear	135	118	118	117	114	
Mullen	43.6	46.4	48	51.7	50.6	
Product	5900	5500	5650	6050	5950	
			Kraft Freeness-476			
Result.						
Freeness	509	451	361	313	305	
Tear	121	133	120	1122	111	
Mullen	48	50.2	49.8	51.8	54.4	
Product	5770	6660	5960	6340	6040	
			Kraft Freeness-422			
Result.						
Freeness	432	452	315	252	250	310
Tear	112	103	121	129.5	118	109
Mullen	48	48.8	52	54.9	54.4	53.7
Product	5400	5450	6300	7100	6400	5850
			Kraft Freeness-364			
Result.						
Freeness	370	420				
Tear	112	101				
Mullen	50.7	46				
Product	5670	4650				

TABLE TWO

Two Pulps Refined Separately

Sulphite Freeness	521	420	288	194
		Kraft Freeness-654		
Result.				
Freeness	610	563	503	490
Tear	129	126	120	124
Mullen	39.6	40.4	43.5	41.9
Product	5100	5060	5210	5200
		Kraft Freeness-567		
Result.				
Freeness	496	475	433	384
Tear	115	113	105	107
Mullen	45	44.2	46.3	47.3
Product	5360	5120	5310	5400
		Kraft Freeness-514		
Result.				
Freeness	446	450	392	358
Tear	108	108	110	107
Mullen	49.7	47.7	48.3	50.6
Product	5360	5120	5310	5400
		Kraft Freeness-468		
Result.				
Freeness	423	402	387	344
Tear	108	107	112	110
Mullen	5400	5350	5780	5550

TABLE THREE

Two Pulps Refined Separately

Sulphite Freeness	606	451	280	120	606
			Kraft Freeness-642		
Result.					
Freeness	572	503	487	406	
Tear	97.2	98.5	115	109	
Mullen	44	44.9	47.5	48	
Product	4270	4430	5460	5240	
			Kraft Freeness-600		
Result.					
Freeness	517	490	489	300	
Tear	94.3	92.2	104	88	
Mullen	45.7	47.1	56.3	51.2	
Product	4210	4110	5840	4500	
			Kraft Freeness-555		
Result.					
Freeness	502	495	468	268	
Tear	89	96	81	98	
Mullen	46	47	44	48	
Product	4090	4510	3540	4690	
			Kraft Freeness-492		
Result.					
Freeness	490	479	420		
Tear	89	85	80		
Mullen	48	49	47		
Product	4260	4150	3740		
			Part A		
			Kraft Freeness-442		
Result.					
Freeness	432	452		310	
Tear	112	103		109	
Mullen	48	49		54	
Product	5400	5050		5850	
			Kraft Freeness-364		
Result.					
Freeness	370	420			370
Tear	112	101			109
Mullen	51	46			49
Product	5670	4650			5300

TABLE FOUR

Two Pulps Refined Together

Series	Freeness	Tear	Mullen	Product
A	644	120	38	4570
B	631	126	39.1	4910
C	630	130	35.8	4660
A	554	109	43.3	4710
B	541	110.5	43.3	4800
C	541	113.5	47.7	5540
A	439	99.6	46.4	4660
B	413	94.8	47.2	4470
C	442	96	52.4	4940
A	298	94.5	49.5	4660
B	302	96.2	49.3	4750
C	276	84.5	58.2	5070
A	247	90	53	4740
B	228	91	52	4680
C	223	87.2	58.2	5070
A	146	80	53	4230
B	159	85.5	58.5	4980

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