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HEMICELLULOSE RETENTION IN PULPING

by

Denise R. Trainer

A Thesis submitted to the
Faculty of the Department of Paper Technology
in partial fulfillment
of the
Degree of Bachelor of Science

Western Michigan University

Kalamazoo, Michigan

April 1975

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ABSTRACT

In order to study the fate of hemicelluloses in sulfite pulping, a full survey of the reactions involved and the techniques which have been successful in promoting the retention of the hemicelluloses was carried out. Experimentation then followed with wood analysis, pulping, and analysis of the three pulps produced. From the results it can be seen that either a determination of pentosans or of hemicelluloses will illuminate the relative amount of hemicelluloses in a set of samples. However, the hemicellulose value is more reliable for sulfite pulp. The total yield of a pulp is greatly increased by starting the cook at an alkaline pH and allowing the acidity to increase as the cook proceeds. At the lowered pH level, the hemicelluloses are redeposited on the cellulose fibers to increase the yield.

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Wood, one of the primary sources of fiber for paper, consists of various chemical species. Cellulose, a crystalline polysaccharide of primarily glucose monomers, has been long recognized as a strong fibrous material, excellent for paper. The amorphous polymer lignin gives rigidity and strength to trees as it binds together the agglomerations of cellulose chains. Additional material is present in wood which is easily extracted by water or alcohol-benzene extraction procedures. The remaining material after such an extraction and subsequent deliquification is termed holocellulose.

"Those portions (of holocellulose) that are removable by alkali and those which are hydrolyzed by dilute acid fall into the class of hemicelluloses--a term devised by Schulze in 1891 to delimit those cell wall components that were intermediate between a reserve polysaccharide (like starch) and the structural polysaccharide-cellulose."⁽¹⁾ These non-cellulose polysaccharides of wood, along with related substances (for example, uronic acids) are in general of lower molecular weight, lower crystallinity, and more heterogeneous and complex structure than wood cellulose.

Hemicelluloses comprise fifteen to thirty percent of the total of a given wood sample. They are

distributed throughout the wood fiber, concentrated primarily in the outer regions. Ray and parenchyma cells contain a larger percentage of hemicellulose than do fibers. After undergoing chemical treatment, the concentration of hemicelluloses shifts to a maximum in the S2 layer of the cell wall as the more accessible hemicelluloses are removed. Studies of hemicelluloses have concluded that chemical bonds between cellulose and hemicelluloses are unlikely but that such bonds may be present between hemicelluloses and lignin.

Quantitative isolation of hemicelluloses from remaining constituents of wood is difficult due to the varying accessibility, a result of location. To isolate hemicelluloses, alkali extraction of wood meal (finely divided wood particles) or holocellulose is followed by precipitation of the species by alcohol or such selective precipitation agents as barium hydroxide, lead acetate, Fehlings solution or alkyl quaternary ammonium salts. Degradation of hemicelluloses during isolation may be retarded by carrying out the extraction at a lower temperature in a nitrogen atmosphere. Reduction of the species by borohydride prior to extraction may also prevent degradation.

Determination of the presence of hemicelluloses

can be made in many ways. The Tappi Standard, a 1971 revision of T19m50 and T22ts63, for pentosans (2) utilizes colorimetric determination after acid hydrolysis to furfural. Another colorimetric method involves the color change of a standard potassium permanganate solution. Small amounts of hemicellulose may be detected using a Technicon AutoAnalyzer. This instrument involves hydrolysis of the hemicelluloses by hydrochloric acid, a pass through a dialysis cell, an orcinol reaction, and spectrophotometric determination of the resulting color. Oscillopolarographic methods may also be used.

Further studies with the aid of forementioned isolation and determination procedures have revealed that hemicelluloses are varied, that they are made up of several different sugars, and that they may be of several main types. The sugar monomers included in hemicellulose are of two types: the hexoses or six membered rings (galactose, glucose, and mannose primarily) and the pentoses or five membered rings (arabinose and xylose). Chains of these sugars combine together and with derivative groups form the hemicelluloses. Examples of derivative groups include

- 1) the methoxyl group,
- 2) the acetyl group,

- 3) the methoxyl group as an ether on the fourth position of glucuronic acid,
- 4) the methoxyl group as a methyl ester of a carboxyl group, and
- 5) the acetyl group as an acetic acid ester.

The heterogeneity, short side groupings, and branching cause the non-crystalline structure of hemicelluloses. For example, in hardwoods one of the major pentosans is 4-O-methyl-D-glucuronoxylan. Softwoods and hardwoods differ in predominant hemicellulose species. One-sixth of the hemicellulose content of a softwood sample is glucomannan. In a hardwood sample, however, glucomannan accounts for only two or three percent of the total hemicellulose fraction. Hemicellulose species also vary in their location in the cell, as is evident from the following table taken from Rydholm. (3)

Distribution of Hemicelluloses in Pine

Summerwood Tracheid

<u>Polysaccharide</u>	Content, %			
	<u>M + P</u>	<u>S1</u>	<u>S2</u>	<u>S3</u>
Galactan	20	6	4	0
Cellulose	35	61	64	22
Glucomannan	8	16	25	14
Arabinan	30	0	0	0
Glucuronoarabinoxylan	7	17	7	64
Wt fractions of cell wall carbohydrates assumed	2	10	78	10

Of central importance in producing pulp from wood are the reactions of the components. The reactions of hemicelluloses are similar to those of cellulose. It is important to remember that one key to which reactions take place is the accessibility of the hemicellulose species by added chemical reactants. Hemicelluloses, being amorphous, are more readily attacked than the crystalline cellulose.

Although they are not fully accessible, hemicelluloses can be partially degraded by acidic, basic, or even neutral conditions. In acid conditions hydrolytic cleavage of linkages between sugars takes place, resulting in two or more smaller molecules which may in turn be broken down. In alkaline conditions such cleavage predominates only at especially high temperatures. Under milder conditions a reaction called the peeling reaction works to degrade the cellulose and hemicelluloses. This reaction was best described by Corbett and Kidd as "progressive stepwise degradation from the reducing end by the cleavage of the reducing end group and conversion of the unit into a saccharinic acid." (4) At each cleavage a new aldehyde site is formed from which the reaction can reoccur. This stepwise procedure is terminated by the conversion of reducing end groups into a saccharinic acid without cleavage. The above reaction has been called the

peeling reaction because of the shortening of the polysaccharide chain by the removal of one sugar group at a time. Other reactions of hemicelluloses include addition compounds at hydroxyl sites, substitution of ether and ester groups and oxidation to keto- and aldo-compounds.

Many studies have been undertaken to determine the influence of hemicelluloses on pulp and paper properties. Hemicelluloses have been shown to improve fiber beatability. Being amorphous, the hemicelluloses take on water. This internal lubrication in the fiber adds flexibility and increases specific swollen volume and specific surface. The increased swelling as the hemicellulose is increased leads to shortened beating time and may thus affect the power consumption in the beater. Some investigators (5) feel the effect of hemicelluloses on beatability should be attributed more to their location in the fiber structure than to their chemical composition and structure. The amorphous nature of hemicelluloses cannot be overlooked, however, as it is vital to the swelling and water take-up of the fibers.

Hemicelluloses act as an adhesive in sheet formation. Studies involving the removal of hemicelluloses have shown that all values of sheet properties which depend on fiber bonding were reduced by the removal of

hemicelluloses. Tear and opacity are specifically mentioned in another study (6) as being increased by the removal of hemicelluloses. As an explanation of the relation of physical properties and hemicellulose content, one author (7) notes the increased fiber to fiber contact during the formation and drying of the sheet due to the swollen state of the hemicelluloses. This leads to increased bond area and bond strength. An excess of hemicelluloses may lead to low opacity, low absorbency, and/or a low drainage rate. Authors differ as to the optimum content of hemicelluloses in a sheet for maximum strength. The consensus indicates that twenty percent hemicellulose is optimum, however.

The challenge, then, is to utilize the knowledge of the location, structure, and reactions of hemicelluloses to produce a sheet of paper which has maximum strength or other characteristics as may be desired.

In commercial pulping hemicelluloses undergo a variety of reactions generally in the direction of more linear polymers. The hemicelluloses are degraded, and the reactions result in a lower percentage of the species in the pulp. For example, in full chemical pulping, eighty percent of the hemicelluloses in spruce or sixty-five percent of the hemicelluloses in birch are lost.

The cooking conditions involved will greatly influence the fate of the hemicelluloses in pulping. Under acid conditions arabinose residues are removed as glucurono-arabinoxylan becomes the artifact glucuronoxylan. Frequent uronic acid substitution and the production of largely water soluble xylan are also characteristic of acid pulping. The loss of mannose due to chain peeling of glucomannan, a large content of largely water insoluble xylan, and the removal of essentially all uronic acid branches are typical of alkaline pulping. Alkaline pulps tend to have a somewhat higher degree of polymerization than acid pulps probably due to the "rapid formation of stable metasaccharinic acid end groups" (8) on many of the hemicellulose molecules. It is important to realize that pulping involves more than one reaction at a time. Many reactions compete with each other to produce pulp from wood. Alkaline pulping, as an example, involves swelling, dissolution, reprecipitation, hydrolysis of acetyl groups, peeling, stopping reactions, and hydrolysis of B-glycosidic bonds.

In recent years the trend in the pulping industry has been to increase the yield of pulp and thus make better use of limited wood resources. To increase the yield, various authors have studied the stabilization of carbohydrates by different methods. Pulping under conditions

favorable to the precipitation of hemicelluloses on fibers from the cooking liquor, improvement of impregnation by surface-active agents, acceleration of delignification by vapor phase or two stage cooking, the use of catalytic hydrogenation of lignin and the use of gaseous oxygen as a delignification agent are all methods that have been found helpful in the stabilization of hemicelluloses.

The addition of reducing agents has been studied extensively. It has been shown that alkaline degradation can be substantially reduced through the exclusion of air as well as through preliminary or simultaneous reduction with sodium borohydride." (9) In another article (10) it has been shown that pretreatment is more effective than simultaneous reduction in increasing resistance to alkaline peeling. The addition of borohydride reduces alkali consumption as it reduces the carbonyl groups and nets a yield increase of up to five percent based on the wood used. Kraft sheets with and without borohydride were made in one study. (11) The pulps with borohydride on light beating give more highly bonded sheets than those without and give higher breaking length and lower tear at equal bulk and fiber density. On further beating these differences disappear. The fibers, upon closer examination, of the pulps with borohydride had a smaller cross sectional

area, a less porous fiber wall, and greater stiffness.

Another reducing agent which has been studied is hydrazine. Less effective than borohydride, ten to twenty percent hydrazine in the cooking liquor is required to stabilize the hemicelluloses.

Prevention of hemicellulose peeling in alkaline conditions can also be accomplished by oxidation of the reducing end carbonyl group to a carboxylic acid group with elementary sulfur or polysulfide. Polysulfide is the chemical with a composition of Na_2S_x where x ranges from two to four-and-one-half. The stabilizing action of the polysulfide is most effective at high polysulfide concentration and results in higher yield and freeness. Also, less beating energy is required to get a desired tensile value and the physical properties of polysulfide pulps are somewhat better than those of kraft pulps.

The hydrolysis of hemicellulose depends on many factors, especially the concentration of cooking liquor and starting raw material. The time of beating to maximum temperature affects the rate of hemicellulose dissolution but not the total amount removed. However, a shorter beating time does reduce the degradation of hemicelluloses.

Another factor important in the consideration of retaining hemicelluloses for improved yield is the pH of the cooking liquor. Several authors (12) (13) (14) (15)

have reported that lowering the pH by addition of sulfuric acid in the later stages of the cook causes redeposition of the hemicelluloses on the cellulose fibers.

This has been rigorously proven by Clayton and Stone (16) using tritium-labeled xylan. Another method of causing the redeposition of hemicelluloses has been described.

Part of the cooking liquor can be removed at about 150°C to 160°C after the most accessible hemicelluloses have been dissolved and the remainder of the cook is completed in the vapor phase or with a second liquor which has been injected. The pH of the withdrawn liquor may be adjusted and the liquor replaced in the last stages of the cook to cause the redeposition of the hemicelluloses dissolved in the liquor on the fibers. A stabilizing agent such as polysulfide or borohydride may also be added to the withdrawn liquor before replacement.

Although several methods of stabilizing hemicelluloses have been described here, there is much research which can still be done in the field of improving pulp yields in all types of pulping.

EXPERIMENTAL DESIGN

The experimental work carried out for this project was divided into three areas; wood analysis, pulping, and pulp analysis. The commercial red oak and aspen mixture of chips was obtained from the Otsego division of Menasha Corporation. The chips were screened and obvious knots and pieces of bark were removed. Those chips which passed through the half inch square screen openings were prepared according to Tappi standard 11 for analysis. The wood meal passing through a forty mesh screen but remaining on a sixty mesh screen was used in the preparation of extractive-free wood (Tappi standard 12). The pentosan content of the wood meal was determined by the standard proposed in Tappi magazine (July 1971, vol. 54, no. 7, page 1165). Further analysis of the wood included determinations of holocellulose content (Tappi standard 9) and hemicellulose content. The hemicellulose content was determined using a modification of the procedure proposed on pages 508-9 of Browning's Methods of Wood Chemistry. Twenty four percent potassium hydroxide was reacted with the holocellulose in a nitrogen atmosphere. The hemicellulose was precipitated in ethanol solution and filtered into a tared fritted glass crucible. No correction for

ash was attempted. Duplicate determinations were made for each value and averaged. The results are summarized in Table I.

The chips which had been retained on the screen were used in pulping. Three pulping conditions were chosen. All pulps were prepared in steel bombs submerged in a hot oil bath for six hours at 140°C. The cooking liquors were acid sulfite, bisulfite, and sulfite in nature. Six percent solutions of chemical were prepared and sulfur dioxide bubbled through the sulfite solution to produce acid sulfite solution. The liquors were analyzed for total and free sulfur dioxide content before pulping according to Tappi standard 604. A three to one liquor to wood ratio was used. The spent liquor from the sulfite and bisulfite cooks was collected and analyzed also. No spent liquor could be recovered from the acid sulfite cook, however. The results of these analyses are summarized in Table II.

The three pulps produced were passed through a disintegrator twice and analyzed for yield, pentosans, holocellulose, and hemicellulose using the same procedures as were used for analysis of the wood. The results are included in Table I with the wood analysis.

TABLE I

WOOD AND PULP ANALYSIS

	% Yield	% Pentosans	% Holocellulose	% Hemicellulose
EXTRACTIVE-FREE WOOD	100	27.86	89.63	44.24
ACID SULFITE PULP	48.08	11.82	98.22	10.04
BISULFITE PULP	57.69	20.96	86.24	23.13
SULFITE PULP	80.13	27.55	79.67	34.54

TABLE II

LIQUOR ANALYSIS

	Before	After
ACID SULFITE		
Total SO ₂	0.796 g/100 ml	-
Free SO ₂	0.534 g/100 ml	-
Combined SO ₂	0.262 g/100 ml	-
pH	1.6	-
BISULFITE		
Total SO ₂	0.721 g/100 ml	0.646 g/100 ml
Free SO ₂	0.261 g/100 ml	0.100 g/100 ml
Combined SO ₂	0.460 g/100 ml	0.546 g/100 ml
pH	3.9	1.7
SULFITE		
Total SO ₂	0.696 g/100 ml	0.6496 g/100 ml
Free SO ₂	0.00 g/100 ml	0.0483 g/100 ml
Combined SO ₂	0.696 g/100 ml	0.6013 g/100 ml
pH	9.9	4.7

DISCUSSION OF RESULTS

All pulping processes are based on the fact that lignin is easier to oxidize than the carbohydrate fraction of the wood. In the sulfite processes, the sulfur compounds activate the hydrolysis of lignin. The removal of acetyl groups, the lowering of molecular weight, and the splitting off of branches are the primary reactions of the sulfite liquor and the carbohydrate fraction. At the same time lignosulfonic and acetic acids are formed. These acids may dissolve and degrade the hemicelluloses present. The carbohydrate fraction of hardwood sulfite pulp is thus cellulose, galactoglucomannan, and arabinoxylan.

In order to study the fate of the hemicelluloses in pulping, an accurate testing method must be available. In this study, two procedures were carried out in all cases. Since the results are different for each procedure, it is important to explain the discrepancies. It is commonly felt that the pentosan content is an accurate handle on hemicelluloses, especially in the case of hardwoods. Hardwoods contain a much greater percentage of pentose sugars than do softwoods. The hemicellulose determination, however, indicates the amount of hexoses as well as pentoses. The

strength of the base, potassium hydroxide, is critical in the determination. The stronger the base, the more hemicelluloses which will be dissolved. In fact, if the base is strong enough and allowed to react long enough with the holocellulose, the peeling reaction may cause part of the cellulose to be dissolved and designated hemicellulose.

(See Table III.) Given that in each case the base strength time of reaction, and wood species is the same, it would be suspected that the hemicellulose content value should at all points be a positive factor greater than the pentosan content value. This, however, is not the case. The difference between the values of pentosan and hemicellulose ranges from thirty seven percent for the wood sample to almost negative eighteen percent for the acid sulfite pulp. (See Table IV.)

Further research indicates that traces of spent sulfite liquor remaining with the washed pulp will be converted to furfural upon standing. This furfural will react with the orcinol reagent in the same way as the hydrolyzed pentosans will. The result will be a pentosan content value greater than the actual pentosan content of the wood. This furfural in the pulp will not affect the hemicellulose determination, however, since furfural is insoluble in twenty four percent

TABLE III

WOOD & PULP ANALYSIS

Basis: 100 Grams Wood

Yield	Grams Cellulose	Grams Hemicellulose	Grams Total Carbohydrates	Grams Non-Carbohydrates
Wood	45.39	44.24	89.63	10.37
Sulfite	36.16	27.68	63.84	16.29
Bisulfite	36.41	13.34	49.75	7.94
Acid Sulfite	42.40	4.83	47.23	0.85

TABLE IV

HEMICELLULOSE VERSUS PENTOSAN

Yield	% Difference, $100(\% \text{ Hemicellulose} - \% \text{ Pentosan})$ % Hemicellulose
100	37.0
80.13	20.2
57.69	9.4
48.08	-17.7

potassium hydroxide. The insoluble furfural residue would thus be filtered out before the precipitation of the hemicelluloses. It becomes apparent that although either of the methods used here will illuminate the relative hemicellulose content in a set of samples, the hemicellulose determination by alkali extraction and precipitation in alcohol gives a truer value for the hemicellulose content of sulfite pulps.

Irregardless of which procedure is used for determining hemicellulose content, it is obvious that the pulping processes have produced different hemicellulose contents and thus different total yields. With all three pulping conditions there has been a loss of both hemicellulose and cellulose material through acid hydrolysis and the dissolution of the smaller sugar chains produced. Referring to Table II, it can be seen that the sulfite liquor is the only one which is initially alkaline. The acidity of all liquors increases as the pulping occurs and as lignosulfonic and acetic acids are generated. As mentioned previously (p. 10), several authors have studied the deliberate acidification of kraft cooking liquors near the end of the cooking cycle to promote the redeposition of hemicelluloses on the cellulose fibers. The work done here shows that the acidification by

20

the acids produced in sulfite pulping causes a similar reaction. Without the addition of supplemental chemicals, the hemicelluloses are first swelled and dissolved in alkaline solution. This makes the wood more receptive to the action of the pulping chemicals. As the acidity increases, the hemicelluloses come out of solution and adhere to the cellulose fibers. It is this action which causes the much higher total yield and hemicellulose content of the sulfite pulp. In a similar manner the lowering of the pH of the bisulfite liquor causes some redeposition of hemicellulose. The acid sulfite condition was too severely acid to facilitate any reprecipitation of hemicelluloses.

SUGGESTIONS FOR FURTHER STUDY

The work done here serves to illustrate that the lowering of pH from an alkaline or mildly acid beginning in a sulfite cook will cause the redeposition of hemicelluloses. There is room for much more work to be done. Controlled studies involving various initial pH levels, buffers, cooking times, and rate of acidity increase should be carried out to determine the conditions which will cause the optimum yield and retention of hemicelluloses.

CONCLUSIONS

The redeposition of hemicelluloses is critical to the improvement of the yield of a sulfite pulp. One way to cause the redeposition is to initiate the sulfite cook under alkaline conditions. During the cook, acids formed will lower the pH of the liquor and cause the redeposition of the hemicelluloses. Controlling the amount of reprecipitation of hemicellulose is the key to better yields in the sulfite processes.

To study the fate of the hemicelluloses, either the pentosan determination or the hemicellulose determination used here will give the relative amounts of hemicellulose although the values for hemicellulose are closer to the true value. Determination of pentosan content of a sulfite pulp is often erroneous because of traces of spent liquor remaining in the pulp.

In addition, the work discussed here has served to show the extent of time and preparation involved in a well done research project. It has shown how valuable a good advisor can be and for his help I am extremely grateful to Dr. S. I. Kukolich. Without his guidance, the work here could not have been accomplished.

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PAPER 470

Work done in forming
this additional

~~Thesis:~~ Non-Sulfur Pulping with Anthraquinone
for Corrugating Medium Manufacture

April 4, 1986

~~Course:~~ Paper 470

Shau-Gah Chang.
Dr. Valley

Adviser: Dr. Valley

Dr. Valley will be
~~Name:~~ Shau-Gah Chang will be
Will be w.e.l

A small section of
arbitrarily curved
surface is shown in

~~Date:~~ April 4, 1986 w.e

Fig. 11-4

Submitted in partial fulfillment
of the requirements of PAPER 470.

△ X

constant
constant
constant

liquid surface

liquid surface

Constant

Curvature liquid surface
Radii of Curvature tension

Foreign Exchange

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五五五

I cannot give you a passing grade for 490 on the basis of this paper. Your work and communication during the semester have be passing grade. This paper should be rewritten. I will give you an incomplete with a requirement that you rewrite and submit by May 19th

~~Summary~~ *abstract*

The objective of this thesis study is the effect of Anthranguinoe (AQ) in Non-Sulfur Pulping for corrugating medium. The cooking agents are sodium hydroxide, sodium carbonate and AQ. The three variables in this Pulping Process are: total alkali, buffer ratio ($\text{Na}_2\text{CO}_3(\text{NaOH})$), and AQ percentage but only AQ percentage is concerned variable.

In such a mild condition, the hemicellulose might be less degraded and delignification rate increase. The chip used is aspen because of its rich hemicellulose content and its availability in Michigan.

Corrugating

AAW

Traditionally, Neutral Sulfite Semichemical Pulping Process used hardwood to make corrugating medium because of its pulp stiffness and higher yields. The most satisfactory pulping agent was found to be a solution of sodium sulfite containing sufficient buffering agent to keep the pH around seven during cooking.

Due to several reasons, many semichemical corrugating mills try to free ^{themselves} ~~itself~~ of NSSC pulping.¹ In most cases there are three ^{reasons} 1) A poor market for the saltcake by product at those mill burning spent NSSC liquor via fluidized bed incinerators.

2) A high chemical cost for NSSC pulping because the sodium sulfate and soda ash cannot be recycled, 3) Sulfur emissions.

Several approaches to non-sulfur pulping have been developed, one of them is Owens- Illinois Process, the active pulping agent in O-I patent ^{is} ~~are~~ a mixture of soda ash (sodium carbonate) and caustic (sodium hydroxide). The critical factor in this process is the ratio of sodium hydroxide to sodium carbonate. ^{The patent} ~~and it~~ claims that 15% to 50% caustic as Na_2O is required.

Varying the ratio has a pronounced effect on pulping properties, degree of delignification, refining horse power, and quality.

The use of anthraquinone (AQ) and related compounds in alkaline pulping have been developed and many authors have examined its mechanism of action. In every case, ^{there is an acceleration} ~~the pulping acceleration~~ of pulping rate and ^a yield increase resulting from the additives.²

← Wood Chemistry Review.

lignin reaction:

The reaction of lignin in alkaline pulping ^{is} ~~are~~ complex and ^{is} ~~are~~ not completely understood.³ It can be concluded that alkaline pulping operates on the basis of hydrolytic (or possible homolytic) depolymerization of phenylalkyl ethers,

thereby reducing the size of the lignin molecule and simultaneously generating new solubilizing phenoxide ions. The addition of nucleophile function group, such as kp: , HS ; NSSC ; HSO_3 can accelerate lignin dissolution from the p-o aryl ether cleavage. In the presence of anthraquinone and anthraquinone mono-sulfonate, the effectiveness of ^{AQ}quinone is based on its redox properties combined with its stability toward alkali. The redox potential seems to facilitate lignin solubilization resulting in higher delignification rates and apparent hemicellulose conservation.

Cellulose and Hemicellulose:

In the alkaline pulping, the most important type of alkaline degradation is the so called peeling reaction.⁴ This reaction involves the gradual shortening of cellulose chain by a B-elimination mechanism. The peeling reaction will remove about 50 to 60 glucose unit from each starting point until finally another reaction called the stopping reaction provides the end unit with a configuration stable to alkali. The stopping reaction lead to the stopping reaction lead to the formation of a substituted metasaccharinic acid, and stabilize the cellulose or hemicellulose chain to further elimination. But in the hemicellulose, the xylosidic bonds between xylose unit are easily hydrolyzed by alkali..

Experimental Procedure

From above introduction of pulping process and wood chemistry the emphasis of this thesis will combine use characteristic of AQ added with the O-I patent process, the effects will be measured by the strength properties and yields of the pulps. will be The procedure is as follows:

- 1) Preliminary cook for yields determination, make Four cooks will be made by varying cooking time under different AQ percentage from

10 25 40 55 minutes respectively, and use regression analysis ^{using} to find yield and cooking time relationship: $y = ax^2 + bx + c$; where y is pulp yield, x is cooking time.

2) Make handsheet to test its strength properties.

After determining the time needed, I can totally get 12 cooks, make handsheets to compare their strength properties and beating time.

3) Cooking condition.

- a) Total alkali: 10% (as Na_2O)
- b) Buffer ratio: 60:40
(NaCO_3 / NaOH)
- c) Liquid to wood ratio: 5:1
- d) Cooking Temperature: 170°C

Your experimental discussion and plan is much too brief and therefore confusing. You should break it into three sections. Preliminary, Pulping and Strength Testing. Detail the number of handsheets, refining, tests to be run.

Recognize them

Recognize

Polymer

Shou-Gan Chang

Shou-Gan Chang

185
32
153

Shou-Gan Chang

376
32
344

Ly is full

273573 = 89

7
80
85
88%

1) James P. Hanson "No-Sulfur Pulping Pushing Out NSSC Process
at Corrugating Medium Mill" Pulp and Paper March 1978.

3) James P. Casey Pulp and Paper Chemistry and Chemical Technology 3rd edition Volume 1. *in ref. 1*

formel way in term
The interfaces pos

Ger
Ring

Anthraquin
methoxyl
Anthraquinol

Pulp and effect of accidental Anthraguin.
fluctuat. Anthragu. Drop

Paper chemistry for the stable exist^o drop

Chemistry Anthrangi 7 a Drop Drop Drop

The emphasis is on those aspects
that have received
surface chemical chemical

Drop weight method
experimental

$$\begin{array}{r} 30 \\ 2.5 \\ \hline 75 \end{array} \quad \begin{array}{r} 12 \\ 12 \\ 6 \\ \hline 30 \end{array}$$

.. The film σp , such that

across the film σp total surface free energy

$$\frac{6 \cdot 2 \cdot 2}{12 \cdot 13 \cdot 2}$$

(132)

$$\frac{6 \cdot 2 \cdot 2}{12 \cdot 13 \cdot 2} = \frac{6 \cdot 2 \cdot 2}{12 \cdot 13 \cdot 2}$$

1 dyne = 10^7 erg

$$\sigma p = 4\pi r^2 dr = 8\pi r^2 dr$$

$$\sigma p 4\pi r^2 dr$$

$$= 8\pi r^2 dr$$

$$\sigma p = \frac{2\gamma}{r}$$

is just equal to the der

Soap bubble

spherical

Where $d\sigma = \sigma dx$

Where $d\sigma = \sigma dx$

Casery is spherical spherical

Casery spherical spherical

Casery spherical spherical

The corresponding SI units

are 'of course, Joules/m

Joules/m

Joules/m

Pressure Pressure

Casery Effect $\sigma p 4\pi r^2 dr$ of Pressure = A

on surface Tension

Casery Casery

Customary units by a pressure

Tendency to do so

to think of γ in terms of energy per unit

must be balanced

by a pressure

We will choose, here

difference across the

to think of γ in terms of

film σp , such.