High Yield Pulping by Polysulfide Pulping Process

By

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An attempt has been made in this work to study the feasibility of Polysulfide pulping on the improvement of Pulp yield based on Bamboo (Dandracalamus Strictus) as cellulosic raw material. Experimental investigations indicate that pulp yield is increased to the extent of 5-8%, with significant improvement of physical strength properties, like tensile strength and folding endurance, under optimum conditions developed in this work.

Based on the investigations it is recommended to study polysulfide pulping on pilot plant scale to confirm the operational datas presented here.

Introduction

It is widely recognised that per capita consumption of paper is an index of the phase of development and standard of literacy achieved in a country.

India needs a paper production of 2.50 million tonnes just to achieve per capita consumption of 5.0 Kgs. which is one of the lowest in the world and to achieve this target of production, requirement of cellulosic raw materials is of the order of 6.0 to 7.0 million tonnes, which presents a collossal and intricate problem. The known existing source of bamboo, the traditional and major fibrous raw materials in India, could be expected to be available, at the most, about 2.50 million tonnes per year to the Pulp and Paper Industry.

To meet the acute shortage of cellulosic raw materials in India, it is becoming increasingly important to study the feasibility of developing a high yield pulping process alongwith plantation of fast growing mixed hard woods on a large scale.

Literature Review on High Yield Pulping

It has been established by the various researchers that considerable amount of carbohydrate dissolution takes place during the initial and final stage of the pulping process due to "peeling" reaction. It has been found that the stability of cellulose to hot alkali increases considerably if the aldehydic end groups are oxidised to stable carboxylic groups. Meller[1] and Hartler[2] showed that the loss of carbohydrate is reduced considerably when the sulphate cook is carried out in presence of sodium borohydride. Due to high cost of borohydride pulping process, large number of investigations were carried out with cheaper additives and this polysulfide pulping process was developed.

The most interesting step of polysulfide pulping is the preparation of cooking liquor. Polysulfide in cooking liquor consists of a series of complexions with sulphur in the oxidised stage. These compounds are formed either by mixing sulphur with sulphide, by suitable partial oxidation of sulphide, or by other well known reactions. The reactions can be described as an autocatalytic process in which sulphide ions react with eight-membered sulphur rings to form polysulfides. In this respect, short chained polysulfides are probably more effective than average polysulfide molecules. The activation energy is very low. On the other hand, a free radical mechanism would be a possibility, but this has been rejected by E.S.R. (Electron Spin Resonance) studies.

During polysulfide cooking, the polysulfide ions can be expected to react according to the following schemes.

* **The views expressed in the article are author's own based on the work carried out by him during his student-ship at Institute and Paper Technology, Seharanpur. Presently he is working as a Shift Incharge, Paper Machine, J.K. Paper Mills, Jaykaypur.**

(i) $S_5'' - 60H' = 3S'' + S_2O_3'' + 3H_2O$
$4S_4 + 18OH' = 10S'' + 3S_2O_3 + 9H_2O$

(ii) $S_5'' + 16OH' + 8RCHO = 5S'' + 8RCOO' + 6H_2O$
$S_4'' + 12OH' + 6RCHO = 45'' + 6RCOO' + 6H_2O$

(iii) $S_n'' + \text{Organic} = S'' + n \text{ Organic S}$

A critical assessment of the literature survey indicates the commercial feasibility of getting significant amount of increased yield by Kraft pulping with admixture of polysulfide chemicals. An attempt has been made in this paper to study the advantages of polysulfide pulping with regards to bamboo as the raw material, in terms of increase in yield and strength properties.

Experimental Work

Screened air dry bamboo chips (Dandrocalamus Strictus) obtained from F.R.I., Dehradun, were locked in a labo ratory autoclave having four tubes. 180 Gms. O.D. Chips were taken for each digestion. The cooking liquor with an active alkali content of 100 g.p.l. as Na_2O with 20% sulphidity was used maintaining a bath ratio of 1 : 3.5. Cooking liquor was varied from 12% to 15% as Na_2O based on O.D. Chips. Cooking time schedule is as under :

Time to raise temperature to 90°C	...	30 Mints.
From 90°C to 130°C	...	60 Mints.
At 130°C	...	60 Mints.
From 130°C to 162°C	...	60 Mints.
At 162°C	...	30 Mints.
Total cooking time	...	240 Mints.

After cooking, the cooked pulp was washed throughly and its unbleached yields along with K. No. were determined.

In polysulfide pulping, cooking liquor was prepared by adding required amount of sulphur based on O.D. Chips in the desired volume of white liquor. Four different experiments were carried out in four tubes in lab. autoclave under conditions similar to that maintained during Kraft pulping experiments.

Results and Discussions

The results along with the digestion conditions are tabulated in Table I.

The freeness of raw pulp varied from 11-15° S.R. The screened pulp was beaten to about 42-45° S.R. Hand sheets were made according to TAPPI standards and tested for their physical properties. Strength properties are tabulated in Table II.

From the experimental results tabulated in Tables I & II and presented in Figures I & II, it is observed that the unbleached pulp yield decreases rapidly (Figure I) by increasing the amount of cooking chemicals from 12% to 13% and then becomes constant. It is also observed in the same table that, there was insignificant amount of variation with respect to K. No., after 13% cook, which indicates that 13% active alkali may be taken as the optimum cooking chemical requirement for bamboo chips studied. On adding crude sulphur from 2% to 8% based on O.D. chips, in each cooking it is observed that, there is an increase in yield upto 6% sulphur added. Moreover, from the results presented in Table II, it is observed that the breaking length and burst factor increases with an increase of sulphur addition from 2% to 4% and then decreases on further addition of the same. From the same table, it is seen that, tear factor decreases with an increase of sulphur addition from 2% onwards. From these experimental investigations, it may be concluded that, 3.0% Sulphur addition during Kraft pulping of bamboo, gives optimum results in terms of yield increase and improvement of strength properties. Since no adverse effect was observed on the rate of delignification at higher pulp yield, it is confirmed that, significant amount of carbohydrate stabilization must have taken place during polysulfide pulping. The increased retention of carbohydrate fraction is resulted from the oxidation of the aldehydic groups into carboxylic groups, whereby, peeling reaction is significantly reduced.

It is regarding the techno-economical feasibility of polysulfide pulping process, preliminary costing has been done and it has been found that, the additional cost of sulphur in polysulfide pulping is more than compensated by the increased yield of pulp, without taking into account the spent liquor recovery process.

TABLE I

Sl. No.		% of Cooking Chemicals: % NaOH+ Na_2S as Na_2O	%S as such.	Bath Ratio	Maximum Cooking Temp. (°C)	Total Cooking Time (Hrs.)	% Yield	K. No.
	a	12	0				45.1	20
	b	12	2				51.5	20
1	c	12	4	1 : 3.5	162	4.00	51.8	21
	d	12	6				51.9	19
	e	12	8				51.6	20
	a	13	0				41.8	19
	b	13	2				49.8	19
2	c	13	4	1 : 3.5	162	4.00	50.2	20
	d	13	6				50.2	20
	e	13	8				50.1	20
	a	14	0				41.6	18
	b	14	2				48.6	19
3	c	14	4	1 : 3.5	162	4.00	49.2	18
	d	14	6				49.4	19
	e	14	8				49.5	19
	a	15	0				41.5	17
	b	15	2				48.5	16
4	c	15	4	1 : 3.5	162	4.00	48.5	17
	d	15	6				48.9	17
	e	15	8				48.6	17

TABLE II

(13% Active Alkali Cook)

Sl. No.	Beating Time (Min)	% S	°S.R. after Beating	Breaking Length (M)	Strength Properties at 23 ± 2° and 65 ± 2% R.H.: Burst Factor	Tear Factor	Folding Endurance
a	23	0	43	3840	45	200	250
b	20	2	44	5330	35	195	400
c	19	4	43	8400	83	169	300
d	18	6	43	6700	62	173	320
e	18	8	44	5600	38	190	300

Conclusion and Recommendation

Based on the experimental results on the polysulfide pulping of Bamboo (D. Strictus), the following conclusions are made :

(i) Significant amount of pulp yield increase is possible in polysulfide pulping, due to reduction of "peeling reaction".

(ii) Bursting and tensile strength properties are increased significantly in polysulfide pulps.

(iii) In case of availability of sulphur, the additional cost of sulphur in polysulfide pulping is more than compensated by the increased yield of pulp, whereby overall cost of polysulfide pulp is less than the Kraft pulp.

Further work is recommended in the following lines :

(i) Studies to be undertaken on the feasibility of recovery of polysulfide chemicals from the spent liquor.

(ii) It is necessary to study polysulfide pulping on pilot plant scale, so as to confirm the operational dates presented in this work.

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