Formaldehyde: A Useful Bleaching Aid To Save On Bleach Chemical Cost

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ABSTRACT

Presently pulp and paper industries use additives in pulping, oxygen delignification and bleaching to enhance the reactions and reducing the processing costs. Simple member of the family of aldehydes (formaldehyde) and ketones (acetone) having a carbonyl group (-C=O) are effective as additive to increase the efficiency of chlorine dioxide bleaching. The performance studies of these additives to bleach the pulp samples after ODL with our raw materials at two different furnishes (100% mixed hardwood and bamboo : MHW 20 : 80) have been carried out to a target brightness of 89 ± 1% ISO. The addition and effect of brightness gain was utilized for the reduction of high cost bleaching chemicals like H_2O_2 and ClO_2 in subsequent bleaching stages.

The paper describes how formaldehyde can be useful in saving 10.4 kg/ton of 50% H_2O_2 solution or 2.66 kg/ton of ClO_2 in a bleaching sequence of CD-Ep-D. In the process, the resultant pulp quality was also found to be better with respect to brightness, viscosity and strength properties. A decrease in pitch content was observed alongwith a reduction of TSS in the combined effluent. An indication of cost aspect has also been covered in this paper. Acetone did not prove useful inspite of saving 12 kg/ton of H_2O_2 (50% solution) and 4.18 kg/ton of ClO_2 due to its high cost.

Introduction

Formaldehyde, a simple organic solvent has a carbonyl group (-C=O) which reacts with chlorites to release ClO_2 (1-3). In practice, industrial process wastes much of the ClO_2 by forming chlorite (ClO_2) and chlorate (ClO_3). Chlorite is normally formed in the chlorination stage by both ionic and free radical mechanisms. Chlorine dioxide ionises to chlorate (ClO_3), chlorite (ClO_2) and chloride (Cl) where hypochlorous acid (HClO) and chlorous acid ($HClO_2$) are produced as reaction intermediates depending on pH (4, 5). Chlorite is also formed by reduction of ClO_2 on reaction with phenolic groups in lignin to give phenoxy radicals by one electron oxidation.

Realising the high cost of ClO_2 generation, it was aimed at converting the ClO_2^- or $HClO_2$ formed in situ, to ClO_2, by use of two organic chemicals, i.e. formaldehyde and acetone. Both of these chemicals were oxidized to their respective carboxylic acid on reaction with $HClO_2$ and liberated ClO_2 as the byproduct. This conversion of inactive chlorite or chlorous acid to ClO_2, increases the bleaching efficiency thereby resulting in increased brightness of final bleached pulp. The increased brightness and bleaching efficiency of ClO_2 can translate into bleach chemical saving in further stages of bleaching.

A mill trial of aldehyde enhanced bleaching for 3 days in 2001 in a Canadian mill was also reported (3), wherein a saving of 10.8 kg. of ClO_2 per ton of pulp at a target brightness of 89.2% was achieved. Therefore a study was undertaken to see the possibility of arresting the chlorite formation or conversely to regenerate ClO_2 from chlorites so that bleaching efficiency and utilization of bleach chemicals are optimized.

Although acetone was found to be equally effective compared to formaldehyde but due to its high cost (Rs.72/kg.) and hazardous nature, the study was pursued with formaldehyde for a possible industrial application.

Understanding the mechanism:

The study was carried out in a bleaching sequence of CD-Ep-D. In CD stage of pulp bleaching, both Cl_2 and ClO_2 are added to pulp simultaneously, first chlorine followed by ClO_2. Initially, molecular chlorine and hypochlorous acid (HOCl) are in equilibrium with equal quantities present at pH 2 and 25^0C (6). When ClO_2 is added to pulp, it reacts with pulp transferring one electron to produce chlorite ion (ClO_2^-). This chlorite is unreactive towards lignin. Under acidic pH conditions, it is converted to $HClO_2$ which oxidizes lignin, to form HClO. The formation of chlorite or chlorous acid represents a loss of oxidizing efficiency of ClO_2(7). A most plausible mechanism of various parallel reactions involving HOCl, ClO2, ClO_2^-, aldehydes and the pulp in the CD stage is discussed below :

It is generally accepted that both ionic and free radical mechanisms are involved in chlorination of pulp. Ionic reactions are predominant with lignin and radical reactions with carbohydrates. Lignin acts as an effective radical scavenger by virtue of favourable reaction kinetics and protected carbohydrates from oxidation. This protective effect diminishes when lignin content decreases. Chlorine dioxide is therefore added to pulp to protect radical attack in the CD stage (6). Literature reveals that within few minutes after the chlorination stage, 32% of ClO_2 is converted to active chlorite resulting in loss of oxidizing power (8). Addition of formaldehyde prevents the loss of oxidation potential of ClO_2 by generating ClO_2 from chlorites. The carbonyl group in formaldehyde converts the chlorous acid ($HClO_2$) and chlorite (ClO_2^-), formed in situ to give back the ClO_2(9). In CD stage, where chlorination is carried out at or below pH-2, one of the ionisation products of ClO_2 i.e. chlorite ClO_2^- is maximum. Chlorite is also regenerated by the reduction of ClO_2 on

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reaction with the phenolic groups of residual lignin to give phenoxy radicals by one electron oxidation (8). This can be represented in the equation below:

$Phenol + 2\,ClO_2 \rightarrow Products + ClO_2^- + HOCl$ (p-quinones or hydrogen methyl muconates)

At this strongly acidic pH condition, chlorite (ClO_2^-) is found to be in equilibrium with chlorous acid as per the equation:

$ClO_2^- + H^+ \rightarrow HClO_2$ ------ (i)

Formaldehyde, if added at this stage, reduces the chlorite to ClO_2 and is itself oxidized to formic acid according to the following equation (10):

$H\text{–}CHO + H^+ + ClO_2 \rightarrow HOCl + HCOOH$ ------ (ii)

As the above reaction proceeds, pH of the solution drops due to formation of formic acid. The increased acidity of the solution promotes the formation of ClO_2 as shown below :

$HCOOH + HOCl + 2ClO_2^- \quad 2ClO_2 + Cl^- + H_2O + HCOO^-$ ----- (iii)

In acidic solution, ClO_2 behaves as an oxidizing agent. The complete reduction of ClO_2 is shown below :

$ClO_2 + 4H^+ + 5e^- \rightarrow Cl^- + 2H_2O$ ----- (iv)

The individual steps of reaction (iv) produces $HClO_2$, HOCl and Cl_2 and all behave as oxidizing agents.

The overall reactions of chlorite during chlorination (CD stage) after formaldehyde addition can be represented as below (11):

♦ $H\text{-}CHO + HClO_2 \leftrightarrow H\overset{\cdot}{C}(=O) + OH^{\cdot} + HOCl$

♦ $H\text{-}\overset{\cdot}{C}(=O) + OH^{\cdot -} \rightarrow H\text{-}COOH$

♦ $HOCl + 2HClO_2 \rightarrow 2ClO_2 + H2O + H^+ + Cl^-$

$H\text{-}CHO + 3HClO_2 \rightarrow H\text{-}COOH + 2ClO_2 + H_2O + HCl$

At higher pH levels above 4 chlorate formation increases when hypochlorous acid reacts with chlorite which also represents loss of oxidizing power of ClO_2 (12).

$HClO + ClO_2^- \rightarrow ClO_3^- + H^+ + Cl^-$

EXPERIMENTAL

Preliminary Study

The experiments were carried out using two types of pulp samples i.e. i) a mixture of hardwood, ii) a mixture of bamboo and hardwood [20 : 80] after oxygen delignification at PAPRI. They were bleached in a CD-Ep-D sequence and before bleaching the kappa no., brightness and consistency were checked.

Preliminary experiments were conducted with 100 gm. of OD pulp (in small polythene bags) following above sequence to know the maximum effectiveness of formaldehyde and the mode of addition to pulp. Experiments were also carried out by adding formaldehyde to the D-stage in addition to the CD stage. The optimum dose of formaldehyde on pulp was added at CD stage followed by Ep stage. The Ep pulp was split in two parts; to the first part formaldehyde was added with ClO_2 in D stage and to the other only ClO_2 was added (blank).

Optimization of Formaldehyde and Acetone Dosing

Three levels of formaldehyde dose i.e. 0.25%, 0.75% and 1.0% and acetone dose of 0.75%, 1.0% and 1.5% on O.D. basis of pulp were tried for optimization.

Detailed Study

Four sets of pulp samples from the mixed hardwood furnish were chosen for detailed study with 400 gm. O.D. pulp. Later on, the similar sets were repeated with B + HW furnish. The first set was taken as blank, second set was with the optimum dose of formaldehyde, third and fourth sets were with reduced dose of peroxide and chlorine dioxide respectively maintaining same dose of formaldehyde. The resultant bleached pulp was evaluated for brightness, viscosity, fibre fractions and strength properties at 40 ^{0}SR beaten pulp. Stage wise process conditions and other pulp properties are tabulated in Table 1.

- **Set I : Blank (without Formaldehyde addition):** A control or blank experiment was done without using formaldehyde using lab scale bleaching conditions standardized at Pulp and Paper Research Institute in CD-Ep-D sequence. Basis of total chlorine demand was calculated as 52% of ODL kappa no. 70% of this given at CD stage and 30% at D stage.

- **Set II: Addition of 0.75% Formaldehyde:** To the second set of pulp, 0.75% formaldehyde was added in the CD stage by mixing with chlorine dioxide. All other bleaching conditions were same as that of blank.

- **Set III: Addition of 0.75% of Formaldehyde and Reducing 35% of Peroxide Dose in EP Stage :** To the third set of pulp, similarly formaldehyde was mixed in chlorine dioxide and added to pulp in CD stage and H_2O_2 dose in Ep stage was reduced from 1.5% to 0.98%.

- **Set IV: Addition of 0.75% of Formaldehyde and Reducing 30% of ClO2 Dose in D Stage :** To the fourth set similarly 0.75% formaldehyde was added to ClO_2 at CD stage but here the ClO_2 dose in D stage was reduced by 30% as compared to blank.

- The total suspended solids (TSS) of the combined effluent mixed in the ratio of CD : Ep : D at 2 : 1 : 3 was checked taking 1 litre. of effluent and filtering it through the normal filter paper. The initial and final weight of the filter paper was taken to calculate the TSS which gives an indirect indication of fines content.

- To know the pitch content in the final D stage pulp, the standard procedure for DCM (Dichloromethane) extraction using a soxhlet apparatus was followed (Tappi Test Methods : T-204).

All the final stage bleached pulps were evaluated for brightness, viscosity, fibre fractions, strength properties, TSS and DCM extractives. Set I - IV experiments were conducted with 100% hardwood (HW) furnish. All process conditions and pulp properties are given in Table-1.

A repeat set of experiments were conducted taking B + HW (20 : 80), process conditions and test parameters remained unchanged (Set I-A to IV-A). Results are presented in Table-2.

Similar experiments were done as above with acetone at an optimized dose taking both HW and B + HW furnish. The results of these experiments are presented in Tables 3 and 4, process parameters and experimental conditions remaining same except the reducing doses of H_2O_2 and ClO_2 (i. Blank without acetone, ii.

With 1% acetone, iii. With 1% acetone + 40% less H_2O_2, iv. 1% acetone + 60% less ClO_2 and v. 1% acetone + 40% less H_2O_2 + 50% less ClO_2).

RESULTS AND DISCUSSION

A higher brightness (90.7% ISO) was obtained when formaldehyde was mixed with ClO_2 and added to pulp than that by adding directly to pulp (88.9% ISO) and without formaldehyde i.e. blank (87.8% ISO). Hence, adding formaldehyde to ClO_2 was more effective than adding it directly to the pulp.

The dose of formaldehyde at 0.75% on O.D. pulp basis was found to be the optimum (with respect to brightness and viscosity) and detailed experiments on 400 gm. scale were carried out, at this dosing. Optimization of formaldehyde dose with respect to brightness has been indicated in Figure-1. Similarly, optimization of acetone by applying 0.75, 1.0 and 1.5% on O.D. pulp was done and the optimum dose of 1.0% on O.D. pulp was selected.

It was found that addition of formaldehyde in both CD and D stages reduced the brightness by 0.6% ISO i.e. 88.9% ISO compared to blank (89.5% ISO). After the formaldehyde dose was optimized in preliminary study, a detailed study (with 400 gm. of OD pulp) was carried out to optimize the dose of formaldehyde at the target brightness level of 89 ± 1% ISO.

WITH FORMALDEHYDE :

The results of study on 400 gm. scale showed that with the optimized 0.75% dose of formaldehyde on O.D. pulp basis, the yield, brightness, viscosity and strength properties increased when added to both 100% HW and B + HW furnish. A decrease in the amount of fines fraction and DCM extractive content in the final bleached pulp was also observed (Table 1 and 2).

The brightness increased from 88.1% ISO to 89.4% ISO in 100% HW furnish and 88.5% ISO to 90.6% ISO in B + HW furnish. The viscosity increase was 13.4% with formaldehyde addition as compared to blank in HW pulp whereas it was 1.3% in case of B + HW pulp. The strength index went up from 1508 to 1663 in 100% HW furnish(Table 1) whereas in case of B + HW, the rise was 1716 to 1797(Table 2). Yield increase was 0.2% in B + HW furnish but no increase was observed in HW furnish. The pitch or DCM extractive content was 42.4% less in

FIGURE 1: EFFECT OF FORMALDEHYDE DOSE ON FINAL BRIGHTNESS

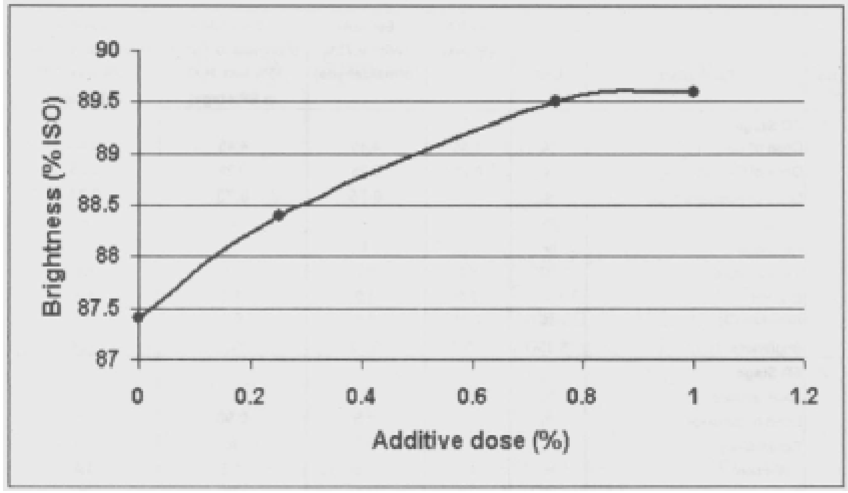

TABLE - 1: STUDY WITH FORMALDEHYDE (100% HW FURNISH)

PO Pulp unbleached kappa no. : 14.1

Sl. No.	Particulars	Unit	Set-I (Blank)	Set-II (With 0.75% formaldehyde)	Set-III (Formald. 0.75% + 35% less H_2O_2 in EP stage)	Set-IV (Formald. 0.75% + (30% less ClO_2 in D stage)
1	**CD Stage**					
	Dose of Cl_2	%	4.45	4.45	4.45	4.45
	Dose of ClO_2 as ClO_2	%	0.25	0.25	0.25	0.25
	Dose of Formaldehyde	%	-	**0.75**	**0.75**	**0.75**
	Consistency	%	8	8	8	8
	Retention	hr.	1	1	1	1
	Temperature	^0C	RT	RT	RT	RT
	End pH	-	1.8	2.1	1.5	1.9
	Residual Cl_2	%	0.2	0.05	0.09	0.08
	Brightness	% ISO	52.3	54.3	54.8	54.1
2	**EP Stage**					
	Alkali applied	%	2	2	2	2
	Dose of peroxide	%	1.5	1.5	**0.98**	1.5
	Consistency	%	10	10	10	10
	Retention	hr.	1.5	1.5	1.5	1.5
	Temperature	^0C	80	80	80	80
	End pH	-	10.7	10.4	10.7	10.3
	Brightness	% ISO	76.6	77.8	75.4	78.1
3	**D Stage**					
	ClO_2 applied as Cl_2	%	2.2	2.2	2.2	**1.5**
	ClO_2 consumed as Cl_2	%	1.9	1.96	1.75	1.36
	Consistency	%	10	10	10	10
	Retention	hr.	4	4	4	4
	Temperature	^0C	70	70	70	70
	End pH	-	2.7	2.6	2.7	2.8
	Residual Cl_2	%	0.3	0.24	0.45	0.14
	Brightness	% ISO	88.1	89.4	88.0	88.2
	Viscosity	cP	8.9	10.1	10.3	10.4
	Yield	%	93.0	93.0	92.7	93.4
	Shrinkage	%	7.0	7.1	7.3	6.6
4	**Fibre classification :**					
	+ 16	%	0.1	0.1	0.1	0.3
	- 16, + 30	%	0.2	0.7	0.2	0.2
	- 30, + 50	%	34.7	36.3	33.2	32.7
	- 50, + 100	%	32.0	31.0	33.2	33.9
	- 100	%	33.0	31.9	33.3	32.9
5	Beating time to get 40^0SR	min.	41	42	50	46
6	**Strength properties :**					
	Grammage	g/m^2	61.9	62.1	61.9	59.7
	Thickness	micron	94.5	93.3	86.9	87.2
	Bulk	cc/g	1.53	1.5	1.4	1.46
	Burst factor	-	39.9	41.4	46.4	45.6
	Tear factor	-	65	76	71	67
	Breaking length	mtr.	5924	5990	6688	6723
	Double fold	no.	21	29	38	29
	Strength index		1508	1663	1733	1647
7	DCM extractive (pitch content)	%	0.33	0.19	-	-
8	TSS of combined effluent (CD:EP:D :: 2:1:3) ratio	ppm	1318	480	398	354

TABLE - 2: STUDY WITH FORMALDEHYDE (20% BAMBOO + 80% HW)

PO Pulp unbleached kappa no. : 14.1

Sl. No.	Particulars	Unit	Set-I(A) (Blank)	Set-II(A) (With 0.75% formaldehyde)	Set-III(A) (Formald. 0.75% + 35% less H_2O_2 in EP stage)	Set-IV(A) (Formald. 0.75% + (30% less ClO_2 in D stage)
1	**CD Stage**					
	Dose of Cl_2	%	4.45	4.45	4.45	4.45
	Dose of ClO_2 as ClO_2	%	0.25	0.25	0.25	0.25
	Dose of Formaldehyde	%	-	**0.75**	**0.75**	**0.75**
	Consistency	%	8	8	8	8
	Retention	hr.	1	1	1	1
	Temperature	^0C	RT	RT	RT	RT
	End pH	-	2.0	1.9	1.5	1.5
	Residual Cl_2	%	0.21	0.5	0.2	0.2
	Brightness	% ISO	55.2	55.5	52.7	53.4
2	**EP Stage**					
	Alkali applied	%	2	2	2	2
	Dose of peroxide	%	1.5	1.5	**0.98**	1.5
	Consistency	%	10	10	10	10
	Retention	hr.	1.5	1.5	1.5	1.5
	Temperature	^0C	80	80	80	80
	End pH	-	10.7	10.6	10.9	10.6
	Brightness	% ISO	77.1	79.6	75.8	77.9
3	**D Stage**					
	ClO_2 applied as Cl_2	%	2.2	2.2	2.2	**1.5**
	ClO_2 consumed as Cl_2	%	1.7	1.8	1.9	1.4
	Consistency	%	10	10	10	10
	Retention	hr.	4	4	4	4
	Temperature	^0C	70	70	70	70
	End pH	-	2.9	2.9	2.5	2.9
	Residual Cl_2	%	0.5	0.4	0.30	0.13
	Brightness	% ISO	88.5	90.6	88.4	88.7
	Viscosity	cP	7.7	7.8	9.8	9.0
	Yield	%	94.6	94.8	94.7	94.9
	Shrinkage	%	5.4	5.2	5.3	5.1
4	Total Cl_2 applied as Cl_2	%	7.3	7.3	7.3	6.6
	Total Cl_2 consumed as Cl_2	%	6.6	6.4	6.8	6.3
5	**Fibre classification :**					
	+ 16	%	0.2	1.1	0.2	1.2
	- 16, + 30	%	8.5	5.4	10.1	8.3
	- 30, + 50	%	35.8	28.9	32.3	30.3
	- 50, + 100	%	24.8	23.5	24.2	24.5
	- 100	%	30.7	31.1	33.2	35.7
6	Beating time to get 40^0SR	min.	40	39	37	41
7	**Strength properties :**					
	Grammage	g/m^2	58.3	60.7	61.4	61.0
	Thickness	micron	88.4	91.8	89.1	86.2
	Bulk	cc/g	1.51	1.51	1.45	1.41
	Burst factor	-	48	49	52	51
	Tear factor	-	72	73	75	75
	Breaking length	mtr.	6323	6326	7166	6336
	Double fold	no.	29	42	57	39
	Strength index	-	1716	1797	1899	1826
8	DCM extractive (pitch content)	%	0.45	0.25	-	-
9	TSS of combined effluent (CD:EP:D :: 2:1:3) ratio	ppm	1385	491	409	364

TABLE – 3: EFFECT OF ADDITION OF ACETONE IN HW FURNISH

Particulars	Brightness (% ISO)	Viscosity (cP)	Yield (%)	Strength Properties				
				BF	TF	BL (mtr.)	DF (no.)	Strength Index
Blank	88.1	8.9	93.0	39.9	65	5924	21	1508
Acetone (1%)	89.4	9.5	93.8	40.5	63	5965	33	1571
Acetone + 40% less H_2O_2	88.1	11.6	95.0	49.3	71	7029	63	1847
Acetone + 60% less ClO_2	88.4	10.1	94.2	49.1	69	6873	40	1757
Acetone + 50% less ClO_2 + 40% less H_2O_2	88.4	12.3	95.8	53.4	68	7605	74	1893

formaldehyde added pulp as compared to blank in 100% HW furnish and 44.4% in B + HW furnish. This may be due to removal of HexA from pulp in acidic conditions by the degradation of HexA in presence of HCHO thereby improving the final brightness (2).

At a similar brightness level by the addition of formaldehyde to pulp with reduced H_2O_2 or ClO_2 doses in the Ep and D stages, the viscosity was further improved to 15.7%, 16.8% (for HW) and 27.3%, 16.9% (for B + HW) simultaneously increasing the strength properties. The breaking length values were also increased to 6688, 6723 from 5924 (blank for HW) and to 7166, 6336 from 6323 (blank for B + HW) at reduced doses of H_2O_2 and ClO_2. The TSS representing the fraction of fines decreased in the combined effluent in all the experiments with formaldehyde in both 100% HW and B + HW furnishes.

WITH ACETONE :

An increase in brightness was observed from 88.1 to 89.4% ISO and 87.9 to 89.8% ISO respectively for HW and B + HW furnishes (Table 3 and 4). The viscosity increase was only 6.7% for HW pulp where as a significant increase of 13.4% was obtained with B + HW furnish. The strength index went up from 1508 to 1571 in HW pulp and from 1716 to 1869 in B + HW pulp. The pitch or DCM extractive content of acetone added pulps of both the furnishes was 0.16% against the blank (0.31% for HW and 0.33% for B + HW). The TSS in the combined effluent decreased to 534, 506, 594 and 586 ppm respectively in acetone added pulps compared to blank (1318 ppm). Also, at similar brightness level, the viscosity and strength properties of final pulp were increased very much at reduced dose of H_2O_2, ClO_2 and H_2O_2 + ClO_2 in Ep and D stages.

Viscosity increase against blank (%) :

Particulars	HW	B + HW
Reduced H_2O_2	30.3	13.4
Reduced ClO_2	13.5	19.5
Reduced H_2O_2 + ClO_2	30.2	28.0

The strength index increased from 1508 (blank for HW) to 1847, 1757, 1893 and from 1716 (blank for B + HW) to 1919, 1822, 1844 respectively at reduced dose of H_2O_2, ClO_2 and H_2O_2 + ClO_2 respectively.

COST IMPACT :

Efforts were made to compare the differences in the cost of bleaching by use of formaldehyde for each set of experiments due to saving H_2O_2 and also ClO_2. The values are given in Table 5 and 6.

TABLE – 4: EFFECT OF ADDITION OF ACETONE IN B +HW FURNISH

Particulars	Brightness (% ISO)	Viscosity (cP)	Yield (%)	Strength Properties				
				BF	TF	BL (mtr.)	DF (no.)	Strength Index
Blank	87.9	8.2	92.4	48	72	6323	29	1716
Acetone (1%)	89.8	9.3	93.7	49	72	6568	71	1869
Acetone + 40% less H_2O_2	88.4	9.8	93.9	47	83	6789	65	1919
Acetone + 50% less ClO_2	88.5	9.1	93.8	50	76	6744	39	1822
Acetone + 50% less ClO_2 + 40% less H_2O_2	88.3	10.5	93.4	49	83	6563	37	1854

Addition of 7.5 kg/ton of 40% formaldehyde solution at CD stage, it is possible to save about 2.66 kg/ton of ClO_2 or 10.4 kg/ton of H_2O_2 (50% solution) at Ep stage. The cost benefit analysis shows that with formaldehyde, a net savings to the tune of Rs. 63.80/ton of B.D. pulp can be made by reducing the H_2O_2 dose. While the net savings in cost is Rs. 21.20 / per ton of B.D. pulp was obtained in saving ClO_2.

The cost of acetone at a dose of 10 kg/ton of B.D. pulp is comparatively high (approximately Rs. 720/-) compared to the costs towards combined savings of 12 kg/ton of H_2O_2 (50% solution) and 4.18 kg/ton of ClO_2 (Rs. 264 + 292.60 = Rs. 556.60/- / ton).

CONCLUSION

Formaldehyde can be utilized as a possible bleaching aid to achieve optimum efficiency of ClO_2. The resultant pulp by the use of formaldehyde or acetone is better with respect to brightness and other critical properties. The viscosity and strength properties further enhanced at reduced oxidizing chemical doses at similar level of brightness to control. There is no yield loss and the overall cost for formaldehyde addition works out to be lower by Rs. 63.80/T of B.D. pulp on H_2O_2 or Rs. 21.20/T of B.D. pulp in ClO_2. Industrial application is possible with proper storage and dosing mechanism on which the institute is working upon.

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TABLE – 5: COST BENEFIT DUE TO H_2O_2 SAVING BY USE OF FORMALDEHYDE

Sl. No.	Particulars	Unit	Usage	Value (Rs.)
1.	Rate of formaldehyde (40%)	Rs./kg	22.0	-
2.	Dosage	kg./T	7.5	165.00
3.	Rate of H_2O_2 (50%)	Rs./kg	22.0	-
4.	Reduction in H_2O_2	kg./T	10.4	228.80
5.	Net saving (4-2)	Rs./T	-	63.80

TABLE – 6: COST BENEFIT DUE TO ClO_2 SAVING BY USE OF FORMALDEHYDE

Sl. No.	Particulars	Unit	Usage	Value (Rs.)
1.	Rate of formaldehyde (40%)	Rs./kg	22.0	-
2.	Dosage	kg./T	7.5	165.00
2.	Cost of ClO_2	Rs./kg	70.0	-
3.	Reduction in ClO_2	kg./T	2.66	186.20
4.	Net saving (4-2)	Rs./T	-	21.20