Energy Saving and Environment Protection Through Improvement in Bleaching

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ABSTRACT

Energy saving and reduction in pollution load are the two important areas, which require due consideration to make the Indian paper industry more economically viable and environmental friendly. This paper describes the importance and need of the improved bleaching processes like oxygen prebleaching, post digester bleaching for indirect saving of energy and the possibility of other energy saving measures like extraction and hypo stage bleaching of agro raw material pulps at ambient temperature etc. it also highlights the role of chlorine dioxide in brightness improvement and effluent load reduction.

INTRODUCTION

The paper industry is known to be an energy intensive industry. Based on the data collected from few of the large mills, the total energy consumption varies from 7.62 to 13.25 G cal per ton of paper (Ippta conventional issue 1985,p-58), ranking in heavy industry after steel and petrochemical industries. The steam consumption in most of the large mills varies from 10.5 to 17.4 tons per ton of paper and the power consumption varies from 1305 -1949 kWh. In small paper mills the energy consumption is found to be almost half to that of the large paper mills. The steam consumption in most of the mills varies from 5 to 9 tons per ton of paper while power consumption varies from 700 to 1500 kWh. The major energy consuming areas are pulp mills, chemical recovery, paper machine, effluent treatment plant etc. The main consumption of the steam is in pulp mill, black liquor evaporators and paper machine while major consumption of power is in raw material handling, pulp mill operation, paper machine and effluent treatment plant.

The impact of the energy prices and its supply position has been very severe on the economics of the paper industry. Out of the total cost of production of paper today, about 20% is the cost of the energy (Ippta conventional issue 1985,p-58).

Therefore it is imperative that energy conservation aspects have to be taken into consideration and is to be implemented effectively, in order to reduce the energy usage. There is a need to think seriously for seeking the ways and means to meet out the energy need and also to reduce the energy demand.

Pollution is another problem of the Paper industry. The most polluting part in this industry is the effluent generated in pulp bleaching.

So far much attention has not been given to the environmental protection from this industry but the time has come to think it seriously: In developed countries, the mills are already forced to take care of environmental protection measures like closing of bleaching system to the extent possible and using

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latest technology for pulp compounds with other bleaching agents such as oxygen, chlorine dioxide etc. Due to these measures the effluent load generated in the mills is approaching to a very low or towards zero level.

Similar measures in the developing country like India is necessary for the sustainability of paper industry. The present permissible limits of pollution load allowed by Central Pollution Control Board of India in Indian papers mills are BOD 30 mg/l, COD 250 mg/l (considering effluent volume generated in bleaching as 100m³/t pulp) and TOCl 2kg/t paper. In coming time these limits will be more stringent and there is a need to think it deeply to take possible measures in advance.

In order to make the paper mills more energy efficient and less polluting, various possibilities are open. There is a possibility of energy saving and effluent load reduction through improvement in pulping and bleaching in the present system by incorporation of developed technologies and findings of research and developmental work mainly concerned to process modification. This paper describes the need for improved bleaching technologies and findings of R&D work done at CPPRI to reduce the energy and effluent load in Indian paper mills

ENERGY SAVING AND EFFLUENT LOAD REDUCTION THROUGH IMPROVED BLEACHING TECHNOLOGIES

Improved bleaching technologies, mainly pre bleaching treatment results in reduction of pulp kappa before bleaching. It reduces bleaching chemical demand and effluent load generated. Both of these are responsible for indirect saving of energy. Some such options are as under:

- Enzymatic pretreatment of pulp
- Oxygen Prebleaching of pulp
- Alkaline leaching in presence of hydrogen peroxides
- Alkaline leaching using sodium hydroxide

Table-1

Conventional CEH Bleaching of Untreated and Oxygen Pretreated Bagasse, Bamboo and Eucalyptus Pulps

Parameters	Bagasse		Bamboo		Eucalyptus	
Unbleached pulps:						
(Before & after O_2 pretreatment)						
Kappa number	14.6	5.6	18.2	9.0	19.2	9.7
Brightness % ISO	26.0	37.1	23.1	32.3	21.1	37.6
Intrinsic Viscosity cm³/g	840	840	830	730	510	510
Bleaching sequence	CEH	OCEH	CEH	OCEH	CEH	OCEH
Chlorination stage:						
Chlorine added %	3.0	1.2	4.0	2.0	4.0	2.0
Extraction stage:						
Sod. Hydroxide %	1.0	0.6	2.0	1.0	2.0	1.0
Hypo stage:						
Hypo chlorite %	1.0	0.5	4.0	1.0	2.0	1.0
NaOH % as buffer	0.3	0.1	0.8	0.2	0.8	0.2
Final pulp brightness %	82.0	78	78	78	77	80
Bleached pulp viscosity	520	630	430	490	280	350
Shrinkage %	4.2	6.2	3.6	4.3	3.9	6.6
Total bleach chemical used						
kg/T pulp						
Chlorine	45	17	80	30	60	30
Sod. Hydroxide	18	7	28	12	24	12

Table-2

Characteristics of CEH Bleach Effluent of Untreated & Oxygen Pre Treated Pulps

Parameters	Bagasse		Bamboo		Eucalyptus	
	Un-treated pulp	Oxygen treated pulp	Un-treated pulp	Oxygen treated pulp	Un-treated pulp	Oxygen treated pulp
Before secondary tratement						
BOD_5, mg/l	113	88	128	53	88	48
COD, mg/l	405	204	435	204	330	163
AOX, kg/T. pulp	2.93	0.86	4.53	1.32	4.18	1.27
(TOCl=0.8AOX)	2.34	0.69	3.68	1.05	3.34	1.02
After secondary treatment						
BOD_5, mg/l	58	24	48	4	21	6
COD, mg/l	339	139	320	97	230	77.5
AOX, kg/T. pulp	1.84	0.5	2.5	0.84	2.1	0.72
(TOCl=0.8AOX)	1.47	0.4	2.03	0.67	1.68	0.66
Bleaching effluent volume 100 m^3/T of pulp						

ENZYMATIC PRETREATMENT OF PULP

Enzymatic Prebleaching of the pulp is also an energy saving route by reducing bleach chemical demand of the pulp and effluent load generated during bleaching. Enzymatic pretreatment of the pulp before bleaching provides a very simple and cost effective way to reduce the use of chlorine and chlorine based bleaching chemicals such as calcium hypochlorite, in addition to the higher brightness of the finally bleached pulp. The benefit of the enzymatic pretreatment depends on the chemical bleaching sequence as well as the residual lignin content i.e. kappa no of the pulp. It is mentioned in the literature that in some cases the enzymatic treatment showed a reduction of about 20% total chlorine and about 15% reduction in the chloro-organics generation during bleaching. Enzymatic treatment is not widely commercialized and still it is at developing stage.

OXYGEN PRE-BLEACHING OF PULP

Studies were carried out at CPPRI on the oxygen pre bleaching of the pulps of widely used raw material followed by conventional CEH bleaching. the unbleached pulp from conventionally used raw material like bagasse, bamboo and eucalyptus of around 15-19 kappa were, produced. These pulps were further treated by oxygen to reduce the pulp kappa of different pulp and further bleached by conventional CEH bleaching sequences to the required brightness level of around 80% ISO. Oxygen pretreatment reduced the pulp kappa by 50-60% and further conventional CEH bleaching of pulps of all the three raw materials could reduce the bleach chemicals consumption i.e. total chlorine consumption by 50-62%, as evident from the Table-1.

Based on the above findings, getting higher brightness (86-88% ISO) by CEH bleaching of most of the pulps is a bit difficult, partial replacement of chlorine with chlorine dioxide in the chlorination stage results drastic improvement in further bleaching response of the pulp. As evident from the Table-3, 15 -20% substitution of chlorine with chlorine dioxide in chlorination stage and partial or full replacement of hypo chlorite with chlorine dioxide resulted a pulp brightness around 88%, with and with out oxygen pre bleaching of the pulp. Complete substitution of the hypo with the dioxide in the final stage of bleaching showed somewhat poorer response compared to partial substitution.

Table-3

Oxygen pre bleaching followed by chlorine dioxide substitution

PARAMETERS	Eucalyptus	Eucalyputs	BAMBOO		Bamboo+Mix Hardwood	
Before O_2 Treatment						
Kappa number	21.8	21.8	16.8		17.0	
Brightness % ISO	26.6	26.6	26.8		29.3	
Viscosity (cm^3/gm)	760	760	1020		890	
After O_2 Treatment						
Kappa number	---	---	10.2		10.4	
Brightness % ISO	---	---	36.0		37.0	
Bleaching sequence	D//CEopDD	D/CEopHD	D/CEopD	D/CEopDD	D/C,Eop,D	D/C,Eop,DD
D/C, stage						
Chlorine dioxide added %	1.0	1.0	0.30	0.30	0.32	0.32
Chlorine added %	4.0	4.0	1.9	1.9	1.9	1.9
Eop, stage:						
NaOH added %	2.0	2.0	2.0	2.0	2.0	2.0
Peroxide added %	0.25	0.25	0.25	0.25	0.25	0.25
Hypo stage:						
Calcium hypo chlorite added as available	---	1.0	---	---	---	---
D-1 stage						
Chlorine dioxide added as available chlorine (%)	2.5	2.0	3.0	2.0	3.0	2.0
D-2 stage						
ClO_2 added as available chlorine (%)	1.5	---	---	1.0	---	1.0
Brightness % ISO	87.8	88.0	85.6	86.0	88.4	89.0
Intrinsic Viscosity cm^3/g	518	481	590	586	540	530

Constant Bleaching Condition:

	O_2 Treatment	D/C	Eop	hypo	Dioxide
Reaction Consistency (%)	10.0	10.0/3.0	10.0	10.0	10.0
Reaction Temperature (°C)	105	35.0	70	40	70
Reaction Time (Min)	45	30	60	60	180
Oxygen pressure (kg/cm^2)	5.0	---	2.0	---	---

Because of kappa drop and reduction in chlorine demand during bleaching the effluent load generated also reduced drastically. Table -2 shows the values of BOD, COD, and AOX before secondary treatment of the effluent ranges 48-88 mgpl 163-204 mgpl and 0.69-1.05 kg/ton of pulp and after secondary treatment were ranging 4-24 mgpl & 77-139 mgpl (considering bleach plant effluent volume 100 M^3/t), 0.5-0.84 kg/t paper respectively. These values particularly of AOX are very well within permissible tolerance limits of Central Pollution Control Board of India. Substitution of chlorine and hypo with dioxide further resulted a drop in AOX values.

For economical reasons there is need for developing simplified procedures for Oxygen delignification since the scale of operations in the Indian pulp & paper industry are far below international norms. Co-operation between machine manufacturers and technologists is needed for developing cost-efective system mainly from capital investment point of view.

POST DIGESTER LEACHING OF PULPS

Because of poor solubility of oxygen in water, thorough mixing of oxygen with the pulp during

Table-4

CEH bleaching of different unbleached pulps as well as sodium hydroxide leached pulps (with and without hydrogen peroxide)

Parameters	Bagasse			Wheat-Straw			Eucalyptus			Bamboo		
	Blank	NaOH	H_2O_2	Blank	NaOH	H_2O_2	Blank	NaOH	H_2O_2	Blank	NaOH	H_2O_2
Unbleached pulp Kappa number	23.9	15.0	14.9	16.2	12.1	12.0	21.6	16.1	15.8	15.7	15.4	10.8
Brightness % ISO	32.4	35.6	36.1	37.1	39.0	39.0	21.6	23.4	25.8	27.2	27.7	29.1
Viscosity cm^3/g	957	934	928	903	909	903	769	833	849	924	914	915
Chlorination stage:-												
Chlorine added as available Cl_2 %	5.0	3.36	3.0	3.5	2.5	2.2	5.0	3.2	3.2	3.6	2.5	2.4
Extraction stage:-												
NaOH added %	2.0	1.5	1.5	2.0	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0
Hypo stage:-												
Hypo added as available Cl_2 %	2.0	1.5	1.0	2.0	1.5	1.0	2.5	2.2	2.0	3.0	2.5	2.0
Brightness % ISO	83.9	83.6	84.0	81.1	81.4	81.8	84.1	83.8	84.9	81.5	80.7	81.0
Post color number	2.6	1.48	0.74	4.6	3.5	2.38	2.24	1.44	0.92	3.0	2.7	2.2
Intrinsic viscosity cm^3/g	567	575	676	553	603	615	341	371	408	428	500	469
Total chlorine consumed %	9.0	6.4	5.0	7.5	5.5	4.2	10.0	7.6	7.2	9.6	7.5	6.4
Percent chlorine reduction	---	28.0	44.0	---	27.0	44.0	---	24.0	28.0	---	22.0	33.0
AOX (kg/t)	4.8	3.3	2.8	3.4	2.4	2.1	4.4	3.0	2.9	4.1	2.9	2.7
Percent AOX reduction	---	31.0	41.0	---	29.7	38.3	---	31.8	34.0	---	29.3	34.0

Constant bleaching condition:-

		Cl_2 stage		Ext stage		Hypo stage
Consistency %	--	3.0	----------	8.0	--------	80
Reaction time (min)	--	30	----------	60	--------	120
Reaction temp (°C)	--	amb	----------	60	--------	40

pretreatment is very essential. However, post digester leaching of pulp by alkali, with and without the use of hydrogen peroxide, does not require thorough mixing, during bleaching. Initial mixing of hydrogen peroxide along with alkali is sufficient for the operation.

Keeping this in view, the detailed studies were undertaken at CPPRI to leach the pulps of different raw material with alkali, with and without the use of hydrogen peroxide, followed by the conventional CEH bleaching of the different pulps, and results are depicted in Table-4.

Unbleached pulps of different raw materials were leached with sodium hydroxide (2-2.5%), with and without the use of different dosage of hydrogen peroxide. Pulps were further bleached by conventional CEH bleaching sequence to the required brightness level of around + 80% ISO. Alkali leached pulps under optimum conditions resulted a kappa reduction of 25-37%, which further resulted drastic reduction in the chlorine and chlorine based chemical demands (22-44% total chlorine) as well as in the effluent load i.e. chloro-organics generated during bleaching (30-40% AOX). Use of hydroxide peroxide (0.25%) along with sodium hydroxide was an added advantage mainly in reducing post color number and further reduction in total chlorine demand in bleaching. Post digester leaching can easily be implemented in the existing mills without much investment. The sodium hydroxide used in leaching along with the organics, leached during leaching, can be sent to recovery with out further diluting the black liquor going to recovery. In addition to the indirect saving of energy through the reduction of bleaching chemical demand and effluent load reduction, the organics going to the chemical recovery is an added advantage of post digester leaching.

ENERGY SAVING BY KEEPING LOWER TEMPERATURE DURING EXTRACTION AND HYPO STAGES OF BLEACHING

Generally, chemical pulps from agro raw materials are little different from the hard wood pulps like that of eucalyptus etc. Which are some what darker in color, possibly due to the presence of extractives.

Today in the most of the agro based mills, CEH or CEHH bleaching sequence is being practiced and temperature maintained during extraction and hypo stage are same as for wood pulps as indicated below.

CONSTANT BLEACHING CONDITION

It is difficult to say that the conditions like extraction at 60-70%°C and hypo bleaching at 40-45°C during CEH or CEHH bleaching of agro raw materials pulps is of any benefit or not. Possibly, there may not be any advantage of carrying out the extraction and hypo bleaching in hot condition for the agro raw materials pulps, which has been practiced for wood pulps.

Moreover, there may be some negative impact on the pulp quality by bleaching under hot condition in addition to the energy loss to maintain the hot condition during bleaching.

Some preliminary studies were initiated by carrying out extraction and hypo bleaching in CEH bleaching by using different temperature in order to explore the possibility of energy saving.

Table-5

Effect of extraction temperature and time on CE kappa and brightness of Wheat straw pulp

Parameters	At 60°C	At 40°C	At 25°C
Unbleached kappa No.	18.77	18.77	18.77
Chlorine applied %	4.5	4.5	4.5
Chlorine consumed %	3.9	3.9	3.9
Extraction time (min)	60	90	120
NaOH added %	2.5	2.5	2.5
Alkali consumed %	1.28	1.27	1.19
End pH	11.3	11.3	11.4
CE Kappa No.	2.05	2.21	2.28
CE brightness % ISO	48.7	49.7	50.5

Table-6

Comparison between bleaching of wheat straw pulp at ambient temperature and normal conditions practiced in mill

Sl.	Parameters	At Normal conditions	At room temperature
1	Unbleached kappa No.	18.77	18.77
CHLORINATION			
2	Chlorine applied/consumed %	4.5/3.9	4.5/3.9
EXTRACTION			
3	Extraction time (min)	60	120
4	Extraction temperature °C	60	25
5	NaOH added/consumed %	2.5/1.28	2.5/1.19
6	End pH	11.3	11.4
7	CE Kappa No.	2.05	2.21
8	CE brightness % ISO	48.7	49.7
HYPO STAGE			
9	Retention time (min)	120	180
10	Temperature °C	40	25
11	Hypo added / consumed %	2.0/1.88	2.0/1.18
12	Final Brightness % ISO	76.4	76.6
13	Post color number	4.18	4.19

Wheat straw pulp of around 19 kappa number was produced. First the straw pulp was chlorinated by using 4.5% chlorine (as available chlorine), and then extraction of the pulp was done at three different temperatures i.e. 60°C, 40°C and at ambient (25°C). At each temperature, the retention time was varied from 30 minutes to two hours (30, 60, 90, and 120 minutes). After extraction, the pulps were washed and CE pulp yield, kappa number and brightness were determined. The results are depicted in the Table-5. Results indicate that the pulp extracted at 60°C for 60 minute, at 40°C for 90 minutes and at ambient temperature for 120 minutes showed almost idential CE kappa and brightness.

Further hypo bleaching of these three pulps was taken for the further studies on the effect of time and temperature in the hypo stage bleaching. Above three pulps were bleached by using 2.0% calcium hypochlorite (as available chlorine), at temperature 40°C and also at ambient temperature (25°C), by varying retention time from two hours to four hours. After hypo stage the pulps were washed and pulp brightness, post color number were determined as per standard procedures. The results are depicted in the Table-6. Results indicate that the hypo bleaching at ambient temperature for one hour longer retention time showed the same effect as in normal bleaching at 40°C for two hour in addition to the less consumption of hypochlorite. Based on the above findings, the energy saving for a 100 tones mills are determined and depicted in Table-7.

Table-7

Energy saving in bleaching of wheat straw pulp at ambient temperature

Parameters	Extraction stage	Hypo stage	Total
Steam per ton of pulp, Ton	0.7	0.39	1.085
Steam per year (100TPD), Ton	25,020	14,058	39,078
Rupees per ton of pulp	347/-	195/-	542.5/-
Rupees per year (100 TPD)	1,25,10,000/-	70,29,000/-	1,95,39,000/-

ENERGY SAVING BY USING HIGH YIELD PULP IN THE FURNISH

Some processes like chemi mechanical pulping and thermo chemi mechanical results in very high pulp yield (80-90%) compared to the pulp yield in normal chemical pulping process (40-50%). In developed countries use of the high yield pulp is increasing not only in wood containing papers like newsprint but also In varieties of paper like writing and printing etc. The use of high yield pulp is not only the raw material conservation but also very cost effective and energy intensive, compared to the chemical pulp. The high yield pulp from some of the light colored fast growing wood and also from some non wood raw materials by using APMP process is of high unbleached brightness, which can be bleached to brightness around 80% ISO, just by one or two stage bleaching by using hydrogen peroxide. The total cost per ton of the high yield pulp, considering pulping and bleaching together is quite lower compared to a bleached chemical pulp.

Studies carried out at CPPRI on few wood like Gmelina arboea, subabul, populous and non-woody raw materials like kenaf and jute showed that the quality of the pulp produced and their bleaching response were quite encouraging. Use of such pulps in the furnish for the common varieties of the papers like writing and printing etc. will be quite economical in addition to the effluent load generated per ton of the paper reduced due to the hydrogen peroxide used in bleaching is an indirect saving of energy during effluent treatment.

CONCLUSIONS

- Oxygen bleaching is the emergent need for Indian paper industry for reducing the consumption of chlorine based bleaching chemicals by 50-60% and effluent load (BOD, COD, & AOX) to very low value.
- Alkaline leaching is helpful in reducing chlorine based bleaching chemicals by 22 -44% and effluent load by 30-40%.
- Alkaline extraction and hypo stage bleaching of agro raw material pulp, at ambient temperature can save huge amount of energy.
- Uses of high yield pulp in furnish also helps in energy saving as well as in reduction of pollution load.