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Cost reduction and Quality Improvement by Optimizing Cooking and Bleaching sequence

Satish Kumar*
Associate Vice President
Quality control & R&D

Anuj Mittal*
Associate Vice President
Pulp Mil

Nar Singh*
Associate Vice President
Power House

Harinder Gupta, DGM*
Deputy General Manager, Pulp Mill

Kajal*
Quality Control Officer

*Kuantum Paper Ltd

Abstract: ***Innovation in advancing technologies for production of pulp and paper has been driven largely by the needs to reduce the environmental impact of pulp mills or to enhance the yield in processes of conversion of wood to fibers. Much of the chemical pulping industry is focusing on use of the Kraft pulping process and making the process more efficient continuously. Both pulping and bleaching operations have been modified and improved. In most of the large wood-based paper mills, pulping of wood-based raw material was carried out in batch digesters followed by the oxygen delignification (ODL) process to reduce the kappa number of the pulp which is the global best practice. The aim is to produce pulp with low kappa number before bleaching, to reduce the chemical requirement during bleaching and to reduce the ETP load. The compromise between reaching pulp target brightness and guarantee a high-quality bleached pulp is often difficult to manage because of nature of last chromophore present. When the pulp is used to manufacture white papers, it is necessary to continue the delignification until the pulp has less than 1% lignin. At that point it is subjected to a bleaching process that removes the remaining lignin and oxidizes residual color bodies, so they can be solubilized during extraction to give a white pulp of high brightness.***

Introduction

Paper industry uses a wide variety of raw materials employing different type of pulping and bleaching processes depending on the type of raw materials availability. Both unbleached and bleached pulps are produced as per the requirement of paper. Requirement of bleaching chemicals are also varied depending on the quality of paper, pulp brightness and environmental considerations. Pulping and bleaching play an important role in pulp and paper manufacturing. Cellulosic content, fiber length, paper strength properties are highly dependent on the type of pulping and bleaching process. Commonly used steps in pulping and bleaching process are:

- Acquisition of raw materials: Hard wood, soft wood, Bagasse, wheat and Rice straw, Sabai grass etc.
- Raw Material Preparation: Debarking, Chipping, Cutting, Screening, Wet washing.
- Pulping: Kraft pulping (NaOH+Na2S), Soda Pulping.

Screening: 3-4 stage washing, screening and centricleaning.

- Bleaching: Bleaching chemicals: Oxygen, caustic soda, chlorine dioxide, bleaching sequence ODL D0EopD1P (ECF bleaching).

The pulping and bleaching technology must match to the quality and characteristics of the pulp and paper to be produced. No single type of pulping and bleaching can produce pulp suitable for all paper products. In a Pulp mill to produce chemical pulp bleaching process is designed to selectively remove lignin from wood chips and to obtain pulp with the specified brightness, cleanliness & strength at the lowest cost. The relationship between the pulp lignin content of Kraft pulp (signified by kappa number) and cooking yield is well established. Thus, a higher cooking kappa number principally correspondence to a higher cooking yield for a given cooking system. A bleach plant is designed to

(i) Remove any lignin carrying forward with the pulp from cooking and oxygen delignification in the first bleaching stage.

(ii) Oxidize the remaining lignin to brighten the pulp and achieve target brightness through application of various bleaching chemicals.

(iii) Achieve the target brightness with target viscosity, minimum effluent load and maximum cleanliness.

Ways to solve typical challenges in pulping and bleaching by process improvement and modification

The paper industry in the last few decades has faced several challenges particularly in the area like obsolescence of technology, non- availability of good quality fibrous raw materials, high cost of basic inputs, environmental issues and competition in global market. So, pulp and paper industry is continually changing the bleaching process to minimize the use of chlorine and chlorine based compounds in order to satisfy regulatory and market demands. Some of the common challenges in achieving target brightness with minimum variability and lowest cost in a conventional bleach plant are as follows:

a) Wood composition variability:

The pulp and paper industry which derives its growth from forest based raw materials and use of freshwater resources, is not only imposing the threat to these resources but also facing the shortage of raw materials for sustainable production. To face these issues industries are doing cloning plantation and recycling water. A full-fledged nursery of Clonal varieties of hard wood plants has been established by the companies as well as sold to farmers in the surrounding areas, which will go a long way in supplementing the requirements of the company as well as increasing revenues for farmers from their farmland.

Figure-1 Nursery of Hardwood cloning

Also working on pulping from different hardwood species such as poplar, Eucalyptus, Subabul, Veneer waste chips and Rulla. Every wood species has different bleachability so it's desirable to have a constant furnish mix for a bleach plant to operate optimally while all the variables associated with raw material like moisture, bulk density, source, age, composition, etc. are to some extent "homogenized" in cooking and oxygen delignification. A social farming of agroforestry initiative was started by Kuantum Papers Ltd. in the year 2008 to fulfill the scarcity of wood resources for paper and pulp industry, since then we have constantly worked on upgrading our own clonal propagation center (CPC) which now has a production capacity of around 10 Lakh saplings per annum.

b) Raw material Evaluation

As a raw material Kuantum is using Eucalyptus, wood veneer waste chips and bamboo for producing high brightness pulp. We analyzed and evaluated different ratios of these raw materials in laboratory and suggested for plant scale pulp production. The Study results and outcomes are tabulated below.

Table No.1 Hardwood Furnish Evaluation

Hardwood Furnish Evaluation			
Parameter	**Unit**	**Value**	
Veneer waste chips	%	40	40
Bamboo	%	10	15
Wood	%	50	45
Yield	%	42.4	43.9
Kappa		15.58	17.1
Viscosity	Cps	6.5	8.7
Breaking Length	Meter	3790	3290
Tear Factor		68.6	88.6
Burst Factor		21.3	19.4
Brightness	% ISO	86.3	88.2

Objective of this work is increasing the percentage of bamboo in furnish of hardwood pulp so that gradually dependency on hardwood get reduced.

c) Pulping improvement

It relates to the optimization of variable parameter of cooking, comparing of various cooking process and furnish design according to availability of raw material so that final pulp properties which we get should improve. Pulping improvement approach has been done by following ways:

Kraft pulping: Kuantum is using Kraft pulping followed by ECF bleaching in agro as well as in hardwood street. A special surfactant based cooking aid is being used to improve pulp quality and yield. The use of kraft cooking brings a number of advantages when compared to other pulping process especially in terms of fiber strength.

Batch digester operation improvement: Pulp mills are increasingly challenged to optimize productivity and quality while minimizing cost and the overall impact on the environment. Advanced batch digester solutions provide complete scheduling, process control and optimization. The efficiency of the digester is improved by implementing interactive controls which help to reduce the cooking cycle time, temperature and maintain consistent Kappa for each blow. So the following changes in KPL has been done for digester operation improvement:-

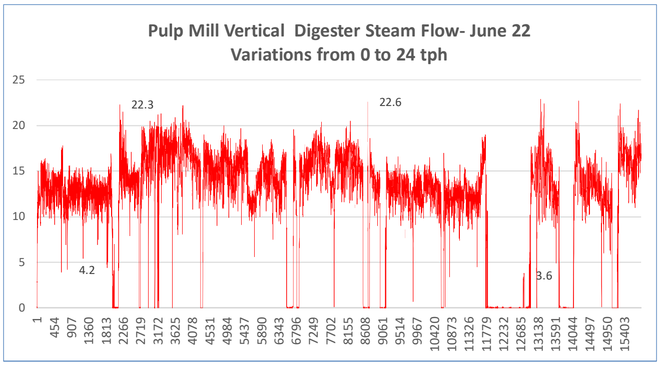
- **Cooking based on H-factor instead of time.**
- **Cooking cycle of batch digester reduced by 1.5 to 2.0hrs.**
- **Cooking temperature reduced 162 0C-158 0C**
- **Optimization of cooking cycle in batch digester to minimize MP Steam (11 kg/cm2) variations. Steam demand varied from 0 to 24 tph. With cycle time optimization overall variations have reduced to 6 to 8 tph. Zero demand has significantly reduced and now steam demand remained from 10 to 22 tph.**

This has resulted in following benefits at Power Plant: -

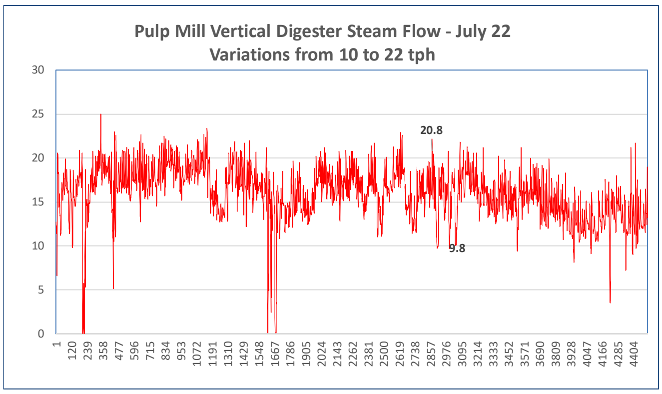
a. Minimize steam venting at Power Boiler during less draw of Steam.

b. Frequency of Operation of Bypass valve during peak draw.

c. Better steam temperature control.



Graph No.1: Pulp mill Vertical Digester Steam Flow



Graph No.2 : Pulp mill Vertical Digester Steam Flow

Due to all these changes our number of blows increased significantly. Consequently, quality of pulp improved in terms of viscosity, strength properties and brightness as well.

Increasing the sulfidity of white liquor: When referring to the concept of Kraft pulping selectivity, this indicates how much lignin is removed in comparison to the amount of the cellulosic material being degraded. The higher the amount of lignin removal the better is the selectivity of the delignification process. This selectivity depends mainly on the levels of sodium sulfide in the white liquor that is used to calculate the corresponding white liquor sulfidity. Due to increase in selectivity cellulose degradation gets reduced and we can observe its impact by tear factor and viscosity of pulp.

As shown in below given table viscosity, tear factor is gradually increasing with rising the percentage of sulfidity.

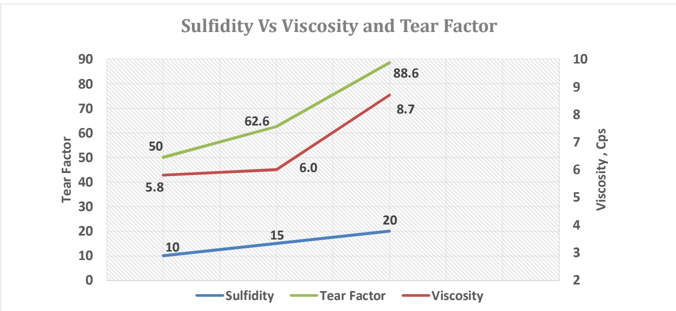
Table -2 Plant Scale result of sulfidity enhancement

This research work was done at Kuantum papers limited – R&D Dept. According to which it is observed that rising sulfidity percentage is favorable

Impact of Sulfidity Report				
Sulfidity	%	10	15	20
Final Yield	%	40.5	40.5	43.9
NaOH	Kg/Ton	565	551	525
Viscosity	Cps	5.8	6.0	8.7
Breaking Length	Meter	3643	3356	3300
Tear Factor		50	62.6	88.6
Burst Factor		17.8	20.0	21.4

up to 20%. With the reference of R&D studies, we at Kuantum papers ltd start increasing sulfidity percentage at plant scale gradually and results are shown in above table no.1 and below graph.

In these experiments cooking time, temperature and liquor to wood ratio were kept constant. The best advantage of multiple nonlinear regression is related to considering the effects of both sulfidity and active alkali charge at the same time on the dependent variables. It can be seen that the consumption of caustic is also reduced as well as yield is slightly enhanced.



Graph No.3: Impact of Sulfidity on pulp viscosity and tear factor

d) Bleaching Improvement

The remarkable performance of the final P -stage is undoubtedly related to the change in the bleaching environment where the pulp changes from an acidic D stage to an alkaline P stage.In this sense, final chemical pulp bleaching with peroxide is carried out under alkaline conditions to ensure the formation of the Primary agents responsible for pulp-brightening reactions, the perhydroxyl anion, HOO-, in accordance with the equilibrium reaction given in Equation

$$H_2O_2 + HO^- \leftrightarrow HOO^- + H_2O$$

Therefore alkaline pulp brightening with peroxide is a result of the selective reaction of the per hydroxyl anion with certain types of chromophores, particularly carbonyl structures (e.g. quinones previously produced in D stages) present in the residual lignin.

Table No. 3 Ranges of experimental bleaching conditions with chlorine dioxide and hydrogen peroxide

Bleaching Variable	Unit	Final D	Final P
Temperature	^0C	70	65
Time	Min	180	150
ClO2 or P charge	Kg/T (odp)	4.5	1
H2SO4 or NaOH charge	Kg/T (odp)	5	1

The main goal of present work was to evaluate the final brightness of eucalyptus bleached-kraft pulp subjected to a D0EOPD1 sequence complemented with a final P stage as a replacement for a D2 stage.

Table 3 summarizes the ranges of bleaching conditions of all bleaching trials run. These conditions are properly maintained at plant scale during run. These ranges are referred from lab study, Hardwood pulp was collected before entering the D2 bleaching stage of a Kuantum pulp mill. These were labeled as pulps A, B. These D0EOPD1 pulps were then bleached with hydrogen peroxide in several trials with various values of retention time, temperature, and sodium hydroxide and hydrogen peroxide charge to reach target ISO brightness. In the case of the most promising bleaching conditions 1kg/ton of hydrogen peroxide at pH7.5. With the intent of performing a comparative study another set of bleaching trials was performed with chlorine dioxide using each of the D0EOPD1 pulps, also with a target ISO brightness. Finally, the best results are obtained in D0EOPD1P compared with D0EOPD1D2 pulps (with respect to brightness, viscosity, and brightness reversion).

Table No.4 Results after replacement of Clo_2 with Peroxide

Plant results of Peroxide utilization at final stage			
Properties	**Unit**	**D2 Stage (Pulp A)**	**P Stage (Pulp B)**
Final Brightness	% ISO	86.5	88.3
Final Yield	%	42.4	43.9
Viscosity	Cps	7.15	8.45

A successful multistage ECF bleaching sequence beneficial for certain amount of its cost-effectiveness, pulp quality, product differentiation, and environmental performance to the final brightness. This work has thoroughly analyzed the frontier between the D1 and the final P stage in terms of the effect of chromophore content on final peroxide bleaching performance compared with chlorine dioxide bleaching. It concludes from the results that pulps bleached with a final peroxide stage have lower brightness reversion and in general better papermaking potential (physical and optical properties) than D2 pulp. The performance of peroxide as a final brightening agent depends on the initial pulp brightness entering the final stage. Although the chlorine dioxide charge to be used is linearly dependent on D1 pulp brightness. Reduction in consumption of bleaching chemical is one of its complementary results of peroxide utilization.

4. Conclusion

- Optimization of process variables and introduction of process modification resulted in substantial improvement in hardwood pulp quality. Kuantum paper limited believes on continual growth and our every team member actively indulge in changes for improvement. Above mentioned are few examples of same. Plantation and exploration of various clone species of hardwood and bamboo is going on, as well as lab studies of all available species.
- Due to furnish evaluation and cooking process modification, final bleached pulp yield increased by 1.5% and physical strength properties are improved, viscosity of pulp rise by 27% as well as improvement in productivity.

- Improvement in multistage ECF bleaching process give better results such as environmental consideration and have lower brightness reversion. Chlorine dioxide replacement of peroxide saves approx. Rupees 300 /- ADT of pulp. Dependency on chlorine dioxide is reduced 1.5kg/ton by increasing oxygen in ODL, EOP with Oxygen extraction and Peroxide at final stage. Steam saving is also observed in last P stage by reducing operating temperature of reaction tower from 1620C to 158 0C.
- Optimization of cooking sequence can reduce power plant losses by reducing MP steam variations.

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