A Cost Beneficial Approach to improve Hardwood Kraft Pulp Productivity

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Improving productivity through low cost solutions is the key for the industry to improve upon its performance so as to meet the global competitiveness. Improving the productivity of hardwood Pulp Street, through a cost beneficial approach has been discussed. The usage of Digester additives on a regular basis has improved the hardwood pulp productivity, with the existing plant facilities. The paper discusses the plant scale trials conducted in hardwood Kraft pulping. Different additives were tried and trials were taken under varying conditions, to evaluate their potential in improving the productivity. Active alkali reduction, reduction in knots generation and cost reduction were noticed, in addition to absorbing the cost of the additive. The results discussed will help other Kraft mills also to improve production without additional investments.

INTRODUCTION

Kraft pulping of hardwood, though an established conventional age-old process, has been posing several operational challenges. Productivity improvement is the key to reduce the cost of production. Very little gain in productivity could be achieved by altering the pulping conditions such as Active alkali charge, cooking time, cooking temperature since most of these are being maintained at optimum levels. Hence there has been intensive research in the development of additives for improving the Kraft pulping. Redox catalysts like Anthraquinone based additives have been well known to improve the pulping during low sulphidity levels. At higher sulphidity levels these anthraquinone based additives have very little to do in terms of improving the pulping efficiency.

Surfactant based digester additives improve the liquor penetration into the chips by their surface-active property have been far more successful with regard to improving the pulping efficiency. These water-soluble additives improve the pulping by their unique wetting mechanism of the chips, enhancing liquor penetration. Since alkali penetration into the chip is the key to efficient pulping, the surfactant based digester additives have proved quite promising in achieving low kappa pulps under similar conditions.

0.3 to 0.4 kg of additive per tonne of BD chips could reduce the kappa number significantly. Based on lab scale trials, plant scale real time trials were planned, to study the real extent to which the additive can absorb the process variations with regard to chip quality, white liquor strength variations, chips moisture variations and process conditions variations.

The paper discusses our experiences with the usage of digester additive in improving the productivity of hardwood pulp line through various optimization trials and through various process condition modifications. The additives from different chemical suppliers were tried and were found to be on par with regard to improving the pulping efficiency. The digester additive is being administered on a regular basis in the plant and the performance has also been consistent.

The Mechanism of the action of Digester Additive

More and more pulp mills are implementing digester additive programs as part of a total fibre management approach to process optimization. The primary objective of a total fibre management approach is to enhance pulp quality, increase operational efficiency and improve overall mill profitability.

The use of digester additives, and especially surfactant-based digester additives, can provide a number of benefits:

- Reduced rejects
- Reduced kappa number
- Reduced alkali consumption
- Improved pulp viscosity
- Increased throughput
- Lower cooking temperature
- Reduced cooking time

Researchers have been actively developing new surfactant-based digester additives to help mills realize

Table 1 : Digester Additive 1 Plant Trials in Hardwood Pulping

Constant conditions:

Chips charged per cook	25 MT
Steaming time	100 minutes
Temperature	166 °C
AA gpl	80-84
Sulphidity %	18-20

Trial No	1	2	3	4	5	6	7	8
Additive dose kg/t	0	0.3	0.3	0.3	0.3	0.4	0.4	0.4
Active alkali %	17.2	17.2	16.1	16.7	16.7	16.1	15.6	16.1
Cooking time min	90	90	90	90	75	75	90	90
Kappa no	20-24	16-19	20-25	21-22	26-28	26-28	28-31	19-23
RAA g/l	2.4-4.0	3.2-4.6	2.6-3.2	3.2	2.3	3.2-3.5	2.3	3.2-3.6
Cost benefit Rs/cook	0	-870	30	-420	-420	-210	240	-210
Knots (visual)	Normal	Very Low	Below Normal	Below Normal	More	More	More	Normal
Remarks		Kappa & Knots very low	Knots low with no cost	Knots low	Knots & kappa high	Knots & kappa high	Kappa very high	No cost benefit

such improvements to their pulping, bleaching and recovery operations.

Chemical Delignification of Wood

In chemical delignification of wood, the following sequence of events takes place:

- Penetration and diffusion of pulping reagents to the reaction sites within wood chips
- Reactions of alkali with phenolic hydroxyls of lignin and reaction of redox agents for depolymerisation of lignin
- Lignin and other reaction products diffuse out of the wood structure into the bulk liquid.

Two mechanisms transport cooking chemicals into wood. They are penetration and diffusion. Penetration is the flow of cooking liquor into wood pores. Diffusion is the transport of dissolved chemicals as a result of a concentration gradient. As the reaction proceeds with liquor present on chips surface, the concentration of alkali at the interface decreases and this is made up by diffusion from the liquor containing higher concentration.

If penetration during cooking is insufficient, this can lead to increased rejects and shive content in the pulp. Other problems resulting from poor liquor penetration include high lignin content, inferior bleachability, variable kappa, non-uniform pulp characteristics, and increased pulp resin content.

Digester additives can be broadly divided into three types: surfactant-based, surfactant-anthraquinone (AQ) combination, and anthraquinone.

Surfactant-based Digester Additives

Surfactant-based digester additives function by improving the penetration of cooking liquor into the wood. Better liquor penetration results in:

- Faster defibering of chips due to improved dissolution of lignin present in the middle lamella.
- Improved diffusion of cooking liquor into chips
- Reduced rejects
- Reduction in kappa number
- Reduction in alkali consumption
- Improved pulp viscosity
- Overall improvements in pulp quality

Adding surfactant-based digester additives reduces the surface tension between the liquor and the wood, allowing a more thorough wetting of the chip surface and thereby facilitating penetration of the cooking liquor into the inner matrices of the wood. Surfactant treatment results in a more uniform cook with lower kappa number and a reduction in rejects. At constant kappa, an increase in pulp yield can also be achieved. Digester surfactants lower alkali requirements and reduce the amount black liquor solids generated per tonne of pulp.

Different surfactants have varying effects, so pre-screening is usually recommended. An autoclave digester has been found to be a suitable device to evaluate surfactant additives quickly in the laboratory. Kappa number, residual active alkali, extractives, and percent

Table 2 : Digester Additive Plant Trials - Pulp Properties

Active alkali	17.2%	17.2 %	16.1%	15.6%
Digester additive kg/t	0	0.3	0.3	0.4
UNBLEACHED PULP EVALUATION				
Freeness ml CSF	300	310	290	290
Bulk cc/g	1.69	1.67	1.76	1.69
Br.length M	7020	6740	6670	7300
Tear factor	70.0	68.6	67.9	68.0
Burst factor	42.2	39.3	44.1	39.8
BLEACHED PULP EVALUATION				
Freeness ml CSF	305	315	300	340
Bulk cc/g	1.62	1.66	1.71	1.69
Br.length M	6930	7370	7330	6980
Tear factor	62.9	60.1	64.3	60.8
Burst factor	47.5	46.1	44.4	41.9

rejects can be chosen as parameters to judge the effectiveness of a surfactant program.

Synergistic Effects of Surfactants and AQ

Studies have shown that synergistic effects are obtained when a surfactant is applied in conjunction with anthraquinone. AQ acts as a catalyst to accelerate delignification and preserve hemi cellulose by reducing the peeling off reaction of hemi cellulose, while the surfactant improves the selectivity of AQ and enhances the rate of white liquor penetration. The advantages in using an optimized surfactant-AQ digester additive program to enhance mill operations and profitability can be significant.

The benefits of a Surfactant-AQ include:

- Reduced AQ dosage, while maintaining the same level of AQ performance as the surfactant ensures better reactivity of AQ
- Reduced rejects
- Reduced kappa number
- Increased pulp yield
- Improved pulp viscosity

EXPERIMENTAL

Different surfactant based digester additives were evaluated in laboratory scale first, so as to ascertain the efficiency of the additive in improving the Kraft pulping. All the pulping conditions were kept constant both in blank and with additive. The active alkali charge, cooking temperature, cooking time, sulphidity were maintained constant. The effect of the additive in terms of kappa reduction, yield, rejects, residual active alkali, and pulp properties were evaluated. The results obtained however indicate the efficiency of the additive in pulping improvement and cannot be directly correlated with plant performance since plant scale pulping involves many variables. Hence the present paper has included only the plant scale experimental results with different digester additives.

The plant scale experimental trials were real time studies conducted over a period of one week for confirmation of the efficiency of the additive and one month continuous trials to ascertain the efficiency of the additive to absorb the process variations and to calculate the cost benefit if any. Trials were conducted in hardwood pulping line with Eucalyptus hybrid chips.

The efficiency of the additive was determined under the following constant conditions

Chips charged per cook	:	25 MT AD
Steaming time	:	100 minutes
Temperature	:	166 °C
Pressure	:	7.5 kg/cm^2
White liquor Active alkali	:	80-84 g/l
Sulphidity	:	18-20 %

The chemical charge per cook and the cooking time were varied. 66 cooks were performed with Digester additive 1. The results of the trial are provided in Table 1, which includes 8 trials along with a blank run without additive. Table 2 provides the pulp evaluation data during the digester additive trials.

RESULTS AND DISCUSSION

The trial 1 was the blank normal pulping to an unbleached pulp kappa number of 20-24. The average results of 24 cooks were taken as the control.

The trial 2 was with Digester additive 1 administered at the rate of 0.3 kg/tonne of chips, keeping all other parameters constant. As evident from table 1, the kappa number dropped to 16-19. In addition the most significant observation was the reduction in knotter

Table 3 : Digester Additive 1 Longer Duration Plant Trials in Hardwood Pulping

Particulars	Unit	TRIAL 1 Blank	With additive	TRIAL 2 Blank	With additive
Unbleached pulp	MT	2637	3943	3552	4719
Active alkali reduced	Kg/t	0	28		26
Additive on Unbld pulp	g/MT	0	744	0	614
Cost Benefit			**45**		**49**
Pulp Properties					
Kappa number		20.4	21.7	21.1	22.2
Alkali loss as Na_2SO_4	Kg/T	15.5	17.4	15.9	14.5
Bld pulp brightness	%ISO	81.5	81.5	82.1	81.5
Viscosity	cPs	4.5	4.4	4.4	4.8
WBL solids	g/l	143	146	146	144
WBL RAA	g/l	3.8	4.3	6.0	4.5
Pulp Strength Properties					
Freeness	ml CSF	320	330	340	340
Br.length	M	7340	7150	6830	6990
Tear factor		60.6	60.8	59.6	60.2
Burst factor		48.7	47.0	46.5	47.6
Fibre Classification					
+30	%	0	0	0	0
+50	%	48.2	49.8	50.8	49.4
+100	%	24.2	23.9	22.8	22.6
+200	5	8.7	7.1	7.8	10.2
-200	%	18.7	19.0	18.6	17.8

rejects, which enhanced the accepted pulp quantity. The residual active alkali was also higher. About 13 cooks were performed under these conditions.

In trial 3, the active alkali per cook was reduced by 200 kg, amounting to a reduction of active alkali from 17.2% to 16.1% on OD chips. Other conditions were kept constant. The kappa number achieved was 20-25 and the knots generation was lower compared to the blank.

In trial 4, the alkali charge was increased to 16.7% on OD chips, (100kgs per cook), so as to minimize the kappa variation of 20-25 in case of trial 3. The kappa obtained was 21-22 with lower knotter rejects.

Under the conditions of trial 4, the cooking time was reduced to 75 minutes from 90 minutes in Trial 5, so as to decrease the cycle time and increase the pulp throughput. The kappa number in this case increased to 26-28, with higher knotter rejects than the blank.

To overcome the higher rejects obtained in Trial 5, in trial 6 the Digester additive quantity was increased to 0.4 kg/t of chips and the alkali was further reduced by 100 kg/cook, but still the kappa number was 26-28 and knotter rejects was higher.

So in trial 7, the cooking time was increased to 90 minutes at 0.4 kg/t of chips additive charge alkali was further reduced by 100 kg/cook. Here again the kappa increased to 28-31 and the rejects level was higher.

Hence in trial 8, at 16.1% alkali charge, 0.4 kg/tonne digester additive was added and the cooking time was maintained at 90 minutes. The kappa number obtained was 19-23 and rejects quantity was low. The results were similar to trial 3.

The summarized results from the above trials showed that the Digester additive 1 could reduce the kappa number significantly over the control, when added @ 0.3 kg/tonne of chips. The rejects was low. Bleach chemical demand was lower and pulp throughput increased.

Reducing the active alkali by 200 kg/cook with Digester additive 1 could result in a kappa similar to blank, with lower knotter rejects. Two advantages were obtained. The pulp throughput increased because of lower rejects.

Trying to reduce the cooking time with lowering of alkali resulted in higher kappa and higher rejects and was not advantageous. So also increasing the Digester additive charge from 0.3 kg/tonne to 0.4 kg/ton of chips did not show any improvement.

Table 4 : Plant Trials in Hardwood Pulping with Different Digester Additives

Particulars	Unit	Control	Additive 2	Additive 3
Unbleached pulp	MT	351.5	379.7	861.3
Active alkali reduced	Kg/t	0	32	31
Additive on Unbld pulp	g/MT	0	425	464
COST BENEFIT	**Rs/MT**		**120**	**42**
PULP PROPERTIES				
Kappa number		21.5	23.0	21.8
Bld pulp brightness	%ISO	80.8	81.2	79.7
Viscosity	CPs	4.4	5.4	5.7
WBL RAA	g/l	6.2	5.2	6.0
PULP STRENGTH PROPERTIES				
Freeness	ml CSF	360	360	360
Bulk	cc/g	1.64	1.66	1.60
Br.length	M	7315	7085	7090
Tear factor		65.2	65.3	71.9
Burst factor		48.6	47.1	50.9

As observed from Table 2, strength properties did not show a drop even at low kappa number, with digester additive 1 dosage.

Calculating the cost benefit per tonne of unbleached pulp trial 3 was found to be beneficial with regard to reduction in cost of production after absorbing the cost of the Digester additive 1, in addition to reduced rejects enhancing pulp throughput.

Hence confirmatory long duration trials were conducted for a period of 1 month with 3000 kgs of Digester additive 1 and two such trials have been presented in Table 3, which are in line with the preliminary trials.

Based on the encouraging results obtained, the efficiency of two other Digester additives, both surfactant based, were evaluated on similar lines and the results obtained are presented in table 4. They were also in line with the Digester additive 1, with regard to performance and cost benefit.

Since increase in 1 to 1.5% yield can be envisaged with digester additive as obtained in lab scale studies, the same cannot to be measured in plant scale at 120 tonnes per day production. The approach of reducing the alkali and reducing the rejects and thereby increasing the accepted pulp quantity improved the productivity of the hardwood pulp street on a long run. About 10% increase in pulp throughput could be realized. The increased pulp processing combined with proportionate reduced bleaching time resulted in a pulp of better strength properties and viscosity at the same brightness level of 80-82 % ISO. Though the direct cost benefit due to the usage of digester additive was about Rs 50 per tonne of unbleached pulp, other benefits included lower rejects handling, better pulp uniformity and improved strength, increased pulp quantity and an equivalent reduction in purchased pulp usage, lower specific bleach chemical consumption and water consumption. Both knotter rejects and screen rejects were reduced.

CONCLUSION

Surfactant based digester additive application could reduce the active alkali consumption per tonne of unbleached pulp resulting a cost benefit of about Rs 50 per MT.

Other indirect benefit included lower rejects both at the knotter and screens, improved pulp quantity and quality.

Improved productivity through increased pulp processing by about 10% with existing facilities, results in reduced specific bleach chemical consumption.

Mills using purchased pulp to cope machine production are more benefited by the improved productivity and cost savings.

The results are repeatable and consistent. The additive was able to proportionately take care of process fluctuations like chips moisture variations, chips size variations, active alkali concentration variations, sulphidity variations and cooking schedule variations.

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