Modified Conventional Batch Cooking (MCBC) - A Step Towards AOX Reduction

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ABSTRACT

Indian paper industry is more than a century old industry. The industry had seen many ups and downs with economic and environmental issues. Industry is now emerging strongly to face global competitiveness inspite of lack of funds to adopt advanced technologies. [4]In Charter on "Corporate Responsibility for Environmental Protection" (CREP) guidelines, control of AOX is one of the major environmental challenges before the Indian pulp and paper industry for its sustainability. The environmental challenges related to AOX generation have already been over come by pulp and paper mills in developed countries by adoption of new fiber line incorporating modern pulping and bleaching technologies. However Indian pulp & paper industry is still at cross roads due to its inability to adopt these modern technologies due to low scales of operation, use of mixed raw materials, and high capital investment. For techno-economical reasons, the industry has to think towards indigenously developed low cost system to minimize the AOX generation.

Development of indigenous system with a prime objective to minimize the AOX generation at source i.e before bleaching, which is very difficult to achieve in conventional batch cooking system followed by oxygen delignification without affecting the quality of pulp to meet CREP requirement.

Looking into ecology and economic conditions, the Indian paper mills require improved/modified cooking system i.e Modified conventional batch cooking (MCBC) followed by oxygen delignification in case they are unable to afford modern cooking system for minimizing the AOX generation because of their high capital cost.

Keywords: Batch Cooking, AOX, Bleaching, Chlorine, Pulp, Oxygen Delignification, Alkali Charge, Temperature, Digester, Cooking cycle etc.

INTRODUCTION

India is a developing country with ever increasing demand of paper and boards. [1]The main raw materials used in paper mills are hardwoods like eucalyptus, Casurina, Acacia etc. Large size paper mills in India are based on conventional batch cooking system. Due to increasing cost of the chemicals, energy, other utilities and very strict legislative controls, the paper industry has to think very deeply for the economical use of chemicals, energy, other utilities and reduction in pollution load generated in the mills. Various possibilities are open to meet these demands. One possibility is the incorporation of the latest worldwide technological developments in the field of pulping more specifically, extended delignification and oxygen bleaching to our paper mills. But this can be very costly and many mills may not be able to afford this. Such mills can consider the conventional batch cooking digester for improved/modified cooking technology to meet the targeted Kappa number of 16-18 without increasing the active alkali charge and maintaining quality of pulp, whereas the conventional batch cooking is giving the targeted kappa up to 20-25 at the same chemical charge. The obtained targeted Kappa No. of Modified Conventional Batch Cooking (MCBC) would also enhance the effectiveness of oxygen delignification compared to conventional batch cooking (CBC). The MCBC concept, MCBC impact on AOX generation and impact of MCBC with oxygen delignification are based on literature reviews and further study would be required before adopting proposed system in Indian paper mills.

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Concept

The concept of pulping starts from lignin chemistry and reaction of Kraft cooking system;

[3]Lignin reactions

Understanding the lignin reactions during cooking requires that the distribution of lignin in the cell wall and the middle lamella is recognized. Lignin comprises 70% - 80% of the middle lamella, but the layer is thin when compared to the thickness of the secondary cell wall. Here the proportion of lignin is only 20%, but since the secondary wall is thick, it contains 70% - 80% of the total lignin. There are also differences in the chemistry and reactivity of lignin in different morphological locations.

Wood has to be well impregnated with cooking liquor before any delignification can occur. Ideally all the cavities of the wood cells are filled with reagents, as are all the pores of the cell walls. It is likely that cooking liquor can penetrate into the middle lamella only via cell lumens and the porous cell wall. Thus it is likely that much of the lignin in the secondary cell walls will dissolve before the middle lamella lignin. This mechanism is supported by the fact that chips maintain their wood-like structure well beyond 80% delignification without falling apart.

[3]Initial delignification:

Lignin reaction in Kraft pulping can be divided into three distinct phases: Initial delignification, bulk delignifica--tion, and residual delignification. Initial delignification takes place mainly in the impregnation phase, well before final cooking temperature has been reached (i.e. <140 °C). Very little lignin is dissolved here (20% - 25% of total). Hydrosulfide absorption in the initial delignification phase will perform two important tasks: it will improve penetration and be in place to speed up bulk-phase reactions, simultaneously protecting cellulose from degrading and dissolved lignin from recondensing.

[3]Bulk delignification

The rate of delignification increases dramatically when the cooking temperature is elevated above 140 °C and 70% - 80% of all lignin dissolves during this phase. The dissolution begins in the lower layer of the cell wall and progresses into the middle lamella. The bulk delignification phase strongly depends on the OH ion and HS ion concentrations and on temperature. The rate of delignification slows down as the concentration of dissolved lignin increases. The overall rate is also slower in thick chips, since the rate is diffusion controlled. That means that thick chips will be left with a higher average lignin content than thin chips.

[3]Residual delignification

The bulk delignification phase will continue until about 90% of all lignin has been dissolved. The residual delignification phase is considerably slower than other phases. Alkali depletion in any phase of the delignification process will lead to recondensation of lignin polymers, and further dissolution will stop. This means that there must be some free alkali concentration (“residual alkali”) left after delignification has been completed (515 g/l is considered normal.)

[3]Cooking principle

[(3)]Hartler and Teder showed that the degradation of carbohydrates can be reduced if alkali concentration at the beginning of the cook (i.e in impreganation) is lower and is increased towards the end of the cook. Selectivity so that viscosity reduction is delayed to a later stage of delignification. This allows cooking to lower residual lignin contents without undue carbohydrate degradation. The effect is improved by reducing the amount of dissolved lignin towards the end of the cook. The degradation of carbohydrates in the early phases of cooking is reduced by lower initial alkali concentration and perhaps also by a higher HS-/OH- ratio in impregnation liquor, particularly through the use of black liquor. Lignin condensation reaction is reduced by maintaining a higher alkali concentration when approaching the residual delignification phase, and the effect is further improved by reducing the concentration of dissolved organics in the cooking liquor.

Approach

The approach adopted for modifying the conventional batch cooking to reduce the impact of AOX is given below;

- Uniform chemical charging at different stages
- Regular/ Intermediate monitoring of cooking liquor
- Impact analysis of AOX generation by cooking system

Modification of Conventional Batch Cooking

In conventional batch cooking, the digester is filled with chips and given a one time charge of cooking chemicals. The alkali concentration in the digester is initially high, but then falls as the cook progresses and the cooking chemicals are consumed. Longer cooks will further reduce pulp lignin content but it will also begin to degrade the cellulose, as the reaction become less selective towards lignin. The conventional batch cooking condition is shown in Table-1.

Modifications required for MCBC

The Conventional batch digester modification for MCBC consists mainly the minor pipeline modification of liquor charging and high pressure chemical dosing pump is required to charge the chemical at different stages. In modified conventional batch cooking, chemical charging of 17% Na_2O is suggested in 3 stages as per the concept of [3]Hartler and Teder. For example Initial stage chemical charging is 16 gpl (2.72%) added along with weak black liquor having 8 gpl residual alkali, 2nd stage chemical charging is being added 34 gpl (5.78%) and 3rd stage chemical charging is being added 50 gpl (8.5%) with conforming cooking conditions shown in Table 2.

Monitoring of Alkali Concentration

The intermediate monitoring of alkali concentration is one of the essential requirements as per the concept of modified cooking system. Therefore, modified conventional batch cooking needs the alkali analyzer to monitor the intermediate concentration of cooking liquor along with other necessary modification. The analyzer results will help to identifying the chemical charging stages and regularly monitoring of active alkali concentration may also help to maintain uniform cooking condition.

Hartler and Teder[(3)] concept is highlighting the different alkali requirements for different

Table -1: Conventional Batch Cooking Condition

Particulars	Time, min	Cumulative Time, min	Temperature, °C	Active Alkali, as Na2O gpl
Chips and chemical charging	60	60	50-70	100
Steaming time	165	225	70-165	70
Cooking time	90	315	165	32.5
Blow	15	330	100	5 (residual)

Table -2: Modified Conventional Batch Cooking Condition

Particulars	Time, min	Cumulative Time, min	Temperature, °C	Expected Active Alkali, as Na2O gpl
Chip and chemical charging **(1st -Chemical charging 16 gpl , Active alkali as Na_2O)**	60	60	50-70	16+8*
1 stage steaming **(2nd - Chemical charging 34 gpl, Active alkali as Na_2O)**	60	120	70-130	34*+8
Retention time	45	165	130	24*
2 stage steaming **(3rd - Chemical charging 50 gpl, Active alkali as Na_2O)**	60	225	130-165	50*+8
Cooking time	60-90	285-315	165	--
Blow	15	300-330	100	8* (residual)

[3]**Figure -1: Active Alkali, Temperature Profile**

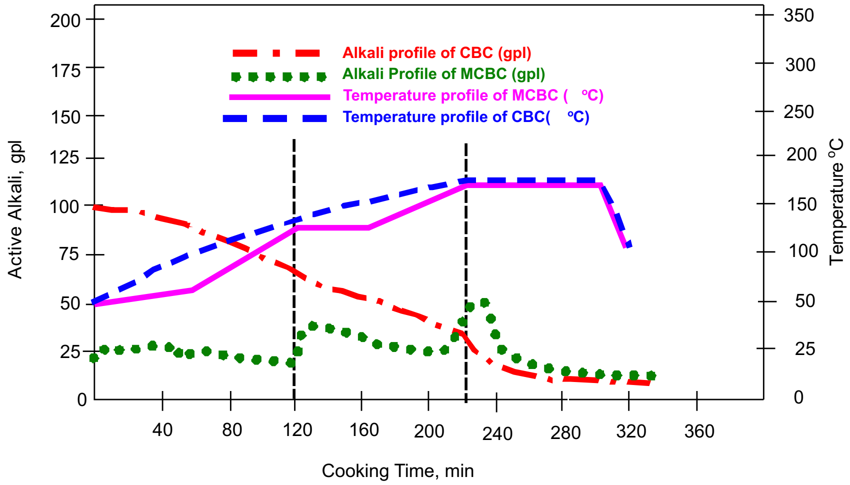

Table -3: Comparison of MCBC and CBC results

Particulars	Chemical Charge, % AA	Kappa No.
Conventional Batch Cooking (CBC)	17	20-25
Modified Conventional Batch Cooking (MCBC)	17	16-18

delignification phases. However in conventional batch system, the chemical charging is done at initial single phase only. This would lead to substantial amount of carbohydrates to dissolve during high OH condition at initial phase and alkali becomes deficit in bulk delignification phase where actually the chemical requirement is high resulting in uneven and higher targeted kappa. In modified conventional batch cooking, the alkali charged in 3 stages as per the Hartler and Teder[3] concept result in uniform and lower targeted kappa compared to conventional batch cooking at the same amount of chemical dosage. The figure-1 shows the active alkali consumption profiles of conventional batch and modified conventional batch cooking.

Conventional batch cooking is getting the targeted kappa no. 20-25 at 17% AA chemical charge where as modified conventional batch cooking may result in targeted kappa no. 16-18 with same chemical charge (Table-3) with marginal improvement in yield due to gentle cooking. The expected results are encouraging towards better bleachability of pulp with reduced active chlorine consumption. Hence, it is possible to reduce the impact of AOX generation at the source.

Impact analysis of AOX generation by cooking system

Lignin is the main contributor to pulp color. In chemical pulp, it has the highest light absorption coefficient of all fiber components. The residual lignin has to be removed by bleaching with active chlorine, which is forming organochlorides i.e. AOX in bleach plant effluent. Several capital intensive options are available for cooking and bleaching system to reduce the impact of AOX generation. In this circumstance, the modified conventional batch cooking is showing the improvement in minimization of AOX generation at the source by reducing targeted kappa no. by 20 to 28% the AOX reduction is possible to same extent that kappa number has reduced by MCBC. For meeting the CREP requirement, AOX generation has to be reduced to less than 1 kg/tonne paper before July 2008. This target seems to be impossible to many mills having conventional batch cooking and conventional bleaching sequence. In this condition mill have to go for oxygen delignification in their fiberline or decide on modified conventional batch cooking to reduce the Kappa number.

Note: Due to variation in Kappa at the inlet of bleach plant, dosing chemicals may be some times higher than required resulting in variation in AOX. Hence we are considering the conservative figure of AOX reduction.

Retrofitting with Oxygen Delignification

It is true that conventional technologies are not adequate to minimize AOX to desired level as per the CREP requirement. [2]Therefore, retrofitting option of oxygen delignification is only to achieve desired level of AOX. However, effectiveness of oxygen delignification depends on the type of cooking system adopted in fiberline. In Conventional batch cooking followed by oxygen delignification will be resulting in kappa number reduction of about 30-35% without affecting quality and pulp yield, where as modified conventional cooking followed by oxygen delignification will give kappa number reduction of about 40-45% without compromising any quality and pulp yield. The retrofitting of oxygen delignification in conventional batch cooking may achieve reduction in AOX but it remains at the threshold limit. In situation like this, modified conventional batch cooking followed by oxygen delignification gives comfortable results of AOX reduction without affecting cost of production and also meets the AOX well within the CREP guidelines

Expected impact on yield

It is expected that the marginal improvement in yield from the modified conventional batch cooking due to uniform dosing of cooking chemicals and selective reaction with cooking chemicals leads to less degradation of cellulose and hemicellulose. Improvement in yield may vary from mill to mill due to variation in raw material mix and process conditions.

Expected impact on energy

In energy consumption point of view, there is no increase in specific energy consumption from the modified conventional batch cooking due to no change in cooking temperature, cooking time and quantity of liquor pumping to the digester. The quantity of liquor recirculation is reduced in initial delignification phase due to intermediate addition of cooking liquor accordingly energy consumption may reduce but it is very difficult to analyze at this stage of study.

Benefit Analysis

No doubt, technologies always payback provided one can afford it. Till then adjustments in process with affordable investment can be tried to achieve the proportional benefits and also to comply with environmental

Table 4: Analysis with AOX discharge

Particulars	Investment, (Rs.)	Expected[2] AOX Reduction, %
Modified Conventional Batch cooking system*	20 Lakhs (for each digester)	20-28%
Conventional Batch cooking system followed by ODL*	20 Crores**	35%
Modified Conventional Batch cooking system followed by ODL*	22 Crores**	40%

* With conventional bleaching sequence and **approximate cost for 300 TPD plant

Note: The reduction in AOX depends on case to case basis and data given above are only indicative values.

commitment. The investment on the technologies versus AOX reduction has been expected as shown in Table -4. Looking into economical feasibility and ecological necessity, Indian mills have to choose optimistic option.

CONCLUSION

Modified conventional cooking followed by oxygen delignification will give kappa number reduction of about 40-45% without compromising any quality and pulp yield. The analysis shows that going for oxygen delignification in conventional batch cooking fiberline could achieve considerable reduction in AOX but remains always at the threshold limit of AOX. In situation like this, modified conventional batch cooking followed by oxygen delignification gives the comfortable results of AOX reduction without affecting cost of production and meets the AOX level well within the CREP guidelines and this approach can be used by mills who cannot afford more costly and modern pulping systems of extended delignification, oxygen bleaching etc. However, further study is required for implementing the modified conventional batch cooking system successfully.

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