Recent Applications of the Modern Control Technology in the Pulp Process Management

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INTRODUCTION

Honeywell is the global leader in providing pulp and paper producers solutions that improve performance. From breakthroughs in QCS technology in the late 1960s to the introduction of the TDC–2000- the world's first distributed control system–to today's enterprise-level production management applications, Honeywell is the leader in delivering revolutionary pulp mill process automation and business optimization solutions. These solutions boost performance by increasing product quality and production efficiency, helping to achieve better customer service, enabling more flexible production coordination and reducing costs through increasing efficiency.

In today's competitive marketplace, pulping operations must run at maximum performance through the pulping stages, at top efficiency in the recovery areas and still meet the challenges of compliance with local and federal environmental regulations.

Advanced Pulping Solutions are comprised of pulping, washing, screening, bleaching, recycling, evaporation, recovery boiler, causticizing, lime kiln, power house and biological effluent treatment solutions. Advanced Pulping Solutions utilize for instance the latest multivariable control technology as well as Fuzzy, Neural Network, Statistical Process Control and optimization algorithms.

Some examples of a pulp mill's benefits from existing installations, just mentioning a few of recent installations.

- Advanced Pulping Solutions increased production by 6% and Bleached Pulp Viscosity by 18% at an North American Pulp Mill in Alabama USA.
- Advanced Bleaching Solution reduced CEK variability by 27% and ET Chemical usage by 17%.
- Recaustisizing multivariable optimization implementation reduced white liquor causticizing efficiency variation by 37% at Irving Pulp and Paper.
- An Finnish pulp mill eliminates boiler's extra water washes with Advanced Recovery boiler controls. The emissions, reduction rate and steam production variability were all significantly reduced (by as much as 21% to 72%). An implementation of the Bed Control module together with Comprehensive Combustion Control reduced furnace carryover, making it possible to run with a higher firing rate (130% of boiler's nominal planning capacity).

The typical economical benefits using the modern control technology are $1-$2/production ton per pulp mill department.

The aim of this presentation is to shed light of the latest development in the pulp mill automation arena. The presentation focus is in the chemical saving in the bleaching plan operation utiliizing robust multivariable controller.

BLEACH PLANT PERFORMANCE ENHANCED USING ADVANCED CONTROLS

Over the years a great deal of effort has been focused

towards controlling the bleach plant, but the results to date have not been that impressive, Many hours of bench scale and "bucket and stop watch trials" have been performed and the "projected" results always look impressive. The real issue is that once the new scheme are placed in the hands of operators, who have not only age old ideas firmly planted in their minds on how the bleach plant should be operated, but also the constant pressure of making the required production, at the required quality level with little or no room for error, usually results in the same methods of operating taking over in a relatively short period of time. In other words, business as usual. It has been said before that sometimes by taking a step back, you can actually get a clearer view of the path forward.

The bleach plant is the final process before the paper mill. Pulp quality such as dirt (shive content), strength (viscosity) and brightness can definitely be affected, both positively and negatively. The bleaching process is characterized by long dead times in the towers that range from 30 minutes to more than 3 hours. Any upset can get you in trouble for a long time. Having continuous feedback and process visibility is a necessity. Capital costs and the entire environmental permitting process make it very difficult and expensive for mills to expand their operations to include a separate bleaching line. For this reason, many mills must "campaign" the single bleach line with shorter runs of hardwood and then softwood. Minimizing the amount of transition pulp (pulp that is in between quality and fiber content), is a business necessity. New fiber lines place a much greater emphasis on exactly how much actual delignification is done in the cooking process and how much is continued in the bleach plant. This is to improve both strength and yield.

For this reason, it is ever more important to be able to accurately and reliably monitor and control the delignification process continuously. Over application of chemical is not just costly, but all effluent streams are now closely monitored and therefore it is important to ensure that the correct dosage is applied.

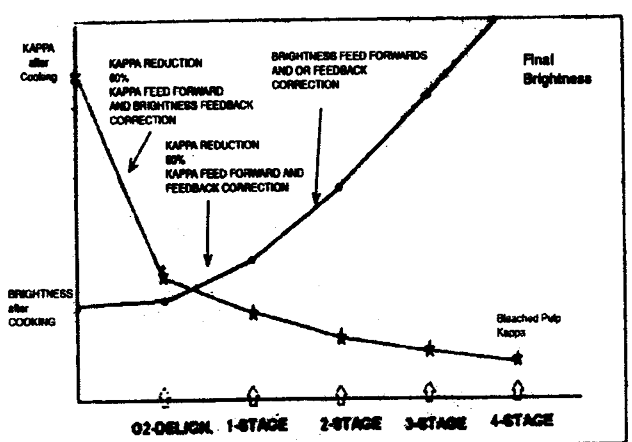


Figure 1 : Brightness and KAPPA through the bleaching process

The bleaching process is actually made up of two distinct functions. Bleaching is most accurately described as the process of making the pulp look whiter or brighter, but before that can happen, delignification must be completed. Figure 1. shows that the rapid increase in the brightness does not occur until the majority of the lignin has been removed. The first two stages of the bleach plant are actually an extension of the delignification process with the cooking process. The first two stages are included in this description, since the oxidizing chemicals are not just applied in the first stage such as the case of chlorine dioxide, but further lignin removal is also accomplished by the proper use of oxygen and hydrogen peroxide. Sodium hydroxide is also very important since the removal of the chloro-lignin that is formed in the first stage is heavily dependent on the correct stoichiometric amount of caustic being applied in the second stage. This is where the concept of sequence kappa factor becomes very important. The total amount of oxidizing chemicals needed to be applied with respect to the bleaching load entering the bleach plant can be reported as the sequential kappa factor (SKf). This definition is used to relate the total applied oxidizing chemicals to the lignin removal process, as opposed to the total applied chemical for the entire bleaching process. It is understood that some minor delignification can still be accomplished in the "brightening" stage of the process but the amount is relatively small in this context.

A way of looking at bleaching chemical demand that is not really new, is kappa factor. KF is defined as the % Total Equivalent Chlorine (TEC) applied divided by the unbleached kappa number. As mentioned, this concept has been around for some time thus the requirement of expressing the applied chemical in terms of TEC even when dealing with an ECF or 100% chlorine dioxide process. It has also been known as Active Chlorine Multiple and the Equivalent Chlorine Multiple. Traditionally it has only been an "after the fact" calculated value since manual testing of kappa was standard. Today, not only are there batch kappa testers available but also a patented in-line continuous type (1).

The feed-forward measurement of total lignin, which defines the bleaching load, is the key to our strategy. This is an important deviation from compensated brightness approaches that introduce a great deal of process variability. The after mixer residual is only used when a high or low limit is exceeded. It is not used in any form of compensation of the kappa factor calculation. If a low limit were exceeded, then the kappa factor set-point would be increased. Feedback from the kappa measurement after the Epo stage is also used to accomplish a ture delignification control. However, delignification does not occur only in the first chlorine dioxide stage. All oxidizing chemicals must be accounted for in order to both efficiently and economically spread the bleaching load out. For a DEop sequence, this value would be known as the Sequential Kappa Factor (SKf).

For a typical D-Eop configuration, the sequence kappa factor would be calculated as follows:

$$SKF = \frac{((\%Cl_2) + (\%ClO_2 \pm 2.63) + (\%O_2 \pm 4.44) + (\%H_2O_2 \pm 2.09)}{\text{Unbleached kappa}} \quad (1)$$

The benefits of controlling to sequence kappa factor are quite clear. This allows for the entire suite of chemicals to be used most effectively and also it allows for the least expensive chemicals to be maximized.

Sequence kappa factor is not just a series of single input single output (SISO) loops. This is by definition a multi-variable control problem with many interactions. For example, if the unbleached kappa number entering the bleach plant suddenly drops, and the only control action that is made is to lower the chlorine dioxide, then after a delay equal to the retention time of the first two towers, the CEK number will drop considerably if no action is taken on the oxygen or hydrogen peroxide. If this is not the case, then the past dosage rates of these chemicals were incorrect and being under utilized. In this case the kappa number is acting as the disturbance variable.

What this means in simple terms is that as the disturbance variable, DV (unbleached kappa) changes, the controller makes co-ordinated changes to not only the chlorine dioxide, but also to the oxygen and peroxide. Included in this matrix is also the sodium hydroxide required for proper pH control and extraction. The manipulated variables (MV's) are the chemicals; chlorine dioxide, oxygen, peroxide and sodium hydroxide. The controlled variables would be the CEK or degree of delignification, the pH and the pre-tower residual. A key factor here is that absolute setpoint control is not required for optimal performance. It is dynamic and the concept of a range control algorithm is introduced. This means that there is flexibility in the solution of the control problem and that the tuning can be adjusted to allow for a solution based on the degree of robustness required. When the cost is also involved, based on the reaction rates, bleaching efficiencies etc. several solutions can exist.

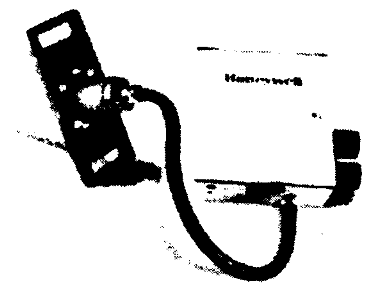
Many control packages only address the first layer or two of the control hierarchy. It is not acceptable to only meet the first level objectives of a 'single loop' controller. Just because the flow meter syas that the setpoint is equal to the process variable, this does not indicate if you are meeting your business objectives.

Today it is important to be able to manage your process in a more coordinated, real-time fashion.

Advanced Bleaching Solution

Honeywell's Advanced Bleaching Solution(ABS) is a complete bleach plant control solution that includes optimization controls, bleaching business tools, specialty sensors and field instruments. The package economically controls your bleach plant operations while optimizing quality control parameters.

Accurate bleaching parameter measurements are key to process control and optimization. The Honeywell's Precision Bleaching Sensor Black provides unparalleled measurement of key bleaching parameters, including Bleaching Load, brightness, ClO_2 and Cl_2 residual and Residual Ink Content. The sensor may also be used in the optimization of chlorine dioxide generator operation with on-line measurement of chlorate and acid strength.



- Continuous in-line measurement improves recycle and bleach plant performance by providing timely, accurate inputs to the control system.
- Accurate control reduces chemical overcharging leading to reduced chemical usage and improved pulp uniformity.
- Interactive PC-based user interface allows maximum productivity in monitoring, troubleshooting and tuning.

The Advanced Bleaching solution allows complete integration of new technologies, including smart sensors, multi-variable control, and neural networks. The package supports levels of control ranging from simple valve positioning and sensor correction to the latest in advanced control concepts and optimization. Advanced Bleaching solution includes:

- Multivariable Predictive Stage Controls
- Stock Tracking
- Grade Change Control
- Production Management
- Cost Calculations
- Sensor Correction
- Statistical Process Management
- Quality Test Entry

Advanced Bleaching solution stabilizes the beaching operation while optimizing process economics and product quality. Typical results include savings of 5% to 7% in chemicals costs along with a 50% reduction in final brightness variation. Proper control of chemical application also leads to decreased environmental impact. Honeywell's Advanced Bleaching Solution is designed to assist opertions personnel in making the "Business of Bleaching" more profitable.

Multivariable Predictive Stage Controls

The Advanced Bleach Solution stage controls are based on Honeywell's Multivariable Control technology. This technology represents the next generation of control and incorporates true robust design for excellent control in all operating conditions. The Advanced Bleaching

Solution package provides control and economic optimization of processes that have significant interaction between variables.

Bleaching is a highly interactive, multi-input, multi-output (MIMO) process. Advanced Bleaching Solution considers the entire bleaching process as a single entity rather than a collection of independent and isolated control loops. Advanced Bleaching Solution thus becomes a tool to keep the process within operational constraints while optimizing economic and quality performance measures.

Stock Tracking

Stock Tracking tracks segments of pulp from brownstock storage, through the entire bleach plant and to the bleached pulp storage discharge, collecting process and control information along the way. Stock Tracking is used within Advanced Bleaching Controls, as well as providing the mill's business and control information systems with accurate information about the properties of the pulp in the bleach plant. This information helps the operator to optimize bleach plant control actions and maximizes the key decision-making information available to mill personnel. Stock Tracking historizes real-time operating conditions for control and statistical evalution. In addition to parameters tracked for control, mill selectable parameters may be added for customized evaluation useful for trial runs and other mill specific evaluations.

Automatic Grade Change

The Automatic Grade Change module allows Advanced Bleaching Solution to change control and operating parameters as a grade change progress through the bleach plant. Initial operating parameters for each grade are stored in an easy to access recipe format. When a grade change is intiated by the operator, Advanced Bleaching Solution will change the mill's selected setpoints as the grade interface reaches the corresponding location in the process. Control setpoints are ramped to their new values over a configurable period. Stock Tracking is used to determine the location of the grade interface.

Production Managerment

The Production Management module changes the stock flow according to a new desired production rate setpoint and given ramp time. During the ramping of production rate, all critical control loops in the bleach plant are monitered. Any defined alarm condition results in suspension of the rate chages.

Sensor Correction

Useful in correcting pH probe and optical sensors for use in control, the Sensor Correction module corrects sensor-based control inputs with laboratory test data. Sensor readings are verified to ensure validity with accuracy in the control inputs.

Statistical Process Management

The Advanced Bleaching Solution uses several advanced statistical process control techniques to control the bleach plant. Critical process variables from sensor inputs and manually entered laboratory data are charted and control values filtered, decreasing noise and reducing possible process instability. On-line control charts are also used as statistical analysis tools to detect true process changes and to assist the operator in assigning probable causes to truly significant process events.

Quality Test Entry

The Quality Test Entry module checks all entries for range before allowing acceptance for control. All entries may be time stamped for actual sample time to allow accurate control. Test data may be entered directly into the package or may be transferred from the mill lab or information system.

Customer Benefits

- Assist in stabilizing the bleach plant operations.
- Provide consistent operation from shift to shift.
- Minimize unwanted variations in pulp quality and chemical usage as measured by CEK Number and final brightness.
- Change production rates and species without upsetting the bleach plant operations and creating excessive transition pulp.
- Correct balance of chemicals to satisfy environmentally based effluent constraints.
- Continue delignification while maintaining pulp strength.

RESULTS

- Improved visibility for the operator and better inter-unit coordination
- A reduction in environmental impact as a result of tighter application of chemicals and the avoidance of upsets
- 5-7% Decrease in overall bleaching cost
- 50% Reduction in CEK/intermediate brightness variations
- 3-5% Increase in throughput
- 50% reduction in final brightness reduction
- Stock Tracking provides ISO 9000 documentation

CONCLUSION

Better technology leads to lower project implementation costs and higher benefits. Multi-variable predictive control coupled with on-line kappa sensors provides control and economic justification of processes that have significant interaction between variables. The real value of this approach is that it allows you to consider the entire bleaching process as a single economic and process entity rather than a collection of independent and isolated loops. Today Windows based tools exist and allow mills to keep the process within operational constraints while optimizing performance measures, such as cost per ton.

Sequential kappa factor is a powerful way to economically shift the bleaching cost.

REFERENCES

1. Millar, O., Van Fleet R. Continuous In-Line Kappa Measurement System (U. S. Patent No. 5,953,111).
2. Williamson, M., Pulp & Paper Vol. 73(7) pg. 37