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Wet-end control - recent developments

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Introduction

Many important qualities of the final paper are established at the wet-end of the paper machine. Therefore, it is of great importance to understand and control the wet-end. Here, the complexity has increased dramatically over the last 20 years and thus has increased the need for improved knowledge and control.

Within papermaking, we have observed the following trends which contribute to the wet-end complexity:

- Closed white water systems
- Increased filler types and content
- New retention chemicals and increased use of other wet-end additives
- Increased production of coated paper
- Increased use of recycle fibers
- Higher paper machine speeds and new wet-end processes
- Demand for higher paper qualities

The wet-end chemistry has become more complicated, partially due to a higher degree of system closure. This contributes to an increase of the so-called interfering substances. These substances affect papermaking in many different ways such as the appearance of spots and holes in the final sheet; retention, formation, and drainage variations; and deposits in the process equipment. Also, system closure leads to a process with strong feedback coupling. This means that process upsets come back and re-disturb the process over an extended time.

Fillers are now an essential component of many grades. In terms of weight, fillers represent the largest non-fibrous component of the paper. Typically, addition levels are 3 to 30%. There have been increases in both filler varieties and filler contents. The varieties of fillers have increased to achieve better qualities for special properties of the paper such as brightness, opacity, and printability. Papermakers have also increased the paper filler contents to reduce furnish costs.

Today's retention aid chemicals are much more efficient and complicated than 10 years ago. In these last 10 years, the chemical suppliers have improved their chemicals thanks to field experiences, better chemistry knowledge, and analytical instruments that provide quick and accurate measurements of the process variation. Multi-component retention aid programs have especially changed the wet-end chemistry control. These programs have advanced in complexity from simple, long-chain polymers, to multi-component specialty polymers. These retention aid programs not only impact the paper quality, but also impact production costs.

The production of coated paper and thus the amount of coated broke, has also increased. Coated broke has a completely different impact on the furnish chemistry than uncoated broke. Additionally, the increased use of recycled fibers requires new approaches to the wet-end chemistry. Figure 1 demonstrates how the introduction of broke into a process in Eastern Canada dramatically affects the furnish fines component. Here, the broke stream also includes reclaimed fiber so there is a decrease in first-pass retention, an increase in white water consistency and an increase in headbox consistency.

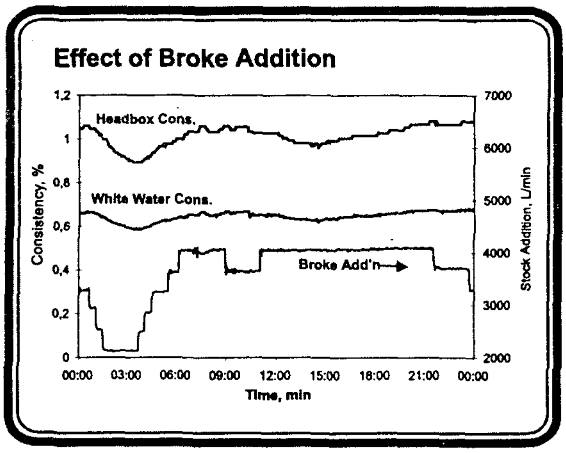

Figure 1 - Effect of broke addition

In paper production, the development in the paper industry has also moved towards faster paper machines, new headbox designs such as CD consistency profile control, and new wet-end processes (Figure 2). This makes it more difficult to achieve high wet-end chemistry performance. At the same time, the demand for improved paper grade quality has increased.

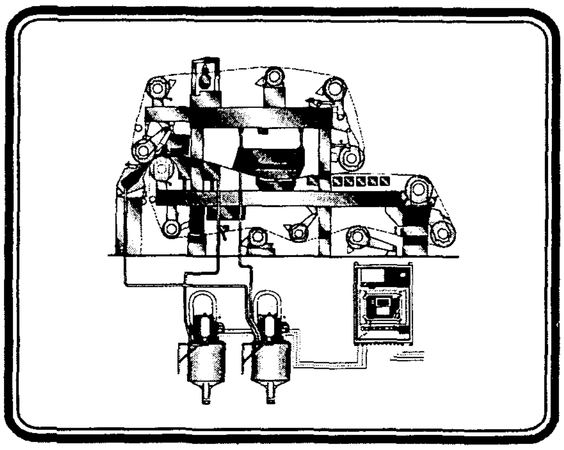

Figure 2 - Twin-wire paper machine

All these trends clearly indicate the importance of the wet-end to obtain high paper quality, produced cost-efficiently. In recent years, better wet-end control has probably been the most active area of interest within papermaking. One of the greatest challenges is to generate a comprehensive, physical-chemical model for the description of all the interactive processes in the wet-end.

But, like mentioned by William E. Scott in the principles of wet-end chemistry: "It does not take much reflection to understand why no comprehensive wet-end chemistry control scheme like that has never been implemented. In the first place, the required process models simply do not exist, and it is highly unlikely that they ever will..."[i]

However, some success in control has been achieve with a more empirical approach. A proven technique in wet-end control is to regulate the white water consistency with the retention aid addition.[ii, iii] This stabilizes the headbox fines content and thus, stabilizes many of the paper properties and the papermaking operations. White water consistency control is well known by the chemical suppliers and the measuring instrument companies. As this paper will discuss, many control loops have been implemented around the world with excellent results.

The control of the wet-end is now essential to produce good paper quality. These advances allow reduction in end-quality variations at a cost-effective price. There are improvements in strength, printability, opacity, basis weight profiles, moisture profiles, sizing, etc. The optimum, stable dosage of the various wet-end chemicals are the major keys to achieve these goals.

Why measure retention?

Retention measurement is the most relevant information of the paper machine's ability to retain the stock from the headbox to the press section. On the other hand, retention is only a calculation that depends on the white water and headbox consistencies. An accurate measurement of the consistency is essential to get a good retention calculation. The first pass retention is calculated as shown in Figure 3.

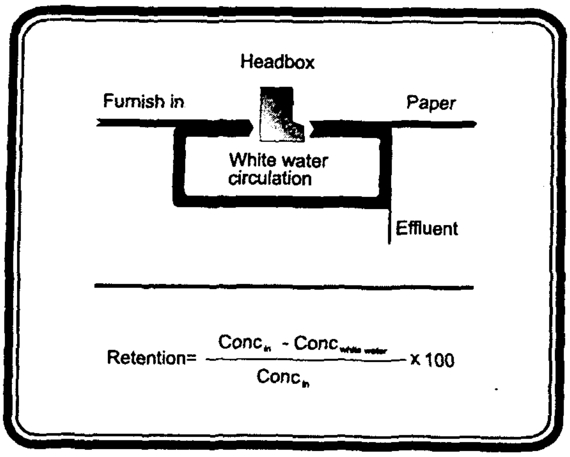

Figure 3 - First pass retention

On the modern paper machine, there are also many other possibilities for retention calculation, such as the addition of the top and bottom wire, but the most relevant and important one remains the conventional, first-pass retention.

Retention measurement provides a window into the process. The headbox measurement provides insight into stock preparation upsets such as refiner behavior (fine/fiber ratio), errors in the stock blending or non-tuned consistency control. Also, the ash measurement indicates behavior of the first pass ash retention and allows more intelligent adjustments of the filler addition level. Figure 4 provides a view of the headbox total consistency and ash content during a filler change from 10 to 20%.

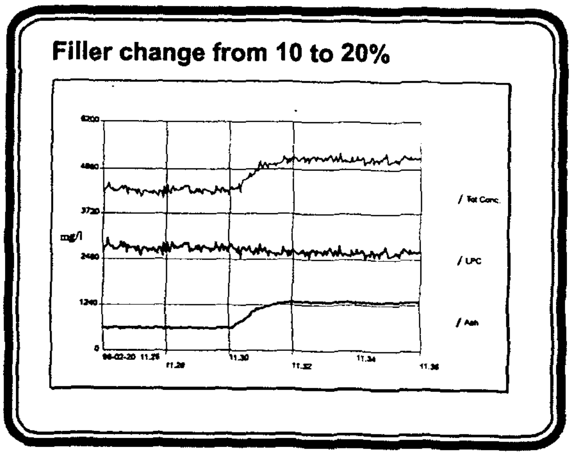

Figure 4 - Headbox filler change

Note that the fiber content in the suspension is not changing during the filler increases.

Retention measurement allows optimization of the forming section. All paper machines have mechanical adjustments that impact drainage and formation. On-line measurement allows quick identification of their effects. For example, it is possible to open the headbox slice lip which has the immediate effect of diluting the headbox stock to improve paper formation. See Figure 5. An on-line analyzer will show the direct correlation of slice opening versus headbox consistency. Other mechanical adjustments including foil and vacuum box placement and optimum wire selection. These decisions are much more apparent thanks to an on-line retention monitoring system. These adjustments can improve runnability and paper quality.

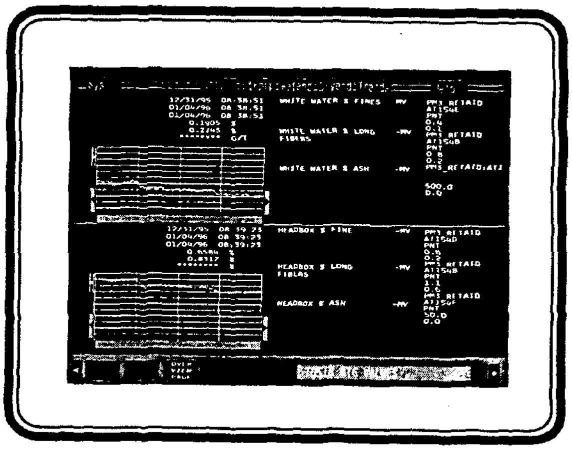

Figure 5 - Effect of headbox adjustment

Retention measurement provides knowledge of retention aid activity. An on-line retention monitoring system allows quick identification of retention aid activity. Figure 6 shows the impact on the white water consistency and filler consistency after chemical variation (colloidal silica) on a Swedish white-top liner machine.

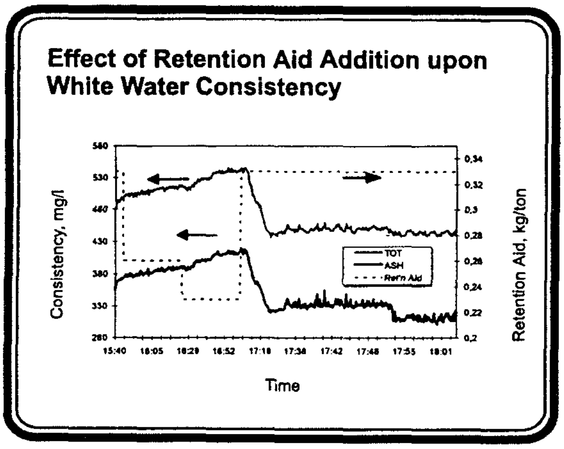

Figure 6 - Effect of retention aid change

Knowledge of the retention aid activity allows the chemical suppliers to improve the performance of their retention aid chemicals. Grades that use expensive functional additives such as sizing agents, dyes, and wet-strength resin will decrease the cost of these additives. Since these additives preferentially absorb to the smaller particle, an increase in retention will increase the performance of these additives. By increasing retention, more of the additives stay in the sheet which reduces the chemical costs and the recirculation of the stock in the system.. Many of these additives deposit on the paper machine if they are allowed to build up in the process. A more efficient use of these additives reduces the wash-up frequency, increases fabric life and improves paper quality.

Allows white water consistency control - Every paper machine has an optimum white water consistency at which the machine runs better. The on-line measurements allow optimization and control of this consistency. When a machine improves white water consistency stability, paper machine operation also improves. Since the majority of the white water is used to dilute the thick stock to the headbox, the headbox stock has a more stable fiber/fines balance. A stable fiber/fines balance stabilizes the wet-end chemistry, headbox consistency, paper machine drainage and drying, and the overall paper quality.

Current trends in the industry

The paper mills, the chemical supplier, and the measuring instrument companies are cooperating more and more in research, development, and machine trials during wet-end experiments. Today's chemicals are much more complex and affected by many process variables that must be measured constantly to achieve good results.

Every time chemical suppliers performs a paper machine trial with a new chemical, they must analyze the process pH, temperature, cationic demand and, mostly important, the headbox and white water consistencies. These parameters are essential to determine the chemical's efficiency. Nalco Sweden, for example, is using an on-line portable suspended solid analyzer to measure the white water total and filler consistency. With such an instrument, they quickly determine if the chemical has the expected effect in the process. The on-line consistency analyzer differentiates the fiber and filler reaction in the wet-end. Since the most difficult component to retain on the wire is the filler, and laboratory analysis takes many hours, such an analyzer is an invaluable tool. This provides the critical information, allowing immediate insight into the process, to determine the optimum chemical dosage for achieving the required filler retention. This was previously shown in Figure 4 during an increase in calcium carbonate, and below in Figure 7 for a basis weight change at the headbox on the STFi FEX pilot machine in Stockholm. Note that the consistency changes within two minutes.

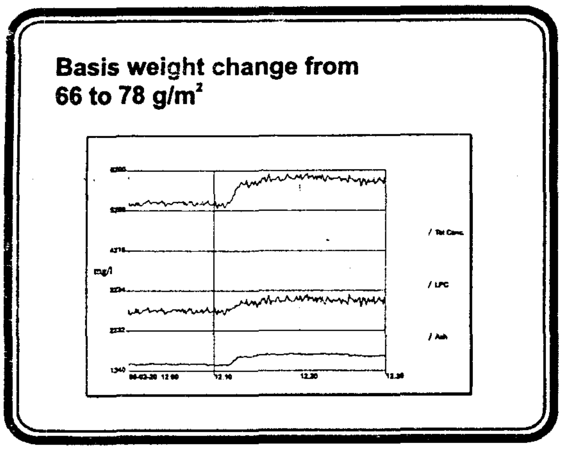

Figure 7 - Basis weight change

There are also many other parameters that attract attention. Drainage, dewatering and retention are essential parameters that are studied by the wet-end process engineer. We have been able to correlate drainage on the wire with coagulant and flocculant dosages, and have been able to optimize the compromise between retention and formation thanks to these measurements.

Sometimes, first-pass retention changes and it is very difficult to determine the reason for variation. In such cases, on-line instruments are essential to locate and correct problems that last only for a few minutes. The periodic laboratory analyses are not sufficient because they are too late and too infrequent for the fast paper machines of today.

Many paper producers have discovered the importance of particle charge measurements in their process. For example, an Italian laminated paper producer has correlated Zeta-potential measurements with pH variation, and its effect upon filler retention. In this particular application, a pH variation drastically affected the TiO_2 retention, and furthermore, each type of TiO_2 used by the mill has an optimum pH working area. There are many charge measurements, such as cationic demand, streaming currents, and particle charges, that are now available in on-line instrumentation. These provide critical information on chemical reactivity and retention variation. Nowadays, on-line instruments are essential tools to stay competitive within the papermaking business.

The main trend within the wet-end area is trying to understand how the wet-end is behaving. We can improve the wet-end efficiency with new chemicals or new mechanical designs. The paper machine manufacturers developed new formers and headbox designs to improve speed and formation, but chemistry still remains a crucial element of papermaking. Even with all these improvements, compromise between retention, formation, drainage and paper machine speed are the key elements for improving quality and production.

Measuring principle

There are many measuring methods to measure the fiber and filler contents in the headbox and in the white water. The accuracy of these measuring principles varies according to the furnish composition and the variety of fillers. Different furnish component properties increase the difficulty in measuring the suspensions, accurately.

Turbidity measurement was rejected many years ago for its sensitivity to size, shape, surface structure and refractive index.

The microwave measurement has been used lately to measure headbox consistency with more or less good results, depending upon the process location. The microwave sensitivity to air bubbles, temperature, conductivity and particle size and shape is well known. Since the white water contains a lot of micro-air bubbles, and the chemical dosage changes the pulp conductivity property, the microwave measuring principle is not suitable for wet-end measurements.

The scattering of light remains a good method to measure the filler and, combined with depolarization of light, gives good total consistency measurement. However, this method is very complicated and the instruments using this method are difficult to calibrate. It can take months before achieving a good calibration particularly if the process furnish changes. The refractive index of TiO_2 is very different from clay, calcium carbonate, or talc so the correlation between the laboratory and the instrument is difficult. This measuring method also requires mobile measuring parts that are prone to failure.

The Peak method[iv, v] is the most simple, and yet accurate method to measure the headbox and white water consistencies. This method measures the large (fibers) and fine particle (fillers) contents in the furnish simultaneously, yet independently. The principal assumption is that a suspension is characterized by two key components - large and small particles. The large particles form a relatively transparent network, within which the small particles move freely. A narrow light beam directed through the suspension is generally affected by both the large and small particles. There is a time frame, though, when the light beam is not influenced or "touched" by the large particles of the network and is only affected by the small particles. This is the "Peak" time. During the other time periods, the light beam is affected by both by the large and small particles. Figure 8 shows the measuring principle.

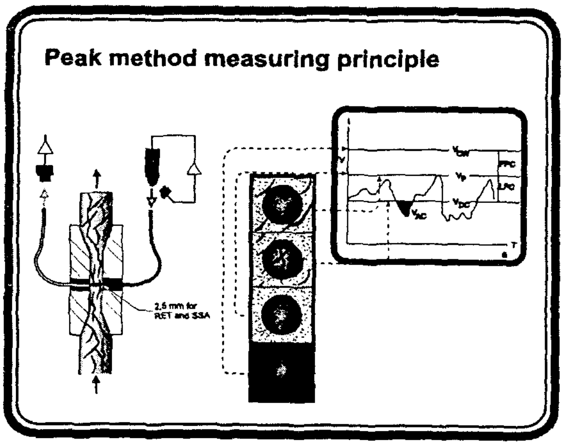

Figure 8 - Peak measuring principle

Automatic retention aid dosage

The automatic dosage of the retention agent is now a common concept for the newsprint and fine paper producers [2, 3]. Different control approaches were tried, and the control method that gives the most economic and process stability advantage is the white water system regulation. The concept is to control the white water consistency to a remote set point by changing the retention aid addition in the approach flow to the headbox. See Figure 9. This concept has been used for many years, and applied to many different papermaking processes. By controlling the white water consistency, the complete wet-end consistency is more stable since the white water is the main dilution source for the thick stock coming from the machine chest.

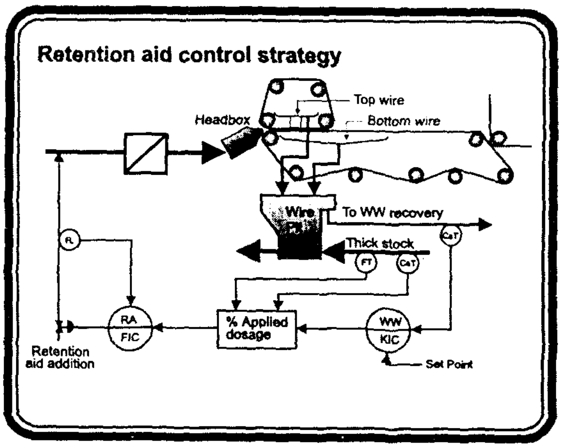

Figure 9 - White water consistency control

It is very important to consider the reaction time and the process dynamics of the paper machine. The overall wet-end process dynamics are very slow in comparison to the chemical reaction dynamics. The control must be very tender. It is important to change the addition of retention chemicals slowly, then observe the reaction in the white water consistency. In the two applications described below, the integration and the proportional time are slow due to the slow reaction of the process. It is very important not to upset the wet-end and interfere with the basis weight control by changing the retention aid flow too rapidly. The basis weight control loop has higher priority than the retention aid addition control loop. A batch measurement that provides new results every few minutes is sufficient to control the wet-end consistency.

Such control has many advantages that are not easy to quantify and elaborate upon. In this paper, we target some benefits in terms of economical saving. Some studies were made in two newsprint mills that are detailed, next. The first installation is Ave nor, Thunder Bay in Ontario Canada, and the second installation is Chapelle Darblay, Grand Couronne in France. Both the mills have closed the retention aid polymer addition loop on their paper machines.

Avenor, Thunder Bay

Avenor is one of the biggest newsprint producers in Canada with three machines in Thunder Bay. The study was performed on Paper Machine No. 3, a world-class machine producing 390 Tons/Day. A retention system is installed on each machine, realizing slightly different benefits from one machine to the other[3]. The PM #3 former is a Beloit horizontal Bel Baie III (see Figure 9). The furnish is composed of TMP, GWD, Kraft and recycle pulp. The retention aid chemical supplier is BetzDearborn and the retention aid is a cationic/cationic coagulant/flocculant program.

The retention analyzer enabled BetzDearborn to quickly optimize ideal polymer dosages and provided the production personnel with insight into the wet-end for optimizing the machine operation. The retention system used is the RET-5300 from BTG. Since the installation, the Avenor mill has realized retention aid cost savings of $500 000 per year by choosing the optimum polymers and reducing the chemical flow. In closed-loop control, the flocculant dosage changes from 40 g/Ton to 250 g/Ton according to the white water consistency. Figure 10 shows the white water consistency change for a flocculant variation.

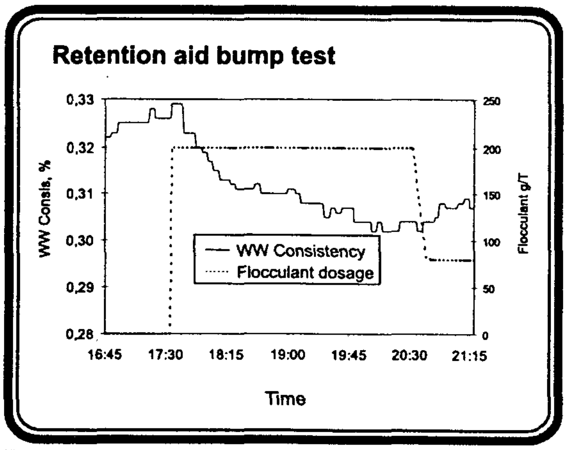

Figure 10 - White water consistency change

The regulation of the white water consistency reduced the standard deviation by 50% - from 380 mg/l before control to 190 mg/l after control. This has an obvious impact in the whole paper machine stability. Figure 11 shows the white water and headbox standard variations. Note that by regulating the white water consistency, the standard deviation in the headbox consistency also decreased by 22%, through all grade changes.

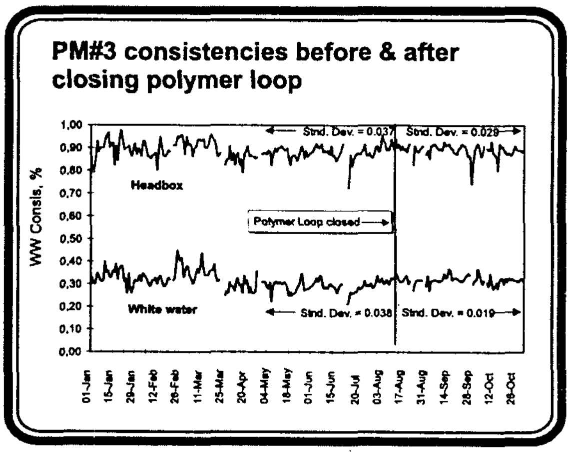

Figure 11 - PM #3 Consistencies

Figures 12 and 13 show the total consistency correlation between the laboratory and the instrument for this typical application.

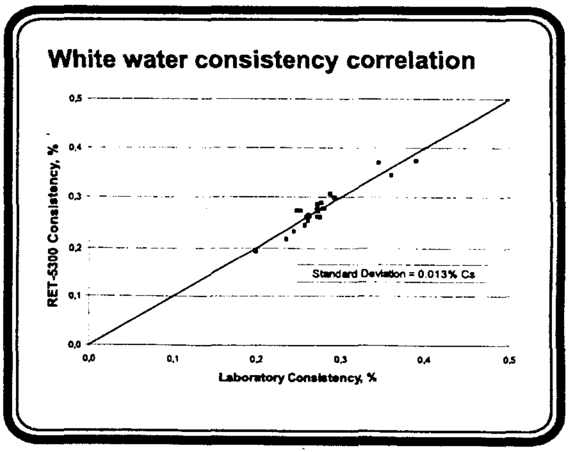

Figure 12 - White water correlation

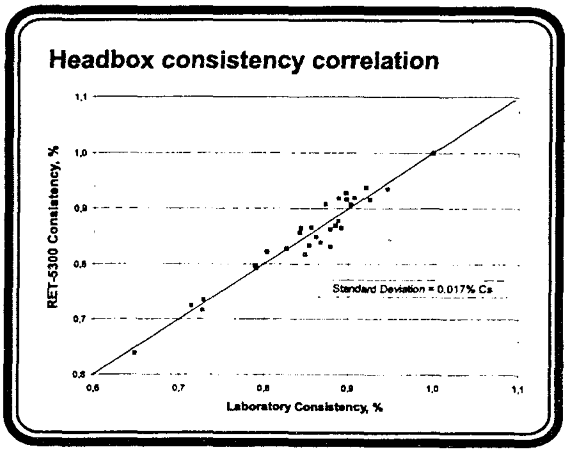

Figure 13 - Headbox correlation

After the white water regulation, the machine efficiency increased from 88% in 1995 to 92% at present. This has increased annual production by 5000 tons per year, or about $2,500,000 of revenue at today's prices. The control strategy implemented by BTG is able to go through all grade changes. Many robustness tests like furnish changes, refiner load changes, paper machine breaks and pH upsets were performed to evaluate the control efficiency. The automatic flocculant addition remains in closed-loop automatic control, at all times.

Ash retention has increased, producing higher gloss value. This allows the mill to off-load the PM #3 calender stack, yielding a 10-15 point increase in CD tear strength and permitting less usage of Kraft fiber, resulting in sizable saving to the mill. The mill reported reduction in the variation of CD and MD moisture profiles, MD basis weight, and caliper.

Other benefits include less deposits and better drainage. Since the retention aids are controlled according to the real demands of retention, the mill reports that the press deposition is much lower than it had been in the past. The mill also reports less steam usage due to better drainage in the forming section. A year ago, PM #3 ran with six dryer cans off; now it regularly runs with ten cans off in the drying operation. Couch trim consistency levels have been elevated to 16%.

Chapelle-Darblay, Grand Couronne

A retention monitoring system has been installed on PM #6 at Chapelle Darblay's Grand Couronne mill since 1992. This mill is a member of the UPM- Kymmene Group from Finland. The Grand Couronne mill has two paper machines, producing newsprint and directory newsprint. The furnish includes TMP and recycled pulp. Over the years, the retention analyzer has helped the papermakers to improve the paper machine efficiency by stabilizing the short circulation and retention aid dosage, and by allowing insight into the process when making mechanical adjustments.

Further advancement was realized last year when the mill, together with Yokogawa, closed the white water consistency control loop. Yokogawa performed intensive process control analyses on the short circulation dynamics to establish the best control approach for PM#3. The white water consistency regulation and blend chest stabilization were selected as the best way to stabilize the wet-end.

The mill has reported improved paper machine stability and production. They have reduced the white water standard deviation by 60% from 80 mg/l to 17mg/l[vi]. The mill has also increased the machine speed from an average of 1250 in 1994 to 1340 m/min today. This increase has resulted in a production increase of 7,2 % which is evaluated to 1470 TPY.

For the operators, the main benefit of the retention system is to provide information from the white water and headbox consistencies. This allows them to make smooth grade changes and mechanical adjustments of the paper machine.

Stabilization of the wet-end also resulted in a basis weight standard deviation reduction of 36%6. The mill's customers are now more satisfied by this particular improvement. The basis weigh standard deviation improvement results also in fiber saving.

Conclusion

Wet-end measurement and control continues to be a significant subject for on-going research and investigation. Due to the increase in wet-end complexity over the past 10 years, better control of the wet-end is essential for production of high quality paper at an economical cost. The paper machine manufacturers, the retention analyzer companies, and chemical suppliers are constantly seeking the most efficient, economical method to control the wet-end processes.

Studies and research show that there are many important factors affecting the wet-end chemistry. Some of these wet-end factors that we can now measure accurately, and which provide relevant information are:

1. Total consistency
2. Filler consistency
3. Dewatering and/or drainage on the wire(s)
4. Zeta-Potential (particle charge)
5. Cationic demand
6. Conductivity

Existing industrial equipment are now available to measure these factors accurately. We are now using this information to develop further understanding of wet-end chemistry and process control.

The advancement of wet-end chemistry is, and always will be, for and by the paper industry. They are the customers of the new technologies and they are the ones who finance the development. There is still a lot to do at the wet-end before achieving the total control of the paper machine. More process knowledge and control strategies will be developed and the industry will be able, in a few years, to control the chemical dosages even better. For now, most paper producers tend to over-dose most wet-end additives to achieve dry-end results. This leads to other issues such as productivity losses and environmental problems.

There are technical and economic problems to solve. It takes time to develop new measurement technology from the basic research stage, to a reliable industrial, commercial product.

High costs mean that instrument companies serving the pulp and paper industry can not carry out all of the development by themselves. Again cooperation is essential. Better control is vital to the pulp and paper industry to achieve improved production rates, to develop new products and reduce the negative effect on the environment. Effective on-line measurement is the only way to achieve these goals.

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