ACTIVE WET END MANAGEMENT

Authors
Timo Rantala, Heikki Kumpulainen,
and Tuomo Ojala

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Rantala, T*., Kumpulainen, H., Ojala, T.***

* Senior Application Specialists

**Solution Manager

Metso Automation Inc., P.O. Box 177, Fin-87101 Kajaani Finland

ABSTRACT

Wet end stability is directly connected to paper machine runnability and to the quality of the end product. Runnability and wet end stability greatly depend on the interactions between fibers, fines, ash and dissolved and colloidal material. By managing these interactions, effective and economical paper production is secured. A very cost effective way to achieve the required stability is based on reliable, continuous measurements for the key wet end variables: consistencies, ash content, and charge level.

First pass retention, calculated from headbox and white water consistencies, illustrates the operation of the wire section. These consistencies indicate the stability of the short circulation. Consistency variations in stock preparation and in the long and short circulations are directly connected to MD and CD variations of paper quality in the dry end. A state of art analyzer for measuring these consistencies has been developed and utilized for automatic control. The solution appreciably improves wet end stability, paper quality, and machine runnability.

Charge density in pulp and paper industry is typically analyzed based on cationic demand titration. It is a measure of the charge of dissolved and colloidal substances in the system. It is essential to know how and from where these components come to the wet end and what is their impact on the stability and quality of the process. A new multiline on-line analyzer of cationic demand meets all requirements set for reliable measurement and control of charge in the process. The measurement is based on conventional titration but the design and operation of the analyzer are new. Charge measured from the correct positions in the process enables the optimization of the system charge. When special chemicals are applied to coagulate the anionic matter, their dosage can be based on closed control loop using the on-line analyzer measurement.

Charge control together with retention control is an excellent combination. When charge management is actively taking care of coagulation, retention control will keep white water consistency stable by controlling the flocculant flow to the process. This wet end management concept is well accepted by the machine operators. Both controls are as crucial part of the PM automation as quality controls based on dry end scanners. This paper gives practical examples of those controls, the use of the controls and main results.

WET END MANAGEMENT

With wet end management we aim to stabilize total and ash consistencies and basic chemistry in paper machine short circulation. Stability is very important because it is directly connected to paper machine runnability and quality of produced paper. This is achieved with as much proactive process management as possible. Stability can be achieved by new process solutions, automation and advanced control systems based on key measurements, together with effective and optimized chemical usage /1/. The biggest benefits at the lowest cost can be achieved by focusing on improved wet end measurements and automatic controls based on them.

Key Measurements

Key measurements affecting wet end stability are shown in figure 1.

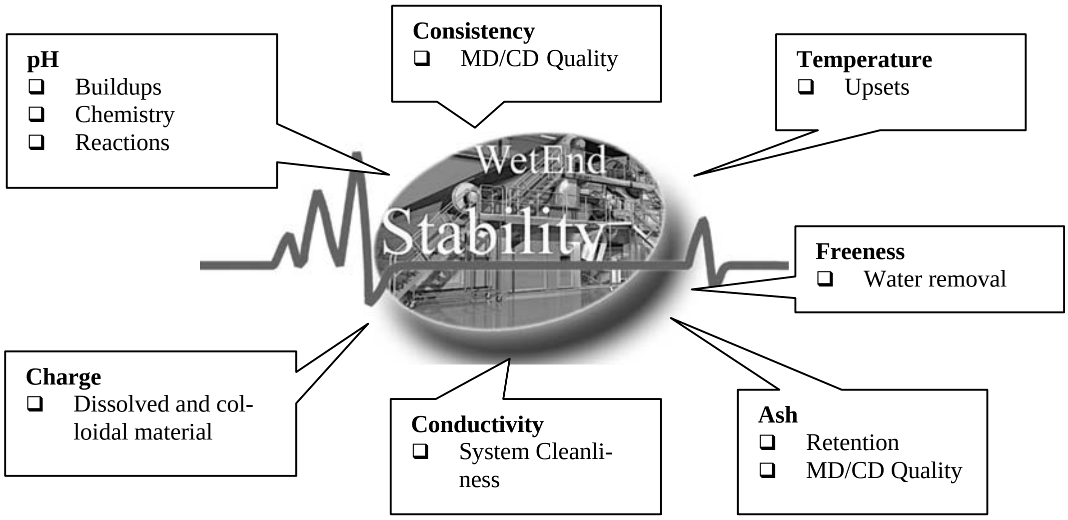

Figure 1. The main components affecting wet end stability.

Consistency variation in the short circulation has a direct impact on paper quality (MD and CD) and break tendency.

Ash variability in the wet end affects paper quality (strength, optical properties and porosity). Accordingly uneven distribution of ash (MD and CD) generates problems on paper machine and in coating and printing.

Drainage is an essential part of web forming and mechanisms behind it. So with a reliable and accurate measurement it's possible to close the refining and proportioning control loops and guarantee both the optimal web formation and maximum efficiency.

pH affects all chemical reactions at the wet end, especially charge level and efficiency of additives and chemicals. Sudden changes may cause paper machine runnability problems.

The ability to control the interactions of charged particles, such as fibers, fines, fillers and dissolved and colloidal material is the cornerstone of the wet end stability. In a way charge management takes care of papermaking key mechanisms such as coagulation, flocculation and sizing. It can also predict adhesion (release angle) problems e.g. in the central roll.

Conductivity indicates the amount of dissolved inorganic material that has a potential to form deposits. Conductivity is a measure of the system cleanliness.

Considerable temperature variations should be avoided due to their impact on reaction kinetics, deposition, formation, drainage and corrosion.

Retention Control

The majority of the poorly retained material is contained in the white water flow and returns from there to the headbox. The retention of these critical components is improved by adding retention chemicals. Reducing total consistency variations in white water will also stabilize consistencies in the entire wet end, and this in turn is reflected in a more stable retention.

The most effective way to stabilize wire retention is by controlling white water consistency with the retention aid flow. Retention is controlled indirectly, through the total consistency control of the white water; the principle is presented in figure 2. There is a cascaded control system where the inner loop is retention aid flow controller and the outer loop is consistency controller.

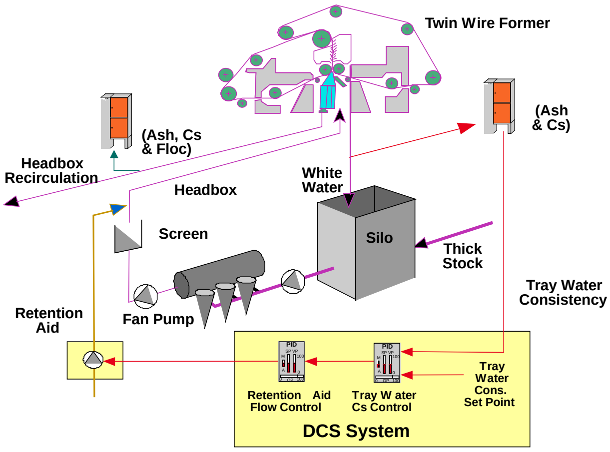

Figure 2. White water consistency control system; retention control.

This control solution optimizes the retention program by always using only the necessary amount of chemicals, and by eliminating underdosing and overdosing situations. It also pinpoints potential problems in the process: retention chemical make-up and dosing system, pulp refining, mixing and broke addition. This control is the last watchdog before the furnish turns into paper, and it can be used to fine-tune the papermaking process.

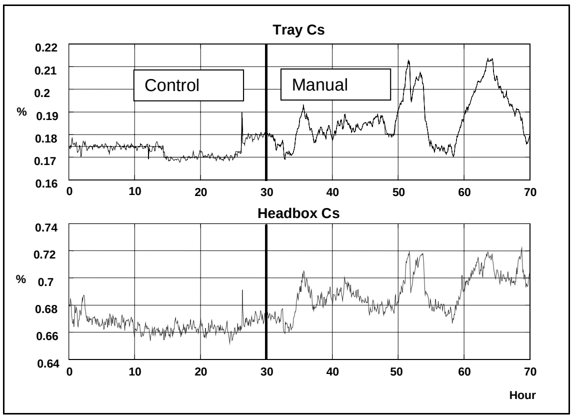

Figure 3. White water consistency on manual and automatic control and its effect to headbox consistency.

Figure 3 and 4 show results from a PM where white water consistency control was put on automatic control. As can be seen the difference between automatic and manual run is clear. The automatic control is able to keep the white water consistency very stable and the effect of this can be also seen as a much more stable headbox consistency and total and ash retention. So by controlling white water consistency we are able to stabilize the whole short circulation.

Figure 4. The effect of white water consistency control and to total and ash retention.

White water consistency control maintains a stable white water total consistency by automatically changing the retention aid flow. But why it needs to change retention aid flow? One reason can be seen in figure 5, where cationic demand and retention chemical flow correlate closely with each other. This is a good example of how changes in charge influence the dosage of other chemicals, such as retention aid: (its action, and hence the required amount), changes when cationic demand changes. If there had been a constant retention aid flow in l/min, then the effective retention aid flow would have changed and caused fluctuations in white water consistency.

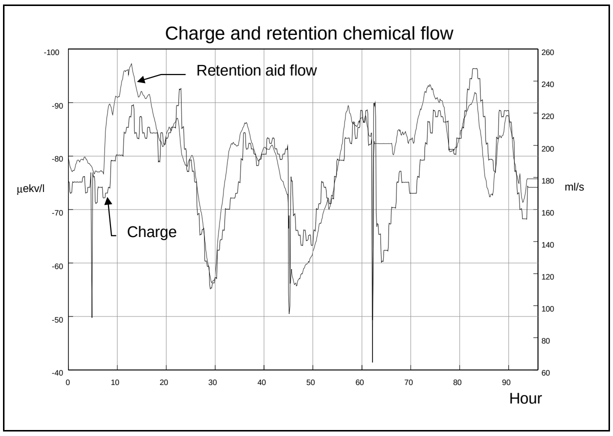

Figure 5. The correlation of retention aid flow and on-line cationic demand measurement.

CHARGE CONTROL

Motivation and target

The level and variation of charge have a considerable effect on process status and operation. These can be considered with regard to three alternative situations: low charge, high charge, and varying charge. As the charge level is very much dependent on pH and is, moreover, closely linked with process status, it is very difficult to give any absolute values for what is "low" or "high" charge.

Charge and its variation may cause the following problems:

1. Low charge (close to zero)
    - paper web adheres to rolls, especially in PM start-ups
    - felt clogging, reduction in dewatering

- retention control is very difficult: e.g. with surface-sized grades, with cationic starch added, retention control cannot be implemented at all because the control might further increase cationic charge in the process

2. High charge
   - poor retention, increased retention chemical demand, poor base formation
   - increased PM contamination
   - sizing effect is lost, as the effect of size is more or less directly proportional to the retention of fines

3. Charge variations
   - variation in retention chemical efficiency and retention; poor runnability, variations in paper quality
   - strength variation, the effect of starch fluctuates, runnability deteriorates
   - overdosage of starch must be applied, microbial activity increases and antimicrobial agents must be added to the process

In short, the consequences can be summed up as problems in retention and water removal, and their effects on the process economy are extremely unwelcome:

- unnecessarily high chemical consumption
- more frequent cleaning is needed
- more frequent web breaks
- poor quality of produced paper (e.g. two-sidedness)
- increased wear of wire screens, more frequent wire and felt replacements
- increased broke production
- load on fiber save-all increases
- load on the vacuum system increases

An ideal situation is a weakly anionic system with a stable charge. Charge reversal – i.e. change from anionic to cationic state and back – should be avoided.

The main phases in the construction of charge control are listed below:

- Installation of kajaaniWEM
- Process follow-up
- Step tests with control chemicals
- Design and programming the control system
- Control on everyday use

The charge measurement is installed in the short circulation, and charge is measured from the white water. Even though the main sources of charge fluctuations may be found already at the very beginning of the process, it is vitally important to know and manage the charge level in the short circulation.

Process follow-up is needed to pinpoint the main sources of disturbances. This information is used when designing the control system.

Extremely valuable information is obtained from step tests with the chemical that will actually be used for control. They help to ensure that the chemical dosaging equipment operates with sufficient speed and accuracy, and also that the chemical has a clear enough effect on charge. Fig. 6 shows an example of a step test with fixing agent.

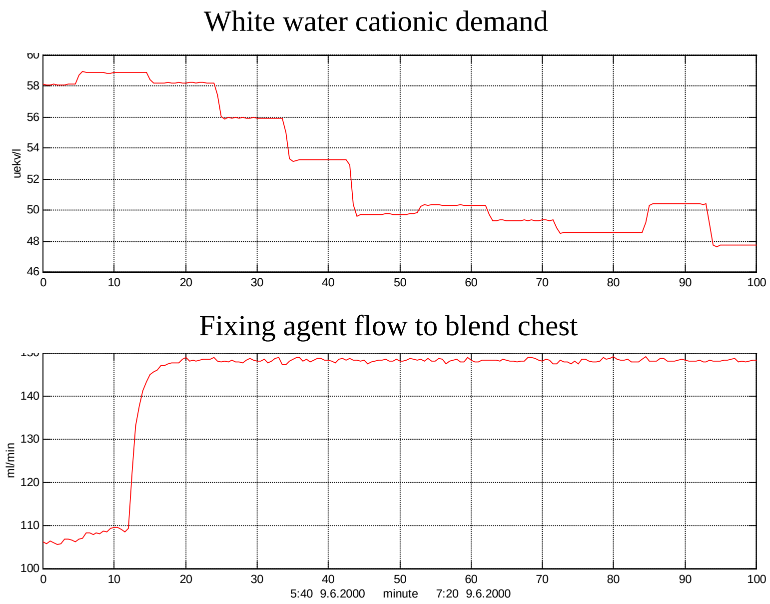

Figure 6. White water cationic demand during a chemical step test.

As the graph shows, the response is very clear. The process settles down to the new charge level in about 30 minutes. In this case a new measurement result comes every 8 minutes, which explains the stepwise signal.

Control solution

The charge control system in typical case consists of “main” and “assistant” controllers and the fixing agent is injected in the most suitable process points, selected according to the results of disturbance source charting. The main control loop always controls the cationic demand in the white water based on kajaaniWEM measurement. The assistant controllers help the main control loop by dampening the cationic demand disturbances coming to short circulation from for example coated broke line, TMP line etc.

The actual control system must, of course, be different for different kinds of paper machines, depending on the chemicals available for control and the main sources of cationic demand disturbances.

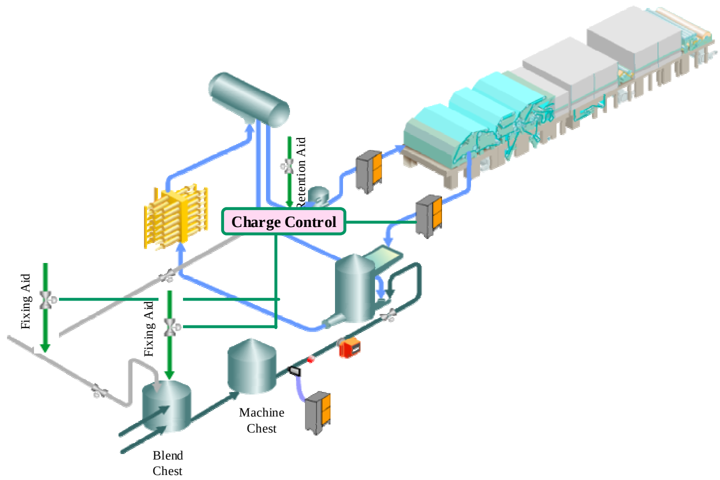

Figure 7. Charge control solution

Control run

Figure 8 shows an example of a control run during disturbances. The graph shows that the control is able to keep the charge very close to the setpoint even though changes occur in the coated broke flow.

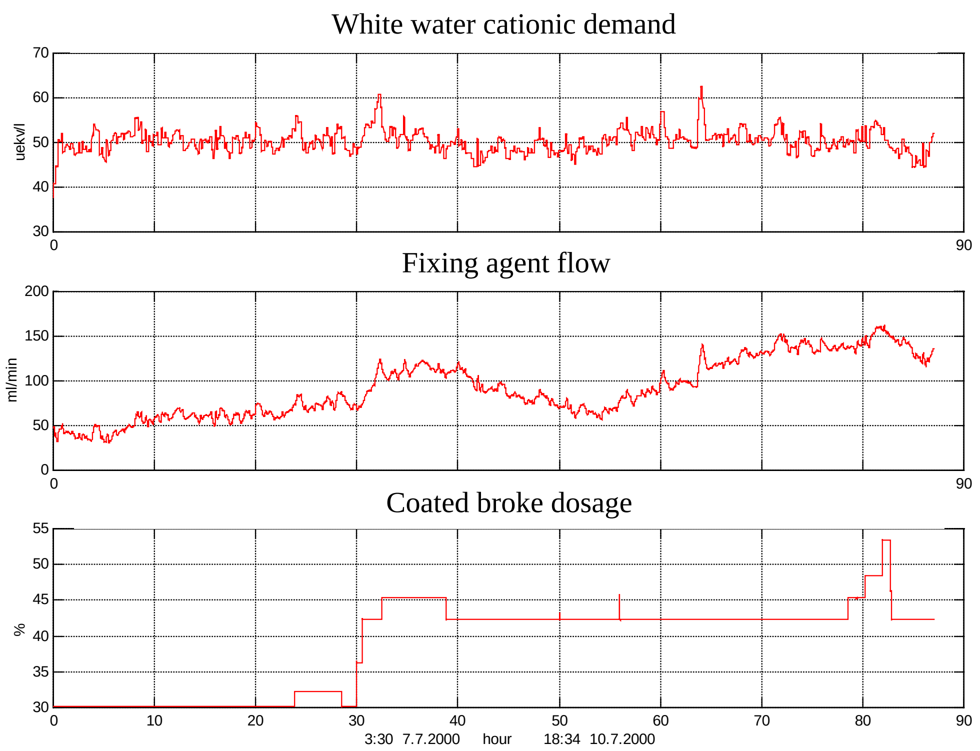

Figure 8. White water cationic demand on automatic control

It can thus be stated with confidence that charge control is possible. Automatic Charge Control based on the kajaaniWEM very effectively stabilizes charge and totally prevents charge reversal. Experience so far has shown that the control is robust against minor process changes, and does not require re-tuning. Moreover, it has many benefits for the process itself.

Advanced Control structure

One important source of charge variations may be coated broke, its quality and quantity. As seen in Fig. 9, there is a clear correlation between the charge trends of white water and coated broke.

When the white water charge control is off, about 15–20% of the charge variations in coated broke are reflected in the white water charge level. At first sight it may appear that such attenuation of charge variations in the coated broke is considerable. However, changes in broke charge may be both large and very rapid. As an example, a change of 400 –> 200 µekv/l in the charge of coated broke causes an approximately 40 µekv/l change in the charge of white water. A control system to maintain a stable coated broke charge would thus significantly improve the total charge control.

This gave the idea to further develop the control by stabilizing coated broke charge separately.

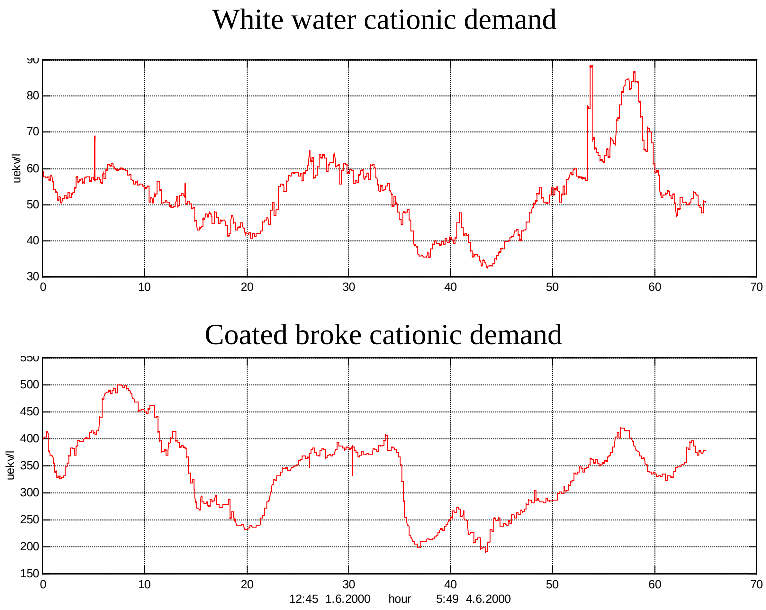

Figure 9. Correlation of white water and coated broke cationic demand

In the more advanced control system, charge is controlled by two separate control loops that take care of the coated broke and short circulation individually. Charge control of the short circulation is based on charge measurement from the wire pit, and the controller controls the fixing agent flow. The control setpoint is given by the operator. The charge level of coated broke is measured, and the controller controls the fixing agent flow to the broke. This control setpoint is also given by the operator.

As Fig. 10 shows, the difference in the amplitude of broke charge variations occurring with and without control is considerable.

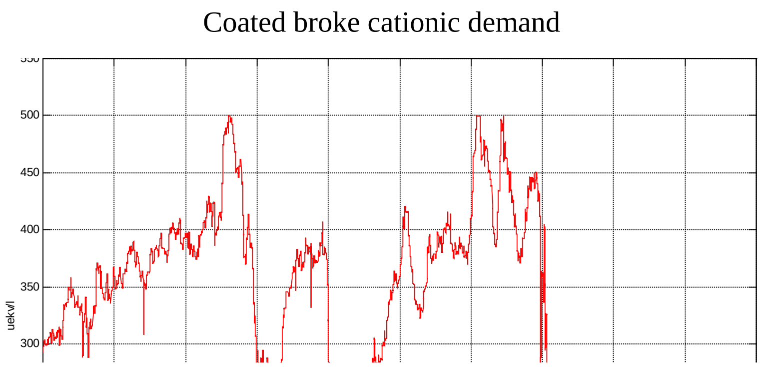

Figure 10. Coated broke charge without and with control. The control was switched on around the 150 hour mark.

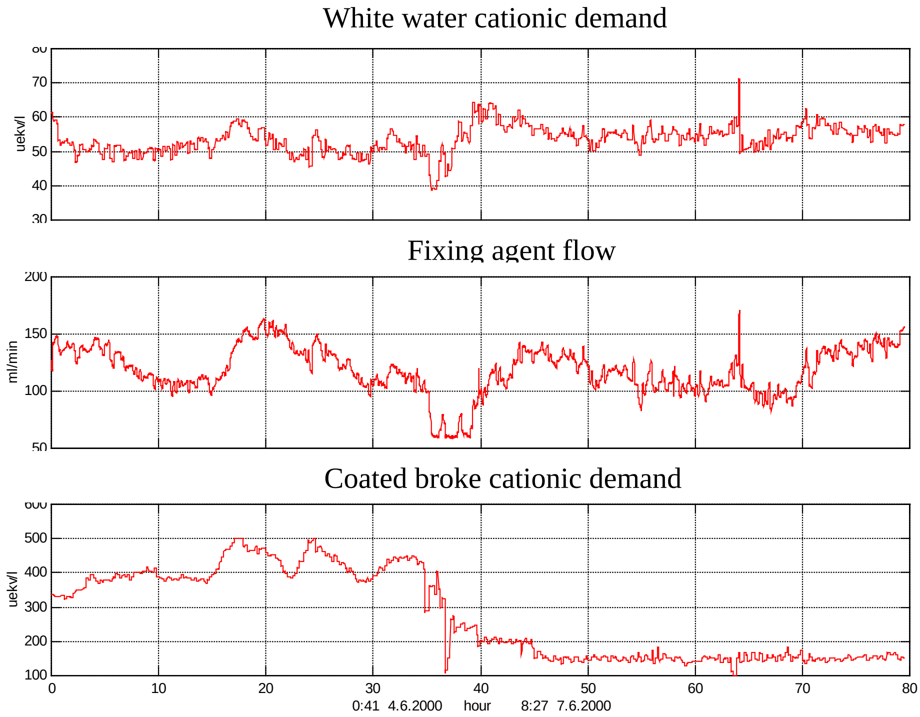

Figure 11. Improved white water cationic demand control when also coated broke is on automatic cationic demand control.

Fig. 11 shows how the stabilization of coated broke charge has influenced the charge of white water. The control was switched on around the 40 hour mark. We can also see that the white water charge is more stable when the broke charge is under control.

Both controls – white water consistency and cationic demand – are effective and useful as independent solutions.

However, cationic demand control by itself does not guarantee a stable white water consistency; to achieve stable retention, white water consistency control is needed. Cationic demand control helps the retention control by preparing optimum chemical conditions for the retention chemical program. So we are dealing with optimization of coagulation and flocculation. The main idea in measuring the cationic demand is to find the average pulp charge density which is the most convenient for the used retention system – may it be mosaic, bridging or microparticle mechanism, fig. 12. Case A shows, where too much fixative is dosed and actual retention molecules sense too positive surface to adsorb properly on particle surface. Case B describes the optimum fixative dose for that certain retention aid and case C shows that the retention mechanism can even change (from bridging to mosaic) when the surface of the particle is left too anionic and there is enough delay time to the wire section.

The controls support each other, and the best results are achieved when using a combination of the two. With these controls, big and sudden variations in charge and consistency can be avoided. This means improved runnability.

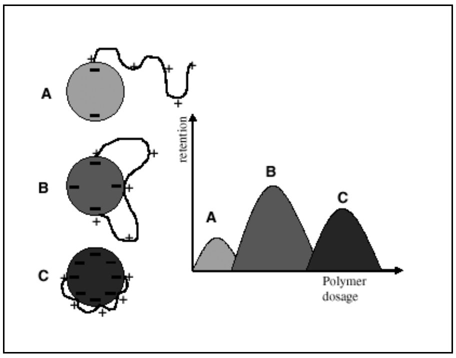

Figure 12**.** Coagulation and flocculation have big impact to each other.

BENEFITS FOR THE PAPERMAKER

Process information

On-line charge measurement provides valuable information about the wet end chemistry of the paper machine. It opens new windows into the process. By looking through these windows, starts a new learning about the process behaviour. This learning supports good decision making during normal operations of PM. The same is happening especially during any trials in the process. Time needed for on-site testing is reduced. Also the risk of loosing production is minimized. On-line charge measurement together with other key measurements give indispensable information to follow the status of the wet end and provide a firm base for management and stabilization. Visible information flow gives new thoughts and ideas. This provides understanding behind the actions and the frame work to optimize the process.

Stability

Stability of the process is valuable as such, and it opens different ways to process optimization. In the 15 years we have been implementing closed-loop controls to PM wet ends, this recognition has been realized. Typically it´s not understood how dynamic the process is. When the only information flow available has been based on laboratory testing, it does not let us know about the process dynamics. So after seeing the first periods of continuous signals, thinking will start. This leads to the learning process and improvements, which were described earlier in this paper.

As an example we will give one study. This finepaper machine has had white water consistency (WW Cs) on closed loop control for several years. WW Cs was measured on-line with our retention analyzer. This so called retention control adjusted automatically retention aid dosage to maintain stable WW Cs. This solution as such was already very positive testimony about the usefulness of wet end solutions. At the PM it was so important to have stable WW Cs, because it was used as a dilution water for dilution type headbox.

So in this rather positive situation the mill installed an on-line charge analyzer. The question was, can we still see any room for further improvements based on new wet end analyzer? After implementation of the new measurement system, charge had been put on closed loop control and it greatly reduced the variability of cationic demand in the white water. Reducing this variability allowed all chemicals, especially the retention chemicals, to perform in a consistent manner. This helped optimizing the addition of chemicals and made the white water consistency control perform even better, thus making the wet end more stable, see the average reduction of critical measurements after analysis on this PM, figure 13. This is important because stability in the wet end is directly connected to paper machine runnability and paper quality.

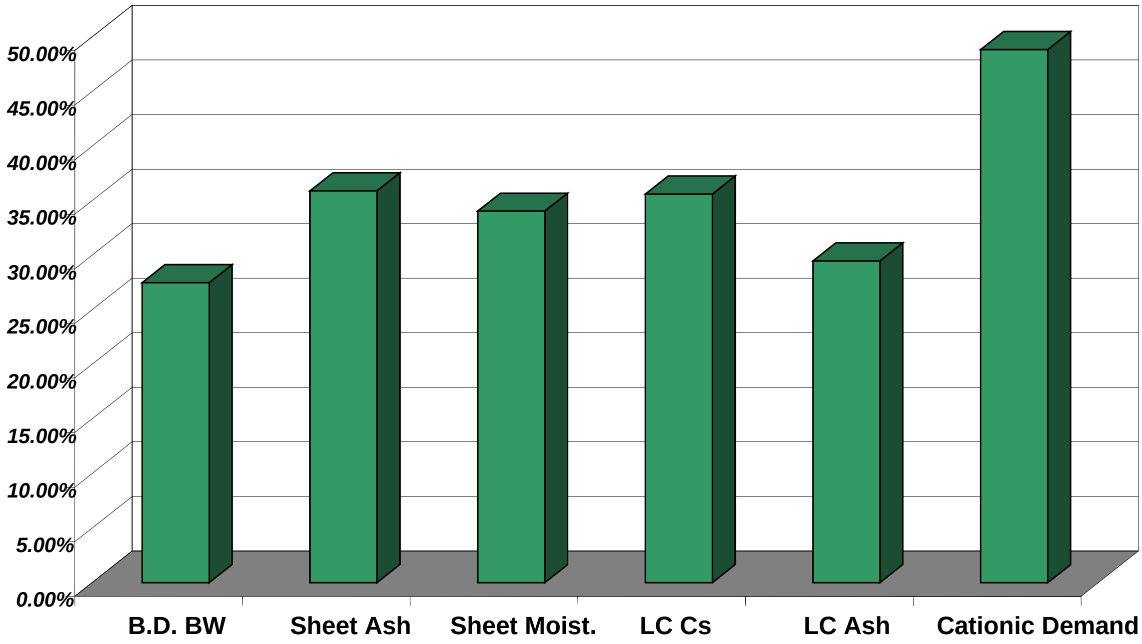

Figure 13. Average reductions of critical measurements by comparing standard deviations with and without charge control.

Runnability

Due to active control of process charge sudden and large variations could be avoided. Variations in charge and consistency reflect in the variability of paper ash, moisture and strength properties, which is indicated as a sensitivity to sheet breaks. Sometimes due to certain reasons automatic closed loop control is not possible. In those cases we have seen, how even active manual adjustments can improve the status of the process. One SC paper machine had severe problems during grade changes because of overcationization. After seeing the system charge and its dynamics, operators started manual control actions of fixative dosage on the basis of the measurement results. Grade changes were speeded up and the number of sheet breaks was decreased. It contributed to improved runnability of the PM.

Naturally the results regarding the runnability will be better with closed loop control than with manual control. And as an additional advantage in both type of solutions, it´s possible to optimize running conditions, when key parameters are under control. It means new dimensions regarding bottlenecks of the PM. For example for many fine paper machines the optimum level for wet end charge might be very close to zero. But running close to zero there is a constant fear of overcationisation and loss of runnability. With on-line charge measurement and closed loop control the charge can be kept at optimum level, i.e. –20…-30 μeqv/l and overcationising totally prevented thus securing good runnability.

Economical and effective use of chemicals

The actual retention chemicals affect process charge through their intrinsic slight charge and by changing the dewatering characteristics of the paper web. The optimum situation for retention chemicals is to maintain the charge, pH and conductivity as stable as possible. Retention chemicals should not be applied for charge control.

One newsprint PM observed nice statistics after closing the loop of charge control compared to the earlier situation, when they had only retention control in use. They reported 50 % reduction in use of flocculant (i.e. chemical, which is used for retention). So there were less actions needed in retention control. Control means that only as much chemical is used as needed; not overdosing, not underdosing. At the same newsprint machine, it meant 10 % less overdosing of coagulant, which brought 200 USD/day savings.

Integration of chemical dosing

Stable charge gives the possibility of optimized use of chemicals. We have already described the effects to use of retention aid(s). When the charge is too high, large dosages of retention chemicals are needed and this may e.g. in turn deteriorate formation. Optimization is possible, when actively using wet end measurements and controls. Figure 14. shows us an simple example of alum testing on a coated finepaper machine. The graphs show that the alum dosage is too high; the retention system operates clearly better when the alum dosage is reduced.

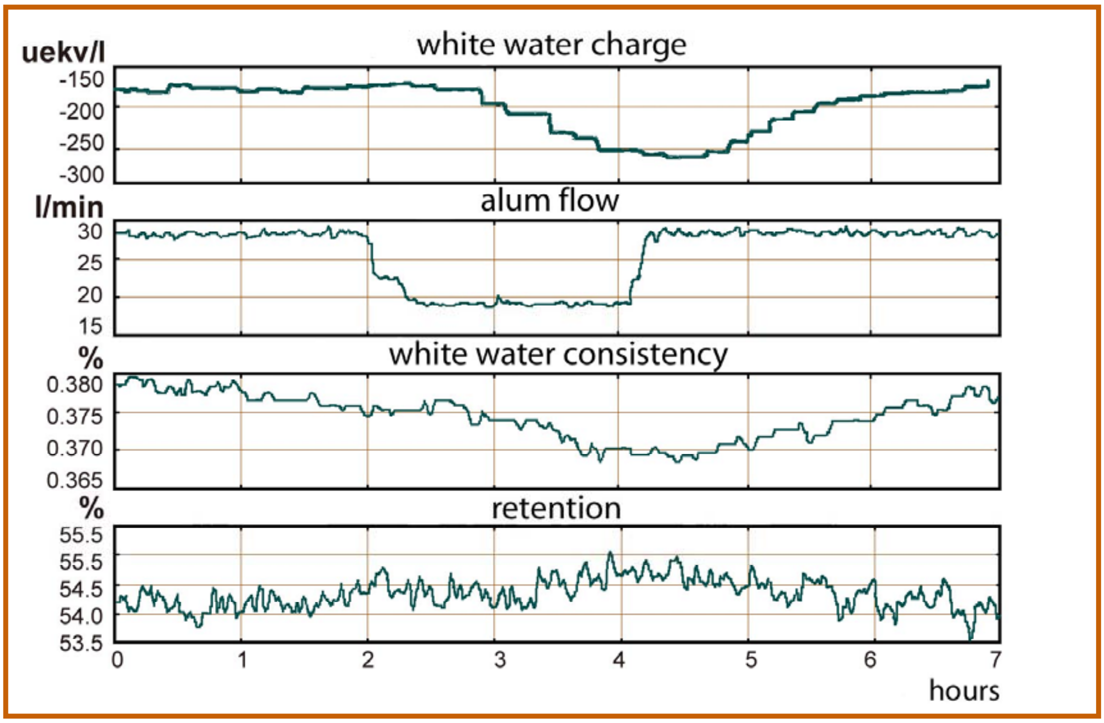

Figure 14. The effect of alum on charge, white water consistency, and retention measured during step test.

Variation in the amount of anionic trash disturbs the effect of starch added to improve pulp strength. Too much starch is often applied in order to ensure sufficient strength and runnability. However, large dosages of starch are very detrimental to runnability over longer periods, because starch provides excellent nutrition for microbes. A stable charge level in the process means that the starch dosage can also be optimized, and so the desired strength can be achieved without harmful overdosages. Microbial growth remains moderate, and this will mean considerable chemical savings on a yearly basis.

Continuous measurement gives immediate information and this makes process tests quicker and easier. It facilitates the testing of chemicals, and the correct dosages and addition points are found with less trouble.

Life of the papermaker

The automatic control operates 24 hours per day, each running day per year. So it frees hands to other important actions in papermaking. Process studies, tunings of the machine, and systematic analysis of the process, just mentioning several important duties, which are never done enough. When machine tenders can rely that certain standard operations are under control, their concentration to the machine activities is improved.

On-line charge also frees laboratory personnel for more dedicated studies than routine follow-up of the process. More over, the analyzer always performs the titration in the same way, at process temperature and pH, immediately after sampling, with the measurement cell always equally well cleaned. Thus it provides better repeatability than any laboratory measurement.

CONCLUSIONS

Active wet end management is very important. The aim of wet end management is to ensure stable total and ash consistencies and stable basic chemistry in the paper machine short circulation. Stability is very important because it is directly connected to paper machine runnability and the quality of produced paper. Charge is one of the key variables affecting wet end stability.

Automatic controls are effective way to improve wet end stability. When constructing automatic controls, continuous real-time measurements are an absolute must. Moreover the measurement instruments must have low fouling tendency, low maintenance need, and good resistance to a sometimes hostile process environment.

Retention control, based on white water consistency control, is highly effective way to stabilize consistencies of whole short circulation. Charge control enables optimum, stable conditions for other chemicals. For example it makes the task of the white water consistency control easier, and when used in combination, these two controls provide a powerful tool that stabilizes the short circulation at an optimum white water consistency and minimum retention chemical dosing levels. The result is remarkably improved PM runnability, efficiency, and product quality.

REFERENCES

(1) Scott,W.E., Principles of Wet End Chemistry, Tappi Press, Atlanta, GA (1996).

(2) Measuring Charge in Process Environment, kajaaniCATi Application report A 4506.0-en, Metso Automation, 2002.

(3) Automatic Charge Control, kajaaniCATi Application report, A 4503.0-EN, Metso Automation, 2002.

(4) Charge Management with kajaaniCATi, kajaaniCATi Application report, A 4504.0-EN, Metso Automation, 2001.

(5) kajaaniCATi, Technical Bulletin B4507.0-EN, Metso Automation, 2002.