Introduction

The on-line measurement of whitewater solids and thinstock consistency using optical sensors for the calculation of first-pass retention has been in use since the mid-1980's. Typically these sensors have been used on machines producing high volume or speciality paper grades. One limitation for the uptake of this technology my more mills, has been capital cost although the proven returns have been high. Suppliers of these sensors have put an emphasis on the measurement of the retention fraction such as fillers (ash) and fines as well as total solids. This created a technically complex sensor design that needed a high level of skill for their use within a mill.

In practise a majority of the whitewater solids fraction is mineral (fillers) since the retention of filler (ash) is the most sensitive fraction in the wet end. The control of retention is typically achieved by regulating polymer addition at the wet end and the retention of ash and fines is a function of this mechanism. The reel ash content is often measured on-line with control implemented through the filler flow rate added to the thinstock loop. Variability in the wet end will influence the balance of fillers retained in the sheet and ultimately reel quality or machine operation. Some mills have implemented automatic control of polymer dosing to maintain total whitewater solids to target and so stabilise wet end retention conditions. A stable wet end will avoid variations in retention which can effect; productivity, quality, raw material costs and effluent losses.

Invista, a supplier that specialises in mill process measurements and environmental monitoring has developed an accurate total solids and filler sensor for the measurement of first-pass retention. This sensor is based upon polarised nIR optics to provide a continuous measurement of whitewater solids and thinstock %Cs where levels of filler can be high and changeable. Using this measurement technique; equipment capital cost has been cut while the comparable operational benefits are still realised on-machine when compared to other high cost systems. This measurement has proved to be easy to calibrate and simple to maintain.

Wet end retention measurement

Retention is a measure of the material that has flowed from the former and is retained by the wire fabric to create the paper sheet. As thinstock flows from the former, solids pass through the wire fabric to be collected in the whitewater system. The measurement of thinstock %Cs. and total whitewater solids is the simplest and most immediate indication of wet end conditions.

Retention Calculation

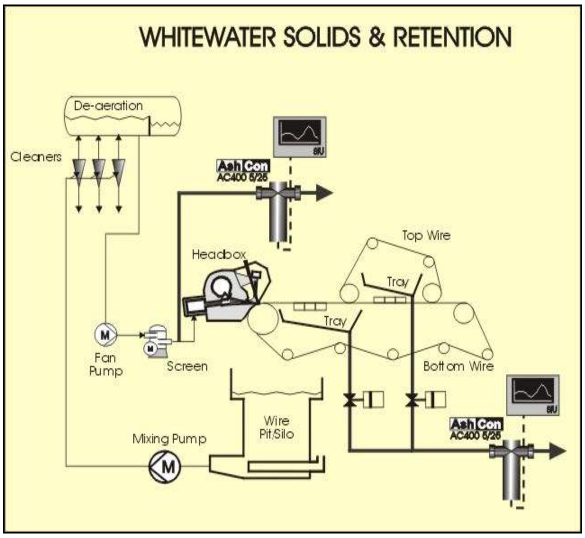
$$\frac{\text{Thinstock \%Cs} - \text{Whitewater solids}}{\text{Thinstock \%Cs.}} \times 100 = \text{Total Retn \%}$$

Total retention is a measure of; fibre retention, filler retention and fines retention. The retention level should be set to achieve the best economic or quality level for filler/fines retention. The retention of chemical additives in the wet end tends to follow filler/fines retention The performance of these additives relies upon the 1st pass retention which is greater at higher total retention levels.

The ideal level of retention will differ with wet end configuration and by grade. Very high retention levels may seem ideal but this can have a detrimental effect on sheet properties as well as high chemical costs. Similarly, low retention levels will lead to; variable product quality, poor machine operation, and high operating costs. Retention is more difficult to achieve on; fast lightweight grades, high shear forming zones and qualities with higher filler or broke content. Recycled fibre quality tends to be variable which will make retention less stable. A machine with a wide grade range and short order runs will have less stable retention conditions.

Technical and production personnel continuously work to maintain a suitable retention level across the grade range. New product trials and raw material tests are fundamental to the continuous improvement of products and the operation of a machine or sub-process.

The forming zone of a wet end is the area where retention can be effected by material additives, machine set-up and process control. Once the sheet is formed, mechanical dewatering by dynamic suction and vacuum influences the removal of water. In the forming zone chemical additives have a major influence on retention once machine parameters have been set. The whitewater trays provide an immediate indication of dynamic retention conditions. At this part of the process the large volume of water removal and high mixing rate, will cause mechanical air entrainment although this is expelled in the whitewater collection channels and in the silo before return to the short circulation system. A representative sample of the wire-part forming section should not have contamination from flowbox edge-bleeds or other reflux streams. Typically, this will be the first collection tray under the wire or whitewater channels located at the backside of the machine.



Care needs to be taken to minimise entrained air since bubbles will refract light and can be seen as noise in the measurement. If calibration samples are taken which contain air, the measurement accuracy will be poor. Excessive air content in the sample lines will disturb the measurement. To reduce this effect, air is removed using in-line T-vents and the sample is pressurised using a sample pump prior to the sensor. The pump acts as a mixer to disperse flocs and compresses air bubbles. The sensor design allows the remaining air bubbles to pass the optics without effecting the measurement.

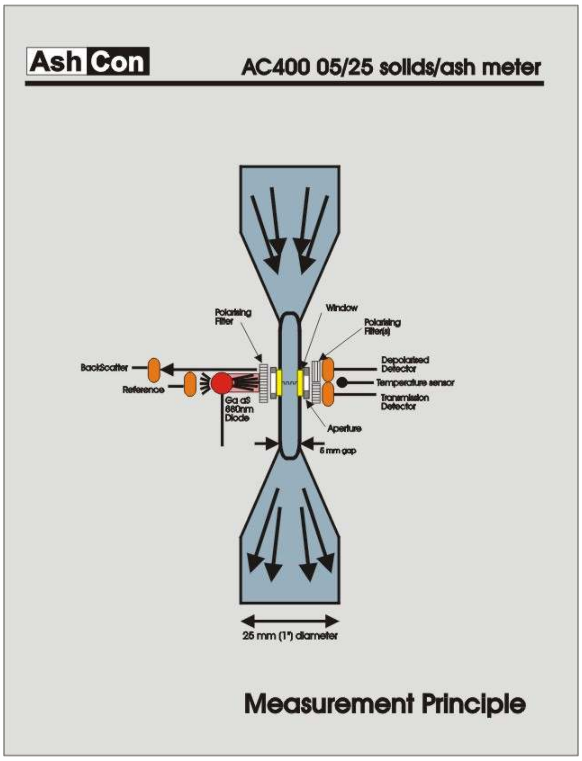
Measurement techniques

Typically a wet end measurement sample is made up from fibres, fines and filler solids. Fillers cause a greater light absorption than fines or fibres (light scattering) and this will effect a standard transmission measurement that does not compensate for the changing proportion of filler particles present in the sample.

All sensors use a transmission measurement of near Infra red light through the process sample between 800 – 900 nm , outside of the visible spectrum (400-700nm). Most use a combination of transmission, reflectance or depolarisation measurement channels although some combine dual IR frequencies, additional light source extinction or the relative signal absorption of small to large particles.

This total consistency measurement sensor uses; forward transmission, depolarisation and backscattered light channels to determine the ratio of filler to fibres and then uses these to give a total solids and filler measurement.

Each sensor is individually calibrated for a particular pulp furnish type or filler(s) mix. Features unique to this sensor involve; temperature compensation, signal sample techniques and the use of logarithmic correction (Beer-Lambert Law) of each measurement channel within the algorithm to calculate the solids %Consistency (Total and filler).

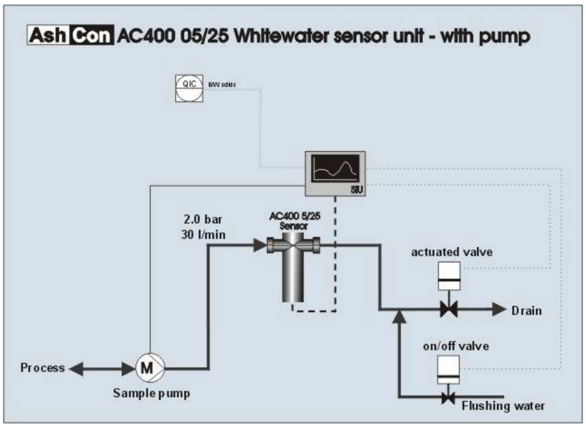


This technique requires only a few calibration points to build a calibration curve rather than a large number of point to point calibration values. Up to four grade specific calibrations can be used for each measurement application.

Process sample verification

At timed intervals (typically each hour) the sensor is back flushed with water to keep the sensor clean and standardise the measurement to an initial value using clean water.

This flush cycle cleans the sensor and sample lines back to the process. It verifies that the sensor is operating correctly and alarms if there is a deposit on the sensor optics. This sensor arrangement ensures that sampling conditions are uniform to minimise process effects (entrained air, consistent sample flow and contamination)



It is important to prevent the build-up of fibrous deposits in pipes and particularly during machine shut washdowns.

Application considerations

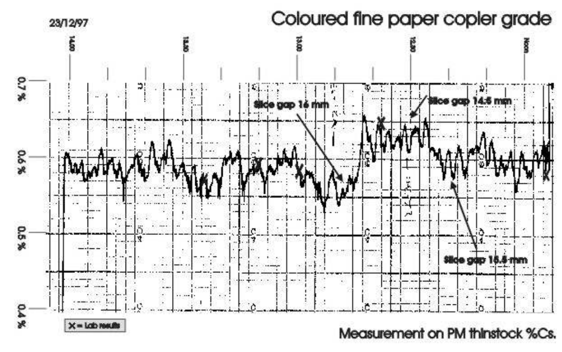
The first step to improve wet end operation is to have a continuous measurement of the total and filler retention.

For chemical or raw material trial/development work spot samples can give a different view to a continuous trend. An immediate change in wet end conditions can be detected in the display of retention. This may be the result of machine settings rather than additive changes. Addition rates can be optimised (operational results versus material costs) by grade using this information.

For a machine producing a wide grade range losses can be reduced on different grades. For example a machine producing high value fine paper writing grades, filler losses to effluent were cut by substituting up to 50% marble into a PCC filled grade without significant loss of paper quality. Whitewater solids were reduced by 20-30% as retention improved. More importantly the wet end stability improved at this higher 1st pass retention level which avoided losses caused by poor retention. At lower retention levels filler/ash retention is poor and this effects other additives such as internal sizing chemicals. Poor retention will lead to excess use of chemical additives, excess size addition will lead to foam, excess defoamer can effect sizing, excess polymer addition can lead to flocs and breaks.

A continuous trend of retention is a tool for papermakers to make informed changes in machine settings or addition rates to achieve the desired wet end conditions or optimum stability.

A continuous measurement of thinstock consistency will provide an immediate feedback of wet end settings for operators at start-up or grade change. The measurement can also highlight process instability that effects the final consistency on the wire.

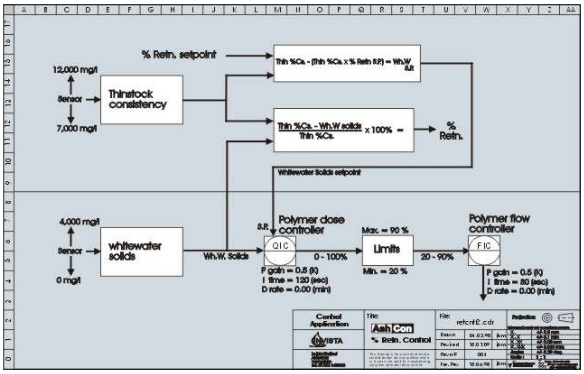


In the above example, slice gap adjustment changes the thinstock consistency and a cyclical hydraulic disturbance is corrected by the total head controller. Ultimately this will affect the ability of the quality control system to maintain the basis weight close to target. Thinstock %Cs. can be maximised within formation constraints to aid wet end retention.

Grade changes can be simple or complex. A simple change may only require a speed or a weight change. In these instances it is likely that whitewater solids (retention) can be automatically controlled although some wet end configurations can be drainage sensitive. More complex grade changes involve filler content (type or quantity) furnish quality, additives, colour as well as other reel quality parameters. As the basis weight increases the fibre mat improves filtration and naturally increases retention. Under these conditions,
retention chemical addition could be reduced to realise cost savings, although a balance has to be made between drainage rate and whitewater solids (retention). The converse applies for lighter weights or at increased speed where retention will typically fall and demand more retention aid. Insufficient chemical addition will result initially in poor retention until the addition rate is corrected. This delay can lead to wet end instability and losses.

Closed-loop control

A control scheme can allow immediate and continuous controller actions to regulate polymer flow. A simple two term (PI) controller, correctly tuned to allow for the time delay and gain (response) in a wet end will perform effective closed-loop control of the whitewater solids. The target solids level will maintain the retention level at the desired level if the thinstock consistency is steady. A primary control variable (typically polymer) is used to effect the retention of solids in the whitewater. As solids increase the addition of more polymer will improve retention and reduce the solids present in the whitewater and visa versa. It is important that clamps are placed on the controller output to limit the polymer addition rate which will avoid the addition of either too little or too much retention chemical, These limits should be based upon operational experience and could be grade specific. The output from this controller will either control the flow rate of a chemical or speed of a metering pump to achieve the desired addition rate.



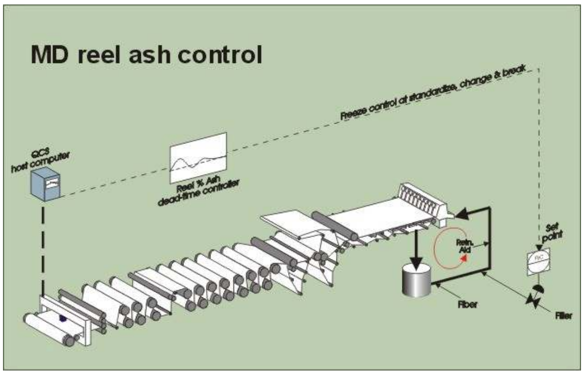
Existing installations using a continuous measurement signal are typically making a significant control action within 2 to 4 minutes and will maintain whitewater solids to within 2.5% of target.

Variable furnish quality. Changing filler content and broke levels each have a significant effect on retention. Closed loop polymer control provides an immediate action to correct these changing conditions and help stabilise wet end operation.

Ash measurement

Ash/filler retention is more difficult to maintain than total retention. As total retention decreases the ash content of the whitewater fraction increases. A small decrease in total retention can represent a much greater loss of filler retention. In order to maintain filler retention the total retention needs to be kept at a suitably high level. Filler retention is a function of total retention. The primary control variable for whitewater solids control (retention) is normally polymer dose control once machine wet end settings have been fixed. This will allow total retention to be altered and indirectly the filler retention.

The final paper ash content is measured and controlled by the reel quality control system. A dead time controller is used to control the filler addition to the wet end using a cascade controller for filler flow rate. Under stable retention conditions the filler will be retained in the sheet to achieve the required reel ash content. An unstable wet end will cause variations in filler retention and this can effect paper quality. Changing the filler content will also affect the mechanical properties of the sheet as well as machine operation (drying, draws, weight etc.).

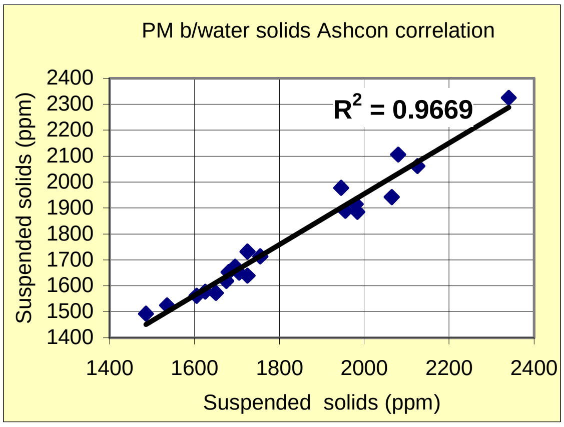


During complex grade changes, sheet breaks and routine (hourly) measurement standardisation, the reel ash control is interrupted. The control of reel ash is made by the reel quality control system (filler flow) but the measurement of the filler fraction is important to allow the retention conditions to be kept stable.

Calibration

A retention sensor should achieve better than 5% error of the calibrated range. For whitewater sample with a range of 0 – 4000 mg/l (ppm) this would represent an error of 200 mg/l compared to the lab. results. This error can be reduced to 2 % of range with attention to the calibration and minimising sampling/test errors, this is approximately equivalent to a correlation of 0.98.

In a simple measurement application, a single calibration adjustment is made using the base (factory) calibration data. A non-linear (6-point) grade specific calibration curve can also be used. Where grade types are distinctly different a grade specific calibration may be used (up to four grades available).



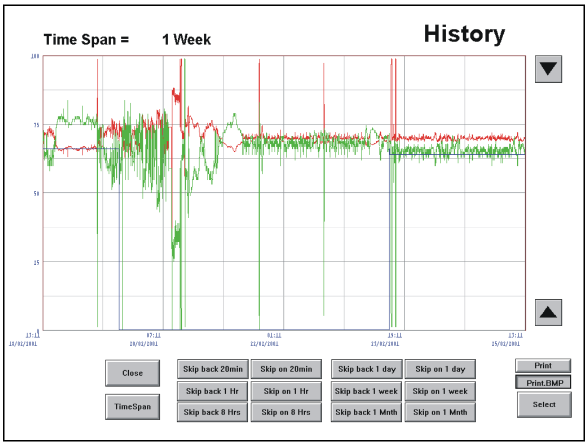
The above results are from a calibration made off-line then corrected by a zero offset based upon process measurement results.

Process visibility

In addition to the retention measurement it is essential that visibility be given to the machine operators so that they can see changing wet end conditions. Each sensor has a graphical operator interface (SIU) that provides trends as well as operational settings.

Where the sensors are connected to a measurement system more information is available. This normally takes the form of trends against time either as an absolute measurement value or as a relative value (all trends equally scaled 0-100% of range). An absolute trend is normally a short-term trend typically over one to two hours so that process stability and immediate changes can be directly monitored. The use of relative trends provides information in the medium (eight to 24 hours) to long term (days to weeks to months).

Many mills have existing process control equipment in use (typically DCS) or extended QCS systems and connect all process measurements into a single system. Often this can be costly in terms of programming.



Existing process I/O connections or processor capacity may also be fully utilised. In these cases, or in mills with simple control schemes a PC based monitoring system based upon SCADA software can be cost effectively used. Remote process I/O units can serially communicate data to a PC and display process information.

Wet end conditions can be quickly displayed to allow machine operators to gain the full advantage of this wet end visibility.

Conclusion

This new approach to wet end retention measurement, cost effectively provides an accurate and repeatable measurement of total and filler retention. When applied to a wet end, a continuous measurement of retention allows operators to make informed changes of machine settings.

Using this measurement; the process will become more stable, material cost savings will be made and product quality will be improved. The correct application of this type of sensor is fundamental to the success of an installation. Most machines should be capable of implementing closed-loop retention control on at least some grades. For a machine with a very wide grade range or particular wet end or quality constraints this measurement will show the operational retention improvement as the process is systematically changed. These alterations may take the form of machine settings, new raw material tests or new product trials. This simple retention sensor application allows both large volume and small volume machines to take advantage of this technology to improve product quality and process efficiency.

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