A new wet-end control system with on-line sensors

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A new wet-end control system clearly demonstrates that it can monitor a number of process variables and give useful information on several important operating factors such as first-pass retention and sheet formation.

The chemistry of the wet end was defined by J. Marton as the physical and surface chemistry of fines and additives and their interactions with fibers (*1*). Marton also noted that mechanical, hydrodynamic, and chemical factors affect sheet formation on a paper machine and almost all paper properties.

From an engineering point of view, improving first-pass retention without deteriorating sheet formation is one of the most important assignments of wet-end chemistry.

It is commonly said that both formation and first-pass retention cannot be optimized simultaneously in mechanical and hydrodynamic ways. However, we have suggested the possibility that first-pass retention could be improved without disturbing sheet formation by using a new forming shoe for twin-wire formers which was designed using computer simulation (*2*).

As for chemical factors, recent interest in white water reuse and the increasing demand for higher paper quality require using more retention aids, strength additives, and sizing agents on the wet end of a paper machine. To use such additives effectively, experiments are carried out first in a laboratory, and then mill trials are performed on a real paper machine. Because a paper machine produces tons of products, care must be taken not to upset the precarious balance at the wet end and not to destroy paper quality with new additives.

To that end, on-line analysis is required. Several paper machine analysis systems have been developed, for example by the Swedish Forest Products Research Laboratory (*3*), Kajaani in Finland (*4*), the Chemtronics wet-end monitoring unit, BASF in the Federal Republic of Germany (*5*), and CIP Research in Canada (*6*). They all seem to be stuck on the pilot paper machine level, or, if they are used on a real paper machine, they monitor only a few limited process variables or outputs. An integrated analysis system from the wet end to the dry end of a paper machine has not yet been developed.

Many papermakers believe that the electro-kinetic charge on furnish components and the addition of retention aid polymers may affect fiber flocculation. Sheet formation is adversely affected when first-pass retention is improved. However, this theory has not yet been verified on a modern, fast, twin-wire paper machine where strong microturbulence takes place on the wire.

We want to optimize the wet-end operation and to improve paper quality. As the first step toward that goal, this study was performed with the following purposes:

1. To develop a new computerized wet-end analysis system
2. To improve the first-pass retention of a Bel-Baie 2 newsprint machine
3. To determine the influence exerted on first-pass retention and on sheet formation by measuring the degree of microturbulence, zeta potential, pH, retention aids, and the properties of stock furnish.

Development of a computerized wet-end analysis system

To carry out mill trials efficiently and to detect an upset of wet-end balance immediately, we have developed a computerized wet-end analysis system using on-line sensors. The system includes Kajaani LC-100 low-consistency sensors to calculate the first-pass retention (*4*), pH meters, electro-conductivity sensors and ultraviolet (UV) sensors at the wet end, an on-line sheet formation sensor (F-sensor) (*6*) at the dry end, and so on.

The F-sensor uses a laser beam to monitor sheet formation, using the principle of optical transparency. It is mounted in a fixed position on the edge of the sheet and gives a formation index, which is the RMS (root mean square) of the transmitted light beam. A small index indicates good sheet formation.

However, we wondered if the F-sensor can accurately evaluate the MD variation of an entire sheet because it measures at only a single point of an edge of a paper sheet. Therefore, the sheet formation of Bel-Baie 2 newsprint samples in Case Study 2, which will be described later, was measured with an off-line sheet formation tester (the FMT-1000 developed by Jujo Paper) at 32 CD points × 10 MD points. The measured data are shown in **Fig. 1**. The vertical axis is the variation coefficient, which is calculated using the same concept as the F-sensor sheet formation index. The sheet formation of a paper edge on this paper

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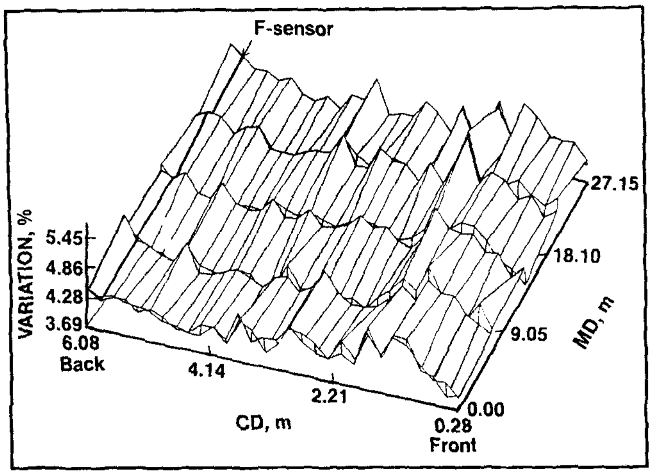
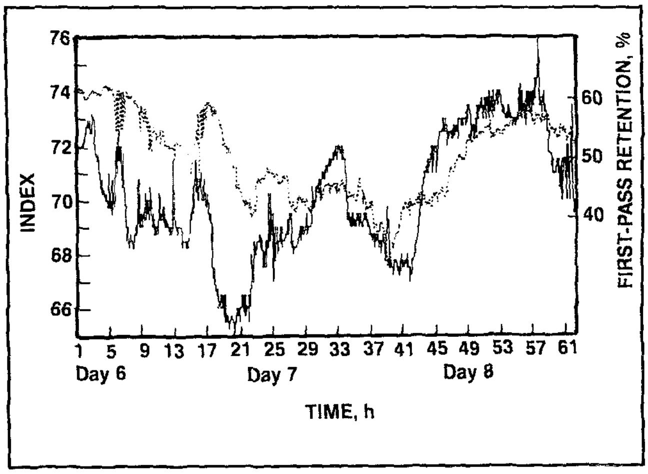
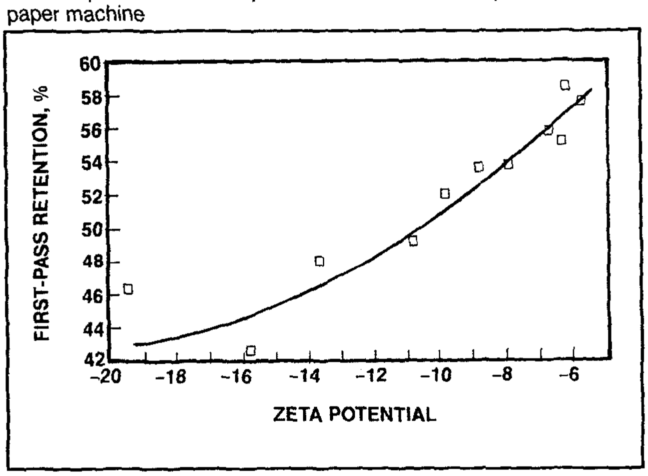
1. Sheet formation on the Bel-Baie 2 measured off-line



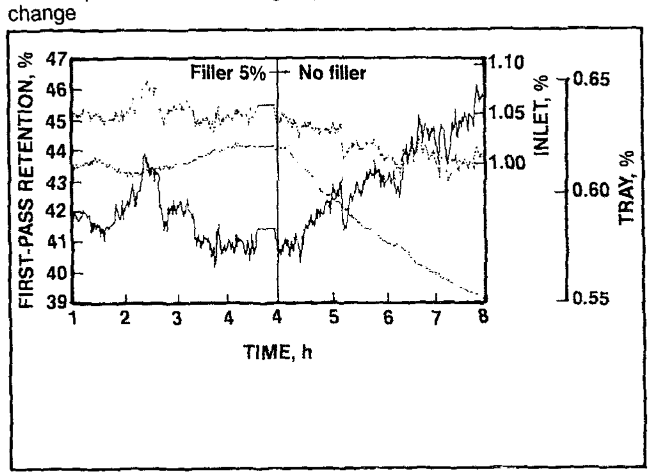
2. Formation index and first-pass retention of a low-speed fourdrinier paper machine



3. Zeta potential vs. first-pass retention of a low-speed fourdrinier paper machine



4. First-pass retention of a high-speed Bel-Baie 2 former during grade change



machine was almost the average sheet formation of a full width of paper and showed the MD variation of the paper.

First-pass retention is calculated continuously by two Kajaani LC-100 low-consistency sensors, one at the headbox and the other at the white water pit. For twin-wire formers, one is installed at the headbox and the other two are fitted on both the No. 1 tray and No. 2 tray of the white water system to compare the first-pass retentions of both sides if required.

Signals from these sensors are sent to a 16-channel analog-to-digital converter and then transferred to a personal computer every minute for several weeks and stored in a database.

Other important process variables such as stock flow rate, stock consistency, dryer steam flow valve opening, basis weight, and sheet moisture are also stored in a computer database. Such variables are quite useful to identify the process variation caused either by wet-end operation or by disturbances.

These signals are not only transferred to a personal computer but also recorded on a multipoint chart recorder. A recorder system shows trends in real time and is used to generate a quick report soon after mill trials. It also acts as a backup to the personal computer system if information is not properly stored in the database.

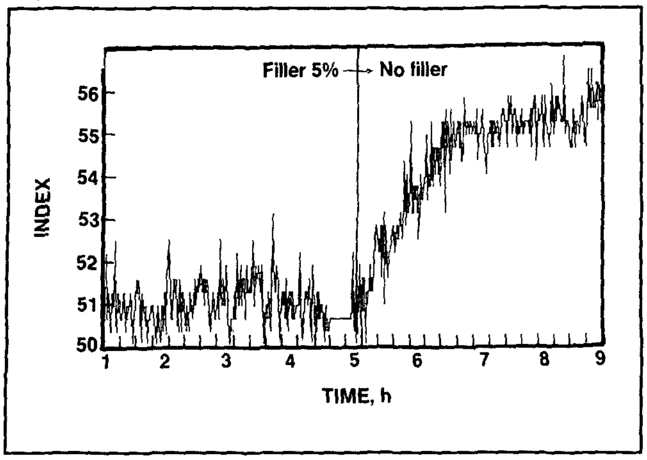
During or after mill trials, necessary files are retrieved from the database, transferred to a Lotus 123® spreadsheet, and analyzed. This way we can make an analysis and write a report without specific programming, and it saves a lot of engineering time.

Zeta potential, aluminum ion, sodium ion, anion colloid, paper surface strength, and other necessary properties are manually measured in a laboratory, and the results are input by hand to the same Lotus 123 spreadsheet containing on-line data.

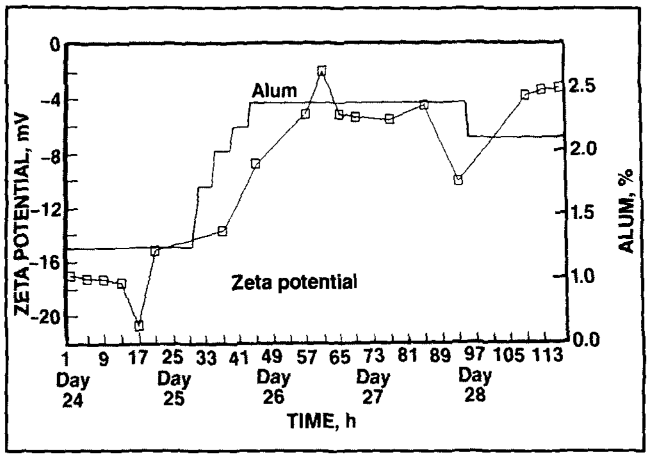
Mathematical calculations, regression analysis, and color graphic presentation are performed on Lotus 123 spreadsheets in a personal computer.

If necessary, data stored on floppy disks are transferred to a VAX mini-computer at the Central Research Laboratory in Tokyo and more sophisticated statistical calculations, spectral analysis, and three-dimensional graphic presentations are carried out.

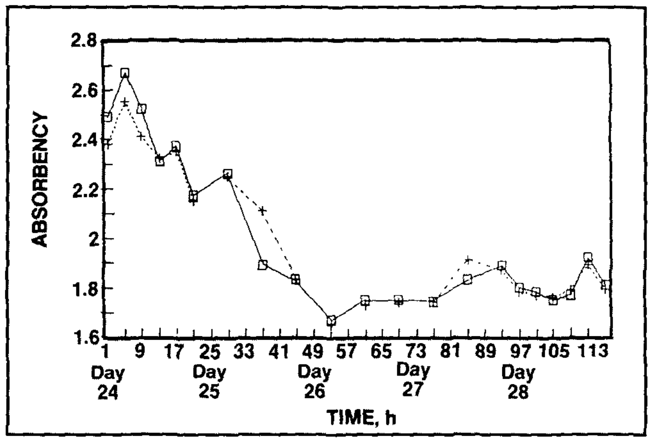
5. Formation index of a high-speed Bel-Baie 2 former during grade change



6. Alum addition and inlet zeta potential in a Bel-Baie 2 former trial



7. Absorbency of UV light (280 nm) of inlet and white water filtrate in a Bel-Baie 2 former trial



Case Study 1: A low-speed fourdrinier paper machine

As a preliminary mill trial, both F-sensor and two Kajaani low-consistency sensors were installed in a fourdrinier paper machine running at a low speed (300 m/min) where mild microturbulence was created on the wire.

Sheet formation was adversely affected by first-pass retention. As the first-pass retention was improved, sheet formation deteriorated, and as the first-pass retention decreased, sheet formation improved (**Fig.** 2).

The predominant factor to affect the first-pass retention was the electro-kinetic charge or zeta potential (**Fig.** 3).

When zeta potential approached zero, electro-kinetic repulsion force decreased and microflocs between fines and long fibers or between fillers and long fibers were formed. Microflocs improve first-pass retention but do not affect sheet formation.

Because the microturbulence was mild, microflocs could easily get together to form macroflocs, which affected sheet formation.

Therefore when the first-pass retention was improved, sheet formation deteriorated on a low-speed fourdrinier. Or to put it another way, the classic wet-end theory on the inverse correlation between first-pass retention and sheet formation was proven on-line on a low-speed fourdrinier paper machine.

We also confirmed that our computer analysis system can work properly.

Case Study 2: A high-speed Bel-Baie 2 former

Effect of grade change operation

The analysis system was subsequently installed on a high-speed Bel-Baie 2 newsprint machine running at 1000 m/min, and wet-end phenomena during grade change operations were monitored. Pulp furnish remained constant; filler content was decreased by 5%.

First-pass retention improved when filler addition was suspended (**Fig.** 4) because fillers easily passed through the pulp mat on the wire. Consequently, stocks containing much filler had lower first-pass retention. Sheet formation was a little damaged (**Fig.** 5). Fillers prevented macrofloc formation of fibers and gave better sheet formation; in other words, fibers could flocculate more easily when fillers were not present in the pulp suspension.

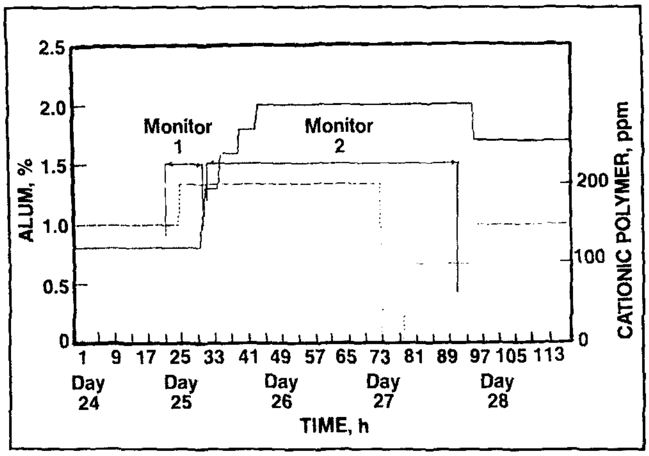
Effects of retention aid polymers

Detrimental substances such as fatty acids, hemicelluloses, lignin derivatives, and many inorganic anions are either partially absorbed or not absorbed at all into the solids in the paper stock, and they accumulate in the white water circuit (*7–9*). These detrimental substances can also make cationic process chemicals ineffective or uneconomical.

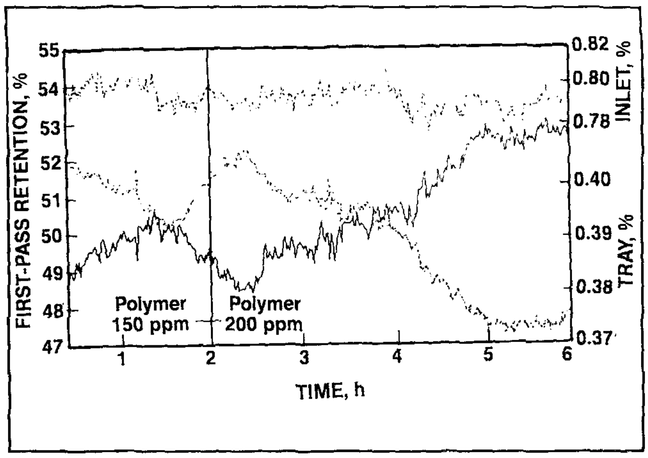
For one of our newsprint mills, which has a problem with detrimental substances in the white water, wet-end studies were carried out in a laboratory. Chemicals and wet-end conditions in which to use them effectively were carefully selected.

Based on laboratory experiments, mill trials for retention aids on a Bel-Baie 2 newsprint machine were planned using the computer analysis system. To use cationic retention aids effectively, we decreased detrimental organic substances dissolved in the white water system (**Fig.** 6), which were indicated with UV (280 nm) absorption, and zeta potential was properly controlled with alum (**Fig.** 7).

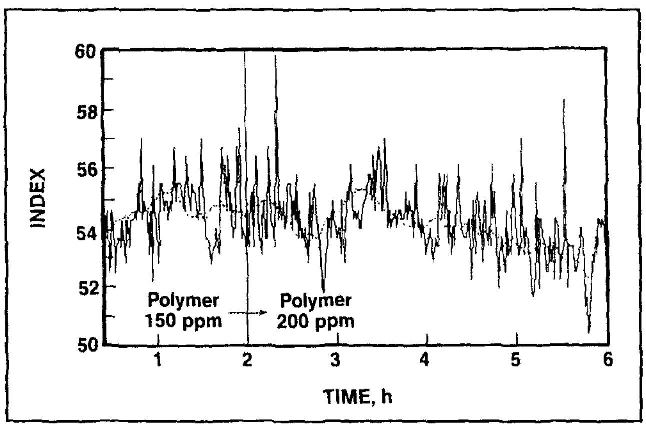
8. Chemical addition in a high-speed Bel-Baie 2 former trial



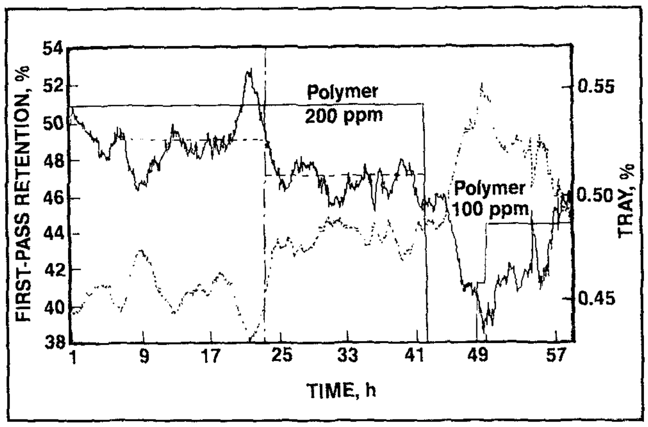
9. First-pass retention of a high-speed Bel-Baie 2 former during Monitor 1



10. Formation index of a high-speed Bel-Baie 2 former during Monitor 1



11. First-pass retention of a high-speed Bel-Baie 2 former during Monitor 2. Filler: 0-13%. Groundwood pulp: 17-22%.



Under the various customers' requirements, grade changes were frequently performed, which influenced the wet-end performance. To evaluate only the effect of retention aids and to eliminate the disturbances created by other process variables, the mill trial of the retention aid addition should be carried out in a relatively short time. Addition of retention aid was changed dynamically as 150 ppm to 200 ppm to zero to 100 ppm to 150 ppm (**Fig. 8**).

When addition of retention aid was increased from 150 ppm to 200 ppm (Monitor 1), the first-pass retention was improved by 4% (**Fig. 9**). Sheet formation was not affected or was slightly improved (**Fig. 10**).

As the retention aid dosage was suspended for four hours and then recovered to the previous dosage level (Monitor 2, Fig. 8), the first-pass retention measured by sensors dropped from 47% to 38%, and then increased as the retention aid increased (**Fig. 11**). Sheet formation was a little damaged from time to time when stock furnish and retention aid addition were dramatically changed (**Fig. 12**). However, from the macroscopic point of view, sheet formation remained unchanged with the addition of retention aids. Sheet formation of papers that were sampled from the reel also was checked later by visual inspection.

Therefore, in a high-speed twin-wire paper machine, where strong microturbulence was created on the wire, sheet formation was not affected as retention aid was added. This phenomenon was confirmed in the range of first-pass retention up to 50%. In other words, it was understood that microflocs were produced by flocculation of pulp and filler fines on the fiber surface in the mechanism of polymer bridging, which improved the first-pass retention. Created macroflocs or fiber-fiber flocs, however, were irreversibly broken down with severe microturbulence on the wire to produce a sheet with acceptable formation.

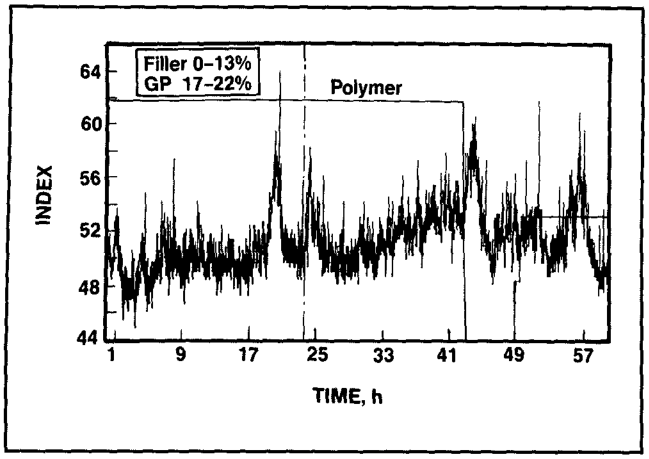
Conclusion

A computer wet-end analysis system has been developed which found that the correlation of first-pass retention and sheet formation depended on the degree of microturbulence created on the paper machine wire.

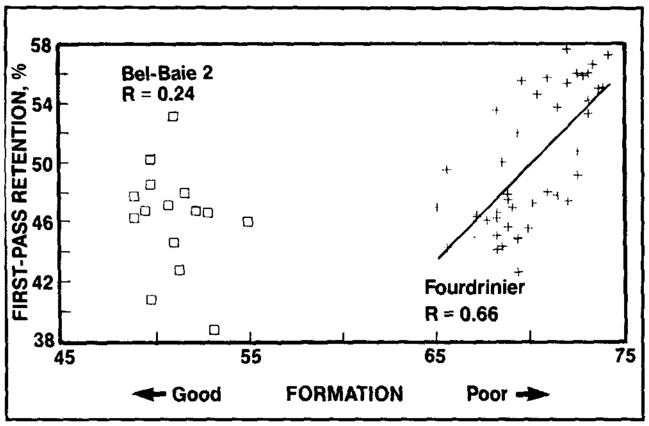
On a low-speed fourdrinier paper machine, where microturbulence was mild on the wire, the electro-kinetic force or zeta potential was a predominant factor to affect first-pass retention. As the first-pass retention improved, sheet formation deteriorated.

On a high-speed Bel-Baie 2 former, where strong microturbulence was created on the wire, macroflocs were

12. Formation index of a high-speed Bel-Baie 2 former during Monitor 2. Filler 0-13%. Groundwood pulp: 17-22%.



13. Retention vs. formation



broken down, and sheet formation was not affected by the first-pass retention up to 50%. Polymer bridging of retention aid polymer was necessary to produce microflocs and to improve first-pass retention.

Retention vs. formation on the Bel-Baie 2 and fourdrinier are summarized in **Fig. 13**. There was a correlation on the fourdrinier but not on the Bel-Baie 2. Sheet formation was better on the Bel-Baie 2 than on the fourdrinier.□

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