ON-LINE SENSORS ARE GROWING SMARTER AND SMARTER

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INCREASINGLY CAPABLE ON-LINE SENSORS ARE IN DEMAND FOR VIRGIN, RECYCLE, AND CLOSED MILL APPLICATIONS.

AUTOMATION IN THE PULP AND PAPER INDUSTRY continues to expand.Rapid advances in microelectronics,hardware and software are fueling process control capabilities. Facilitating these changes in the daily operation of a mill is an influx of industrial engineers trained in the midst of the digital revolution.The upshot:papermakers now have greater control over process quality and production than ever before.

Papermaking used to be more of an art than a science.History gave way when papermakers began finding quantifiable relationships in the raw material, e.g., lignin content and sheet strength. On-line sensors were then developed to measure for those values. The result is a transformation of papermaking into a more scientifically controllable industry.

The first on-line sensors were installed back in the 1950s. "Generally they were mounted on the paper machine next to the reel," says Paul Williams of ABB. According to Williams, these were single-point, beta gauges.The attentuation of beta radiation provided basis weight measurements."For a long time the extent of on-line detection was basis weight and moisture content," noted Williams.

Today, on-line sensors are found in all areas of the pulp mill and the paper mill, where they are used for a number of purposes.The most basic functions of sensors are to report on the chemistry and composition of pipe flows and the state of the pulping and papermaking process. On a mill-wide scale, sensors serve as the first line of defense, warning operators of potentially hazardous conditions developing in the mill. Sensors can also aid in preventive maintenance, monitoring dosimetry, managing energy consumption,and maintaining environmental responsibility.

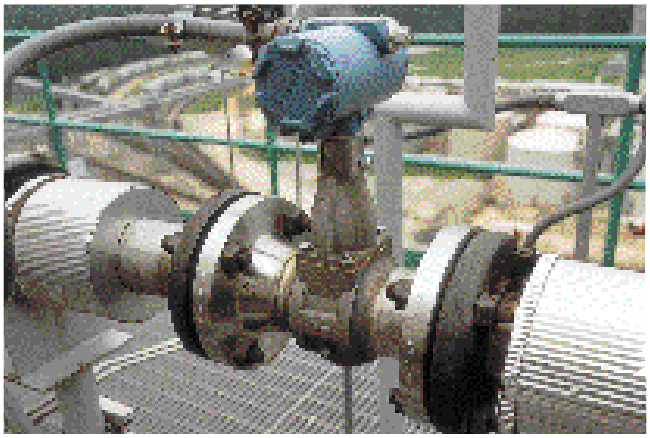
SET POINTS

Process control utilizes a sensor to adjust the setpoint. Data generated from the laboratory is used to confirm the performance and health of the sensor. This information can be stored on-site at the sensor, or in a process database. How the new data matches up over time describes the stability of the signal and the development of any mechanical malfunctions. Quick detection of these problems at an early stage reduces the overall impact of maintenance time,cost of repairs and replacements,and process upsets on production.

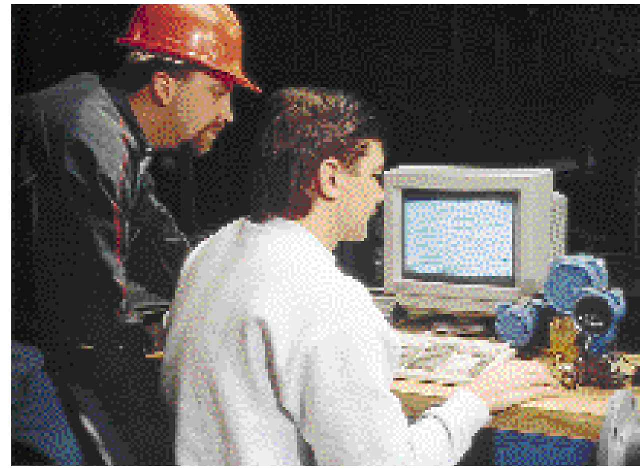
To get the most accurate data,on-line sensors should ideally be designed to obtain direct measurements. On-line sensors, however, when immersed into the process environment have shorter lifetimes. This is due to the high temperatures in the digesters and refiners,and corrosive conditions in bleach plant effluents and recovery flows. Engineers have responded to the challenge by designing more robust sensors, for example, using titanium metal alloys.

The other alternative is to redesign the sensor so that it has less contact or is no longer in direct contact with the process; while still sensing a direct measurement. Examples of technological innovations in this area are the use of radar for sensing level,and vortex and Coriolis meters for measuring flows.Other instruments using near infrared, infrared, and ultraviolet light can quantify process flow components such as residual lignin and adsorbable organic halides (AOX).

In order to improve the performance of on-line sensors,"smarts"have been added to many pulp and paper on-line sensors on the market today. The "smarts" are microprocessor chips located in the transmitter. "With the intelligence going closer to the sensor, calibration is easier, pre-calibration is better, and instrument replace-



Smart vortex flowmeter



Two engineers diagnosing a valve

ability is better," says Antti Kuisma of Valmet Automation. Manufacturers can build in more features into the "smarts" including self-diagnostics, more corrosion-resistant materials, and remote access. "Mill personnel prefer to supervise and tune the instrument without having to work in the field," says Dan Millard of Honeywell.

Preventive maintenance of on-line sensors cannot be entirely ignored because maintenance helps to extend the useful life of the equipment. On-line sensors in direct contact with the process are subjected to corrosive conditions and high temperatures. Under these extreme conditions, mills expect their sensors to maintain, "not only accuracy and stability of the measurement signal, but [be able to meet] reliability and maintenance, requirements," says Karen Milbrath of Rosemount Measurement.

Demand has risen for specialized applications of on-line sensors in the pulp and paper industry. "Historically, mills have not dedicated the necessary staff to keep the on-line instruments performing up to original design specifications," says Mike Pemberton of Rosemount Analytical. Current on-line sensor designs reflect vendor adaptations with improved performance and minimal maintenance requirements. Serge Miller of Foxboro says, "Today, more than half the systems we ship include digitally integrated intelligent transmitters."

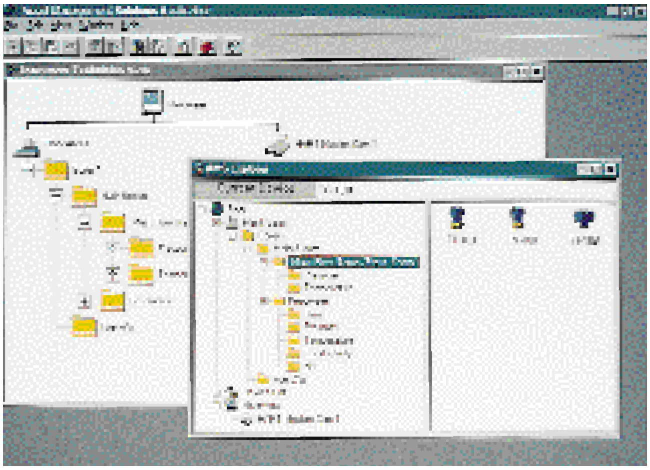
There are still many aspects of the pulp and paper manufacturing process that can benefit from sensor application but the technology still awaits development. An industry needs workshop conducted in 1994 for the Advanced Technology Program, identified the following list of sensing needs (see **Table I**). According to Sanford Levy of Union Camp, the list has not changed much in the last two years.

SENSOR INTEGRATION

Successful application of on-line sensors to process control in the pulp and paper industry is knowledge limited and technologically challenged. More information about the pulp needs to be measured during pulping and during sheet formation in order to design more effective control strategies. Current technology either lacks the capacity or the speed to handle process control in dynamic situations. The ideal goal would be to maximize the adaptivity of the control scheme so control loop adjustments can take place the instant the process experiences an external disturbance. There are several approaches now being explored with this goal in mind.

One approach is to enhance the sensor interface. The traditional sensor signal interface to the control system has been a single analog signal. Most sensor packages, however, have more information relative to the measurement. Digital networking, at the field or systems level, has allowed the control system to access all of this information. "Access to the array of sensor generated information enables the development of more intelligent, reliable and robust control strategies," says Glenn Gregg of Orion CEM.

Digital communication connections in intelligent sensors to the data historian dramatically expand the power of setpoint determinations. Large-scale distributed control systems (DCSs) supply the greater computing power required to support these mini data systems. Where sensor intelligence can only handle single and limited multivariable calculations, sensors integrated into DCSs are not limited in the same manner. The benefit for mills is enhanced self-diagnostics where "Good sensor to DCS integration provides protection against intermittent bad readings from the sensor and also



Desktop control for monitoring sensors in the mill

detection of sensor failure," says Bob Goodfellow of Fisher-Rosemount Systems.

New innovations in mill architecture are enabling on-line sensors to communicate with one another as well as with final control devices. In turn,these devices can also communicate with each other. With this change in topology highway addressable remote transducers (HART™) and the new fieldbus standard can now support the integration of on-line sensors from different suppliers into the mill-wide control scheme.

"Future DCS and sensor systems, built on fieldbus standards,will allow multiple paths for control and information integration within the larger mill information architecture. New types of non-control information,such as diagnostics, statistics, and process equipment performance, will be available from smart digital instrumentation and will provide information directly to maintenance and inventory management applications. This information will even be available for process engineers to better understand their current process condition from their DCS system consoles," says Goodfellow.

ADVANCED CONTROLS

Even with better management of the data for dynamic processes,the problem of real-time control in a dynamic domain still remains.As mentioned earlier, there are certain instances where inferential measurements are better adapted to control a unit operation more accurately than direct measurements.Dynamic processes are well suited for such application."Typically fuzzy logic control of on-line sensors is used to set the firing strategies in the lime kiln and the recovery boiler," says Bill Allcock of Beloit Corporation.

On-line process measurements integrated with artifical intelligence tools,like neural networks,can be trained to predict process changes. "These virtual sensors are beginning to be applied where direct measurements may not exist or be practical. They are also being used to validate sensor-based measurements," says Goodfellow.

Advanced control strategies are not without their own set of limitations. If the model is not trained on enough data,it will produce less-accurate predictions.If the process engineer decides not to include a unit operation in the model,the prediction will be skewed."Constant monitoring of the operation of the sensor and the computer generated synthetic variable is necessary to confirm proper operation," comments Fred Bader of Moore Products.

PULP MILL

The pulping and bleaching units have the largest impact on product quality;therefore proper control is essential. The more significant parameters to be measured are typically consistency, pH, pressure, temperature, mass, and brightness.In chemical pulping,the critical area for concern is the digester. On-line sensing for kappa number provides the quality feedback utilized to dynamically tune the cooking model, or temperature and cook time curves. In mechanical pulping, refiner control is dependent on being able to measure pulp consistency and freeness measurements.In the bleach plant,dosimetry of the bleaching agent on the pulp depends on brightness measurements. In all cases, process optimization equates to tremendous cost savings in terms of energy, chemicals, and efficiency.

"Sampling systems still remain a major weakness," says Gregg of Orion CEM."They are very high maintenance and contribute to measurement deadtime. Improvement in measurement sampling and analysis speed are desired to get closer to continuous measurement." Sampling problems are an issue of plugging and/or coating of the sensor when it is in direct contact with the process. Rosemount Analytical's Pemberton says, "Straight-extractive sampling systems work well with relatively clean samples." However, once these streams become contaminated with either organic or inorganic particulates,plugging and coating also become problems.

PAPER MILL

In the paper mill there are a different set of problems posed for on-line sensing.Sensing concerns here are split into dry-end and wet-end applications. Dry-end on-line sensing typically involves either mechanical- or spec-

Woodyard	pH	Refined stock properties
Chip moisture	Pitch content	Surface energy
Chip thickness	Dirt particles	Freeness
Chip density		Wet fiber flexibility
Chip mean particle	**Recovery**	Porosity/formation
Length and distribution	Black liquor viscosity	Dry-line detection
Bark content	Black liquor heating value	Fiber orientation
	RB temperature	MD/CD/ZD strength or
Pulping	Chloride in black liquor	Stiffness
Digester level	Droplet size	Curl
Residual alkali	Leak detection systems	Mottle
Lignin content	TRS/opacity on stacks	Gloss
Pulp viscosity	Causticizing efficiency	Coating weight
Shives level	Kiln temperature	Ash content
Dissolved solids	Lime availability	Web tension
	Lime particle size	Drainage
Bleach Plant	Lime moisture content	Rush/drag ratio
Flow meters		CD jet profile
Consistency	**Papermaking**	CD shrinkage
Fiber properties	Recycled fiber content	Coating quality
Brightness	Rroke brightness	

1. Paper industry sensor needs

troscopy-based scanners to measure for sheet uniformity in formation, basis weight, caliper, density, moisture content, brightness, ash content, opacity, color, coat weight, and gloss.

"Starting about 10 years ago,papermakers began measuring more qualities on line,with the intention of shipping by the gauge," says Keith Lantz of Measurex.Laboratory measurements are now used secondarily on the reel, to verify the measurements of on-line sensors.Lantz adds, "An additional advantage of on-line measurements over the lab is the capability for closed-loop control and more complete statistical information on the product."

In the dry-end there is less control over manipulating the sheet to meet specifications. On-line sensors there function as monitors for final sheet characteristics."Mills are pushing for on-line scanners that have greater CD capability, higher resolution, and higher speed in achieving higher resolution," says Peter Typpo of Impact Systems. The advanced optical scanning technology would enable papermakers to detect for faults in the finished sheet. This augments quality control on the outgoing product.

"Increasingly, on-line high resolution measurements are being connected to Management Information Systems for the purpose of quantifying the quality of the entire roll," says Don Hart of ABB Industrial Systems Inc. "Product assessment software can then be applied to optimize downstream and converting operations (i.e. ,slitting, roll tracking, etc.). Additionally, papermakers can provide their customers a proof of compliance to their purchasing specifications report. These functions place higher demands on the accuracy, resolution, and reliability of the on-line sensors."

On-line sensing strategies for the wet-end are a more recent development."The only closed control loop in the wet-end involves on-line sensing for the retention of fines and fillers which is used to control the dosage of the retention aid system," says Kuisma of Valmet Automation. Other on-line sensing instruments in the wet-end only serve as indicators for troubleshooting. The difficulty in controlling the wet-end is that the process events occur too quickly. If on-line sensors can be developed for closed loop control around the headbox and the forming board, then sheet formation problems can be stabilized earlier on in the process.

RECYCLE/DEINKING MILLS

In the area of recycle/deinking most "people have been using older technology from the paper machine to apply to the recycle plant area," says Loreen Ferguson of Boise-

Cascade. There are some critical aspects of recycle pulp, however, that do not exist in virgin fiber. Recycle pulp is a mixture of different furnishes. The variability of the mix cannot be controlled, making some sensor measurements difficult to calibrate. In addition, recycle pulp contains contaminants such as dirt and stickies, pitch, and slime. It is critical that these contaminants, with priority to dirt and stickies, be removed prior to the paper machine.

Sensors for wet dirt counts are gradually gaining exposure. "Development has fairly well advanced but utilization by mills is still in its infancy," says Bill Predmore of Phoenix Technologies. Dirt counting can be done using either reflected or transmitted light. Using reflected light allows dirt particles to be detected on the basis of their darkness relative to the base stock. Transmitted light measurements detect on the basis of the "opacity" of the particle.

Each approach lends itself to specific measurement applications. "In virgin fiber pulping operations, the use of transmitted light for dirt and shives detection in both brownstock and bleached pulps usually produces the best results," says Predmore. "For recycled fiber reflectance measurement may be the only viable option, particularly early in the process where high levels of ash can prevent the use of transmitted light. Later in the process, after much of the ash has been removed, transmitted light can be used to detect for stickies, latex flakes, and similar opaque but light colored contaminants in addition to ink particles."

"There is a desperate need for on-line sensing of stickies," says Gary Thurman of Union Camp. The problem is that stickies are one of the tougher contaminants to remove. Stickies generally are adhesives, glue from book bindings, and other tacky materials. Besides marring sheet quality, stickies can damage the equipment. "Because of the stickies problem, new sensor designs focus on non-contacting techniques to avoid build-up," says Lantz of Measurex.

CLOSED MILL

In the closed mill environment, all effluent flows are to be recycled. This means that non-process elements (NPE) in the water loops will buildup over time. "On-line sensors will have to be designed to handle the higher concentrations," says Kuisma of Valmet Automation. He predicts that sensors will also have to be able to track the species through the flows and measure for the bleaching components in the bleaching effluent. In addition, all on-line sensors will have to be robust enough to withstand corrosion, high temperatures, and high pressures just as in the standard pulp mill.

CONCLUSION

On-line sensing brings the process information from pulping, bleaching and papermaking more efficiently to management PCs. Sensors provide detail about the pulp, the chemistry and composition of pipe flows, and the state of sheet formation. If on-line sensor technology can be implemented at all points of the mill then engineers would be better equipped to make real-time adjustments. With continuing advances in sensor design and communication standards, the paper industry is well on its way to meeting the challenges of the next century. **TJ**

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(Photos courtesy of Fisher-Rosemount)