

By MARK WILLIAMSON

Different technology, different designs but all aimed at improving measurement and thus quality

OPTICAL CALIPER SENSING COMES OF AGE

Traditional magnetic caliper sensors have provided long-lasting service to the paper industry. The sub-micron precision they achieve is truly amazing as they can resolve less than one percent of the width of a human hair. That resolution is required for good CD calender control and consistent parent reel and finished roll structure. But, after recycled furnish was introduced to many grades and machine speeds vaulted above 1,500 m/min, some problems with these two-sided contacting sensors cropped up.

Stickies and other contaminants could build up on the contacting surfaces and the pinching action produced by the two contacting heads periodically punched holes in the sheet and caused web breaks. With increased web speed more air was entrained in the boundary layer surrounding the sheet and that could cause measurements to be unstable. More pressure could be applied to the sheet to overcome this problem but that aggravated the sheet break problem. Abrasion of the sensor surfaces by fillers and coatings was another issue. Moreover, in some cases caliper measurement was never successful on pressure sensitive coated papers since the sensors marked the sheet.

VERY DIFFERENT DESIGNS

As a result, papermakers were looking for a better caliper measurement solution that did not cause holes and runnability problems on some problematic grades and could be used on sensitive sheets where caliper measurement and control was never possible before. So quality control system (QCS) suppliers started development programs for an optical sensing technique more than ten years

ago. Today, the four major QCS suppliers – ABB, Honeywell, Metso and Voith Paper Automation – have come up with very different designs, and that makes for an interesting evaluation process by their papermaking customers.

First, let's talk about the similarities and what all sensor designers have to deal with while measuring a web of paper or board. While scanning across the web a non-contacting optical sensing technique locates the distance of the top or bottom of the paper by measuring how light interacts with the micro-scale variations of its surface. To calculate the caliper, the separation between the upper and lower heads or between the optics and a fixed reference (the z-direction) must be measured very precisely. That is done magnetically in all sensors with the already well-proven technology used in previous sensors. The real key is to deal with a sheet which may be slightly tilted or wrinkled since uneven tension is common. Uneven sheet position can completely negate any attempt at a precise sub-micron scale optical measurement. How the suppliers deal with this is quite different.

Of course, mechanically scanning of the sensor introduces some slight misalignment (the x-y direction) which must be measured by magnetic sensors and a secondary correction is applied. Sensors must also be designed to be robust in a typical papermaking environment, be easy to clean if required and not wear excessively.

As a final outcome, the four suppliers have designed quite different optical sensing and referencing techniques. All sensors have a very small spot size to measure the micron-scale sheet surface variations and, as you would expect, very fast processing speeds. The differences in measurement approach are explained.

ABB

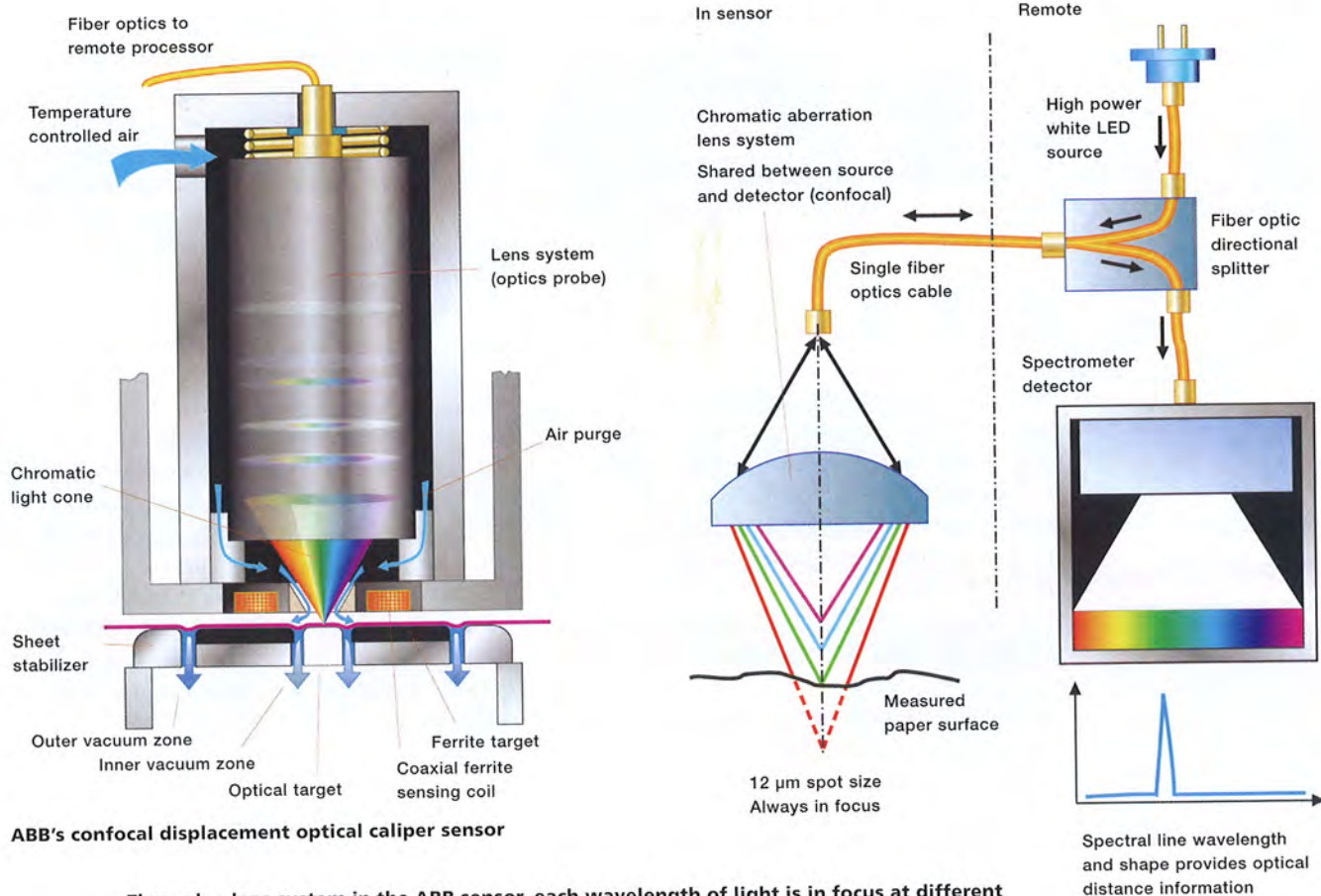
The first field test of ABB's sensor was made in January, 2008 and the final sensor was released to the market in May, 2009.

The confocal displacement technology in the ABB sensor utilizes a specific technique called chromatic aberration in which a broad-band white light source is split into its spectral components — all visible wavelengths from violet to red. Through a lens system, each wavelength of light is in focus at different distances from the light source. Thus the sharp focal-point of these wavelengths can be used to detect the position of the top surface of the paper sheet with excellent precision. A spectrometer connected to the sheet measurement signal determines the wavelength of these sharp

focus-points and that is a measure of the distance from the sensor optical head to the paper surface.

An absolute measurement the paper sheet caliper profile is made with respect to a fixed passive reference plate on which the sheet is supported as it scans. Although the sensor measures the surface profile of the sheet, appropriate corrections are made in software to ensure the measurement is calibrated to offline laboratory measurement which uses a wider contact area and compresses the sheet to a certain extent. ABB reports the sensor rarely requires grade-dependent offset corrections.

The reference plate has a large surface area to ensure sheet stability, particularly at the sheet edges where tension variations are common. Two concentric vacuum rings with a large open area ensure the

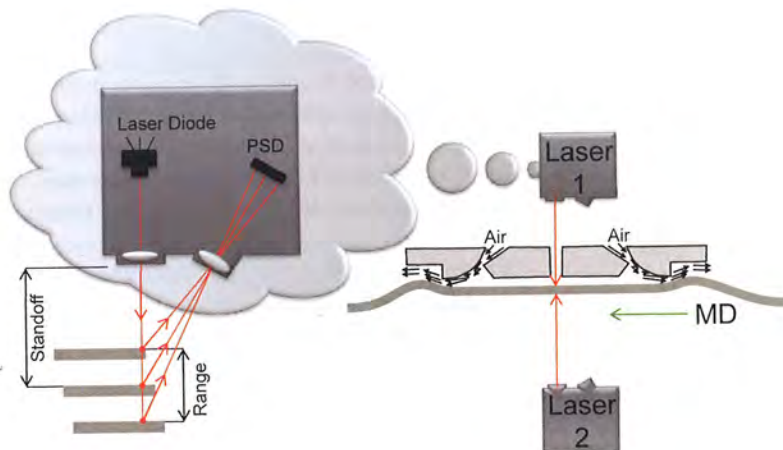


sheet is stabilized and dust is removed. One ring is on the perimeter of the reference plate and one surrounds the central optical target where the measurement is made. The reference plate is coated with a slippery ceramic substance to resist dirt buildup. Some wear of the reference plate may be expected with abrasive fillers and coatings. Since it is a passive element, changing it out is easy. ABB reports the first reference plate installed in 2008 is still in operation.

HONEYWELL

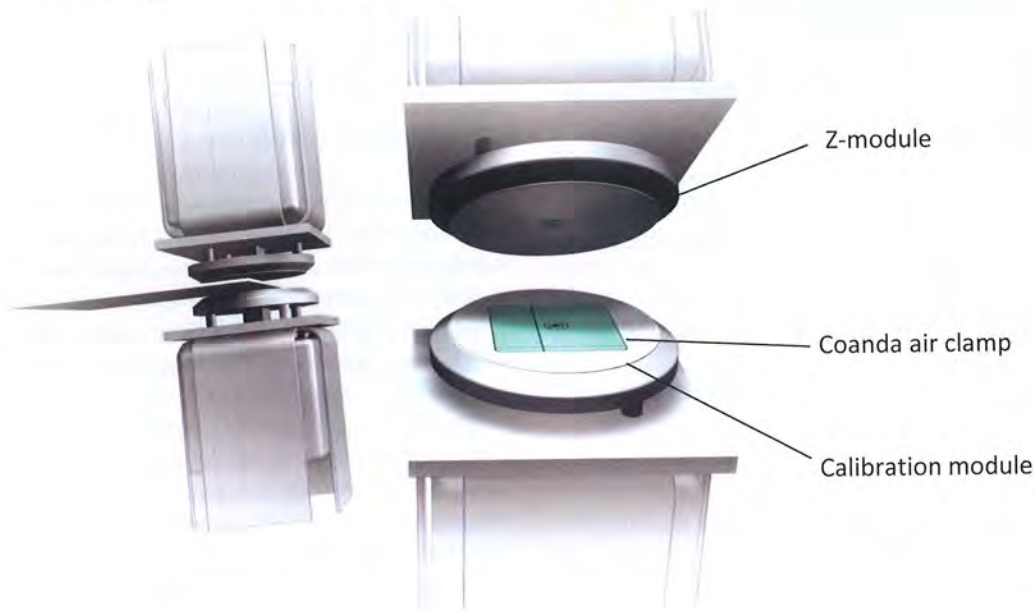
Introduced in 2006, the Honeywell offering is based on a dual laser triangulation measurement, made simultaneously on the top and bottom side of the sheet. This measurement does not require a contacting reference surface for its accuracy and therefore avoids surface contamination and wear. The laser triangulation measurement detects the surfaces of the top and bottom of the sheet by measuring the angular deflection of the incident laser light which is related to the distance to the sheet. The sheet surface distances minus the measured z-separation of the sensors heads give the sheet caliper.

The Honeywell-designed paper sheet air-clamp is a key enabling technology which makes this measurement very precise and not affected by



paper sheet fluttering and uneven tension. The large surface area air-clamp uses a Coanda-effect air float principle to hold the sheet perpendicular to the lasers. This perpendicularity reduces the need to have the lasers precisely aligned with each other. When the sensor is off-sheet standardizing an optical target is inserted in the center of the air clamp and stepped up and down with its position measured by an LVDT device. The LVDT measurement is then compared to a factory set calibration, ensuring consistent long-term calibration.

Honeywell's optical detection system includes two laser-based paper surface position detectors (PSDs). The sheet position is fixed by an "air clamp" to provide a solid reference



The Honeywell optical caliper sensor configuration

METSO

Metso introduced its optical caliper sensor in 2005. The measurement is based on a single-sided laser triangulation principle which determines the position of the sheet surface. To measure the absolute sheet thickness the distance to a passive reference plate on the bottom of the sheet is measured magnetically and then subtracted. The reference plate stabilizes the sheet so fluttering and tilting are not measurement disturbing factors. The large area reference plate is coated with a hard slippery material to reduce wear and avoid sheet marking. To achieve a fixed sheet reference, a vacuum is applied through an annulus around the plate and through drilled holes in the plate surface which surround the central optical target. This reference is not significantly affected by x-y alignment. The sensor is calibrated while on-sheet by moving the reference plate up and down by a known amount and then making corrections for any offsets.

The sensor's reference plate may wear over a long period if the sheet contains abrasive fillers. It is designed to be easily and cost-effectively replaced. One Metso customer who uses the sensor on supercalendered LWC grades replaced the reference plate after three years of

continuous use. The automated calibration takes care of any calibration offsets after the change.

VOITH PAPER AUTOMATION

Voith Paper Automation introduced its new optical caliper sensor in mid-2010. The paper sheet is guided and stabilized without any sheet contact through the sensor measurement gap by dual air bearings located in the top and bottom sensor heads. The sheet is separated from both heads by 100 to 250 microns. The sensor's air bearing uses a high volume air stream originating from the sensor window.

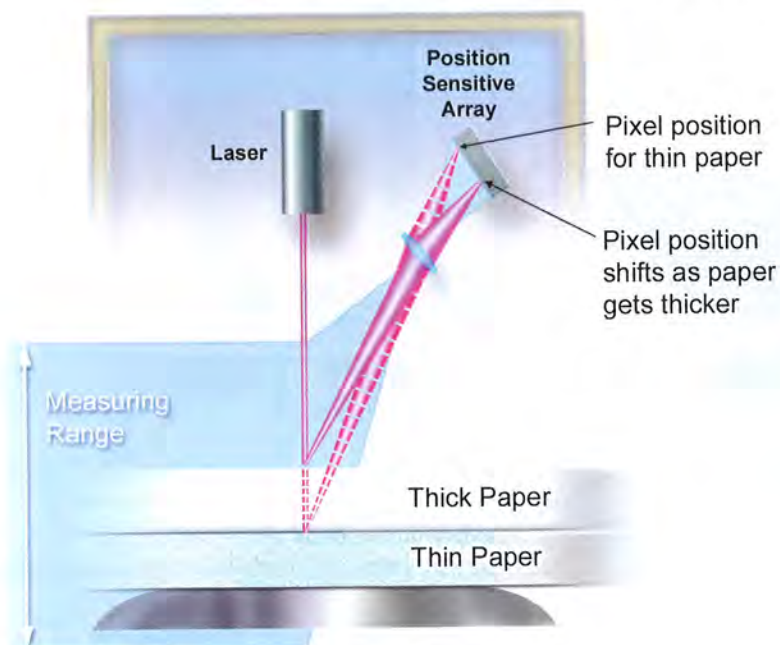
The position of the top and bottom paper surfaces are precisely calculated in three dimensions using three optical distance measurements on each sensor head. The sensors are like surface sensing devices used in CD, DVD and hard disk drives. This method compensates for any error caused by sheet tilting or fluttering. The sheet surface sensors are based on a confocal measurement technique which uses light scattering as the method of detection. The optical detectors have been miniaturized to fit into a compact enclosure.

To determine the caliper of the paper sheet, the distance between the upper and lower sensor heads is measured and subtracted. Sensor head alignment is monitored precisely using three high resolution magnetic sensors in addition to one XY sensor. Any effects caused by sensor head misalignments are removed from the calculated sheet caliper.

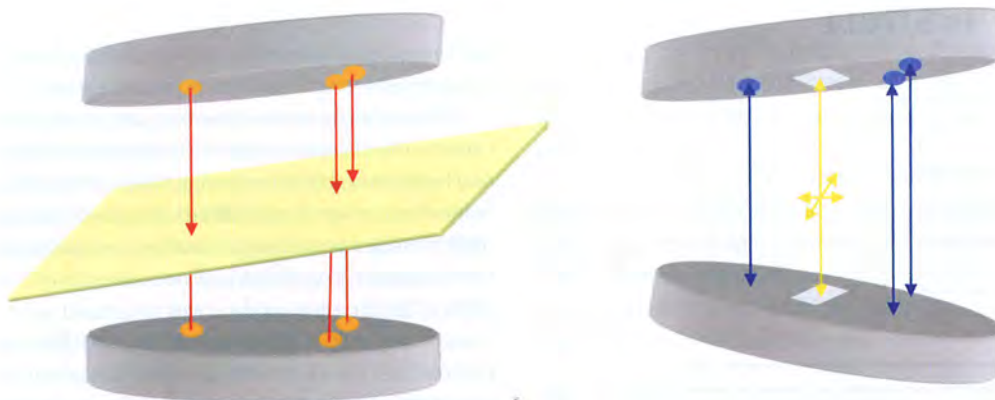
REFERENCES COUNT

There are four different approaches to optical sheet surface detection. Two suppliers use fixed contacting reference plates and two use non-contacting air float sheet guides, although the referencing is accomplished differently. It makes for an interesting and challenging decision since all suppliers naturally promote their best and different features.

Do all roads lead to Rome? Despite different technical paths it appears that optical caliper measurements achieve the objectives set out. All suppliers can demonstrate that their optical sensors correlate well with traditional magnetic caliper sensors, and in many cases that is enough proof for good measurement and control. In the early stages of development



Metso's optical caliper sensor configuration



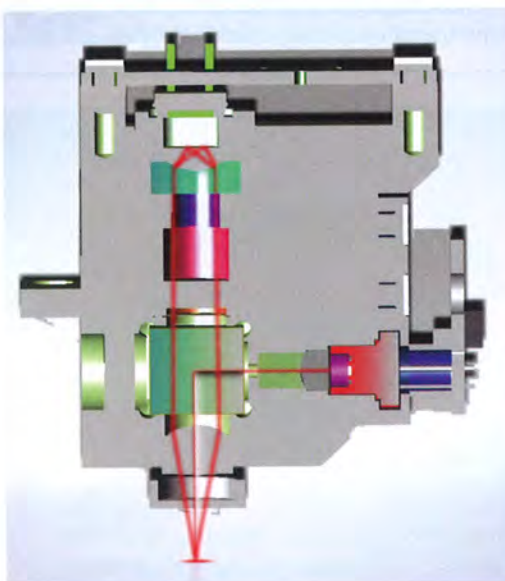
In Voith Paper Automation's design the position of the top and bottom paper surfaces are precisely calculated in three dimensions using three optical distance measurements on each sensor head(left); Sensor head alignment is monitored precisely using three high resolution magnetic sensors in addition to one XY sensor

the new sensors were installed beside the traditional ones so direct comparisons are convincing. In some cases the optical sensors are compared with off-line automated laboratory testing and profiling devices.

Since optical detection systems do not contact the sheet, they measure the micron-scale topography without compression whereas the Tappi standard lab test contacts the sheet over a much wider area and compresses it with a standard pressure. Is absolute standard measurement required? It depends on the application. For many papermakers, a stable and reliable profile measurement is all that is required since the replacement of a traditional scanning measurement used for CD control is called for. Normal calibration offsets applied to many QCS sensors can give a representative scan average reading. If the paper grade is specified precisely by caliper then suppliers should be evaluated for their calibration procedures and stability of calibration. References on similar grades should be checked.

With so many different measurement techniques offered by suppliers and a high level of product differentiation reference-checking is a must for making an informed decision. According to the list below, there are quite a few of them. Check with users who make similar grades and furnishes and have encountered similar problems. Reference-checking is, of course, commonplace in the paper industry. It's second nature.

Regular servicing requirements should be evaluated also. All suppliers agree that some sort of regular surface dusting is required – once per shift or once per day depending on the application. More thorough



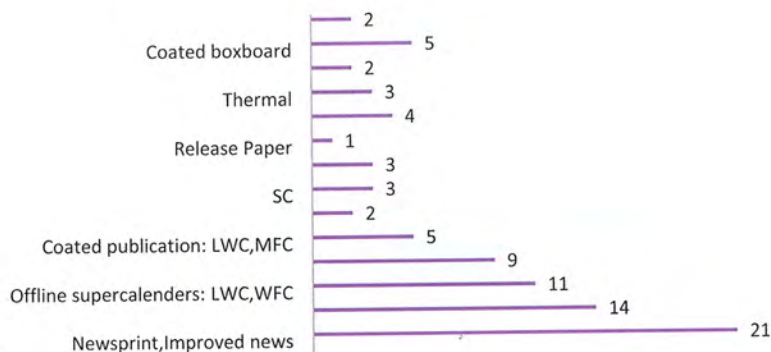
The Voith Paper Automation sheet surface sensors are based on a confocal measurement technique that use slight scattering as the method of detection

contaminant removal may be required periodically. Although contacting reference plates may wear it appears their lifespan and replacement cycles are quite long.

APPLICATIONS AND RESULTS

Since 2005 to the time of publishing 85 optical caliper sensors from all suppliers have been installed. The top application is newsprint and improved newsprint with recycled furnish content up to 100%, followed by uncoated woodfree, offline supercalendered paper and woodfree coated. The supercalender applications rep-

Optical Caliper Installations, All Suppliers : to 5/2011



resent a new market segment for caliper measurement since sheet marking with previous caliper sensors was a concern. Other applications include coated publication papers, sensitive specialty coated papers like carbonless

and thermal paper, coated board, recycled linerboard, and very light sheets like bible and cigarette paper.

One of the immediate benefits, particularly for recycled content paper producers, is that sheet breaks and holes caused by the pinching action of two-sided contacting sensors have totally disappeared. That in itself is a major benefit which justifies the purchase. Optical caliper sensors can now operate reliably 100% of the time and produce well structured reels. Does optical caliper measurement improve CD control? There is no theoretical or practical reason to expect this since optical sensors provide a resolution equivalent to magnetic sensors. There are some cases where control has been improved if the magnetic caliper sensor did not read properly because of sheet instabilities. Some customers report lower caliper variations and reduced roll structure rejects.

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Caliper and reel structure control is now used on grades where it was previously not possible because of sheet marking problems. For instance, supercalender operators can now build consistently structured reels to avoid winding and converting problems. One user reports that the profile shape can be precisely controlled to avoid hard edges and associated break problems. Customer claims have been reduced.

INDUSTRY STANDARD?

Are optical caliper sensors ready to replace traditional magnetic sensors? Not in all cases. The magnetic sensors still work well in many applications and are the online standard to be measured against. Since optical caliper sensors carry a higher price tag, customers must look at their specific needs and existing prob-

lems to see if the purchase is appropriate. For some grades, like recycled furnish sheets and marking-sensitive coated sheets they are becoming the preferred if not the only solution.

Are spin-off measurements possible? Since the signals contain information about the reflection and scattering effects of light interacting with the sheet surface, measurements such as roughness, smoothness and gloss may be possible according to some suppliers. Time will tell. **PPI**

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