ABB

Innovation in action

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Papermakers have long sought a caliper sensor for their paper machines that is accurate, reliable and does not mark or break the sheet. ABB has successfully launched such a sensor, which has proven to be far superior to other optically based caliper sensors. Customer feedback tells of reduced losses and improved quality.

QCS suppliers have focused on optical caliper sensors, usually using the laser triangulation technique. This method has been plagued by substantial errors caused by instability in a fast moving sheet, tilt effects from a non-flat sheet, sensor alignment, surface topography effects, and not least, laser light penetration into the semi-translucent paper body.

ABB now has experience and results with a different, non-laser optical approach, one that provides greatly improved measurement accuracy and stability. This new sensor, the latest in its 50-year history of pioneering online paper quality measurements, finally provides papermakers with a precision tool to measure and control caliper on even the most demanding paper grades.

Laser triangulation has found acceptance in industries such as metals, rubber and plastics. It compares a physical gap and a laser triangulation distance measurement to the free sheet surface. Triangulation works by focusing a laser beam onto the paper and following the position of the reflected light (Fig. 1a). The distance from the sheet surface can then be determined by analysing where this image is formed. Triangulation works extremely well for surfaces that have no penetration issues, such as metals. However, if the light penetrates into the bulk material, as can be the case with paper, then the method will have difficulties determining the true surface location and hence give a false distance measurement (Fig. 1b).

Light penetration can be easily demonstrated by measuring five different paper-grade sheets taped together using a dual-sided contacting versus a dual-sided laser triangulation caliper sensor (Fig. 2).

The agreement on the fine paper grades ranges from approximately 1 μm to about 10 μm. Often, the quality specification of these paper grades calls for a caliper variation of no greater than ± 1 μm, so such variations in agreement can pose real problems as grades are changed on a single machine, or even as process conditions change. In addition, there are enormous discrepancies when paper grades change more extensively, such as the 30 to 50 μm offsets recorded for the card stock and kraft grades, for example.

Along with moisture and weight, accurate caliper measurement, which has often proven elusive, is critical for defining paper. On some thin paper grades, laser sensor caliper errors can approach 50 % of the sheet thickness. To compensate, time-consuming fiber and filler-dependent calibrations have to be made.

Efforts to overcome many of these problems yielded only limited success. However, because customer demand for a laser-based system was so high, ABB decided to embark on its own laser sensor development project. A parallel study carried out to investigate the potential of technologies from other industries uncovered one technique that attracted much attention – an optical confocal displacement technique. The company's non-laser optical approach provides papermakers with a precision tool to

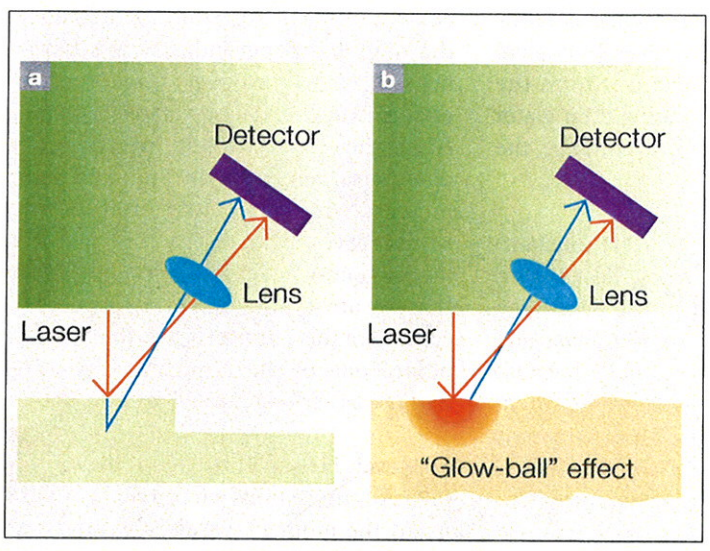

Fig 1: Laser triangulation principle: The position of the reflected light changes as the sheet thickness varies (a). In (b), the glow-ball effect causes measurement uncertainty in most paper grades

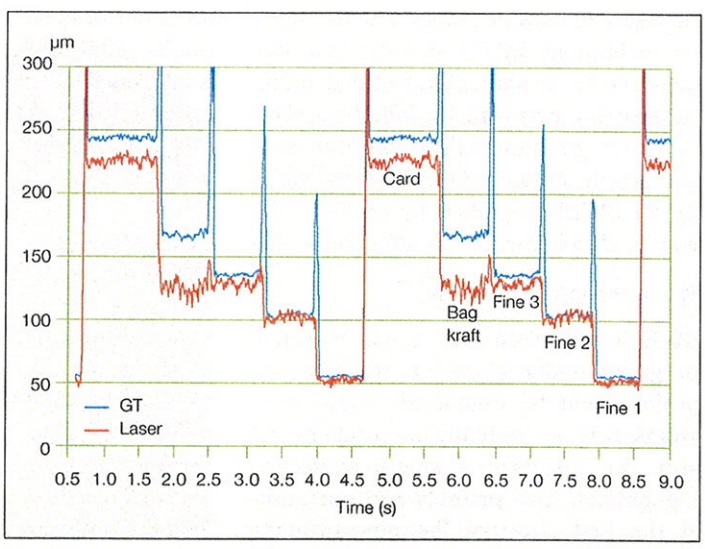

Fig. 2: The performance of laser triangulation versus contacting caliper (GT) on card, bag and three fine writing paper grades

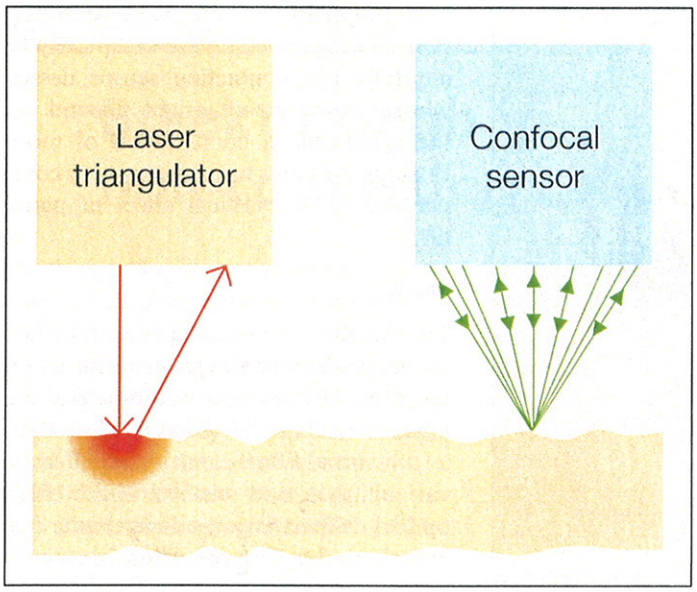

Fig. 3: A confocal sensor vastly reduces errors from light penetration that may occur with laser triangulation

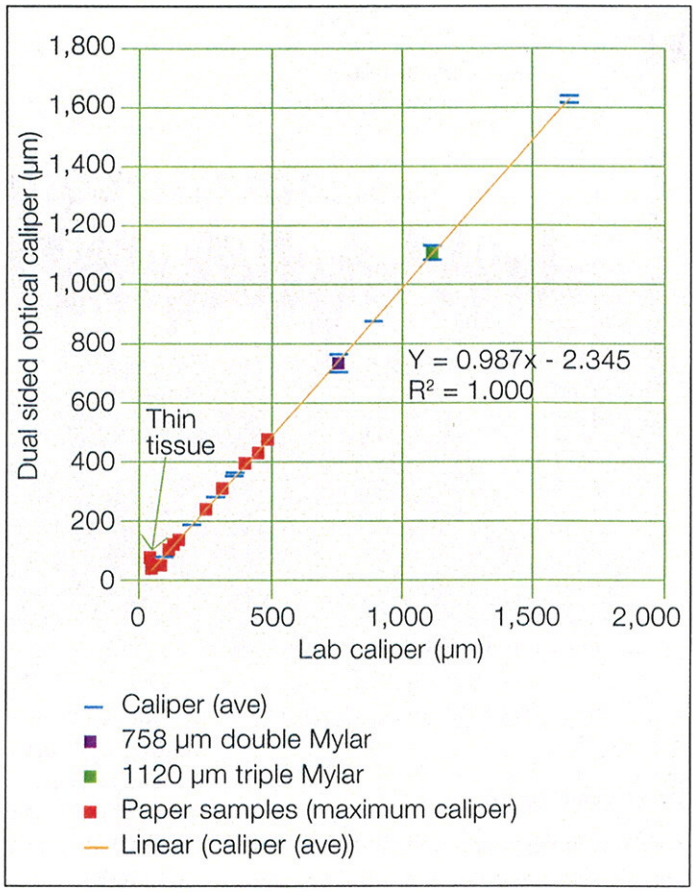

Fig. 4: Confocal sensor reading for a variety of sample types and thickness levels, with the same calibration

measure and control caliper on even the most demanding paper grades.

Optical principle

The confocal method works by projecting a small spot of broadband light (12 μm) from a high-power white LED source, via fiber optics and through a lens system, onto the sheet surface. The lens system is designed to provide a high level of chromatic aberration, i.e., the light is split into its component colours as it passes through the lens system. Each individual colour is positioned at various distances from the lens. The reflected light from the sheet of paper is returned via the projected light path, i.e., through the lens and the optical fiber. This shared optical path is one of the features that makes this a more accurate method than laser triangulation.

The confocal optical caliper sensor uses wavelengths to measure the height variations of paper surfaces. A special spectral shape analysis algorithm further improves the agreement between sensor and laboratory, even for sheets with pronounced surface topography. This algorithm simulates the slight compression of the peaks that would be observed when measuring caliper on an offline laboratory instrument.

The sensor output for a variety of demanding paper grades and Mylar samples, all with the same calibration constants, is shown in Fig. 4. The grades of the paper samples used included tissue, SC-A, coated, uncoated, linerboard, newsprint, card stock, and glossy calendered grades. The fascinating thing about the graph is that it is very linear over a wide range of samples, implying that the measurement

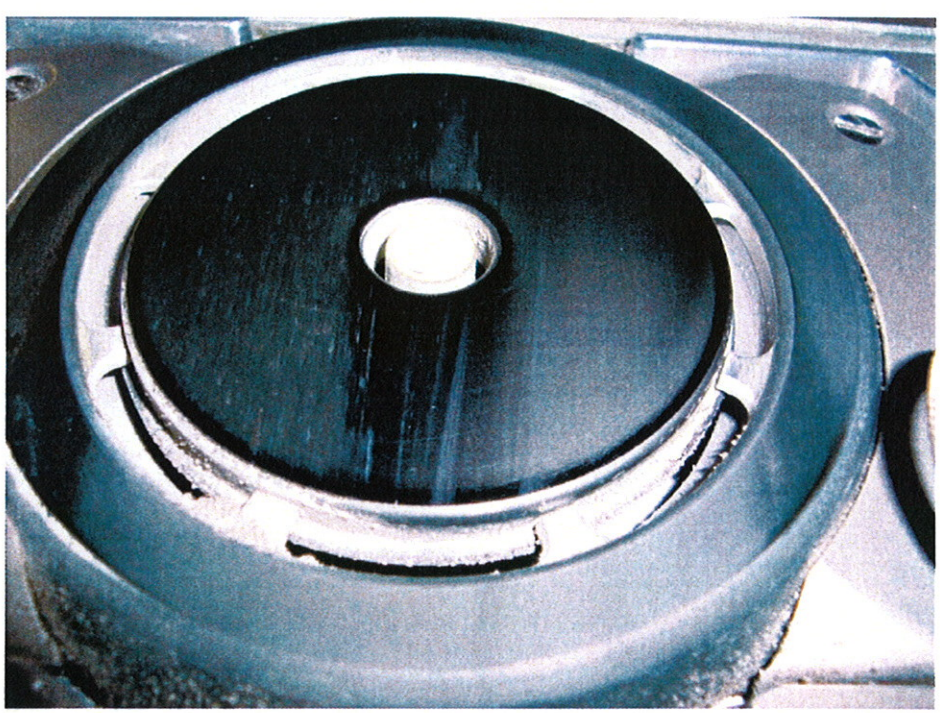

Fig. 5: Even after a year of continuous running little dust built up inside the vacuum chambers and this is easily controlled by a simple once daily wipe down triangulation

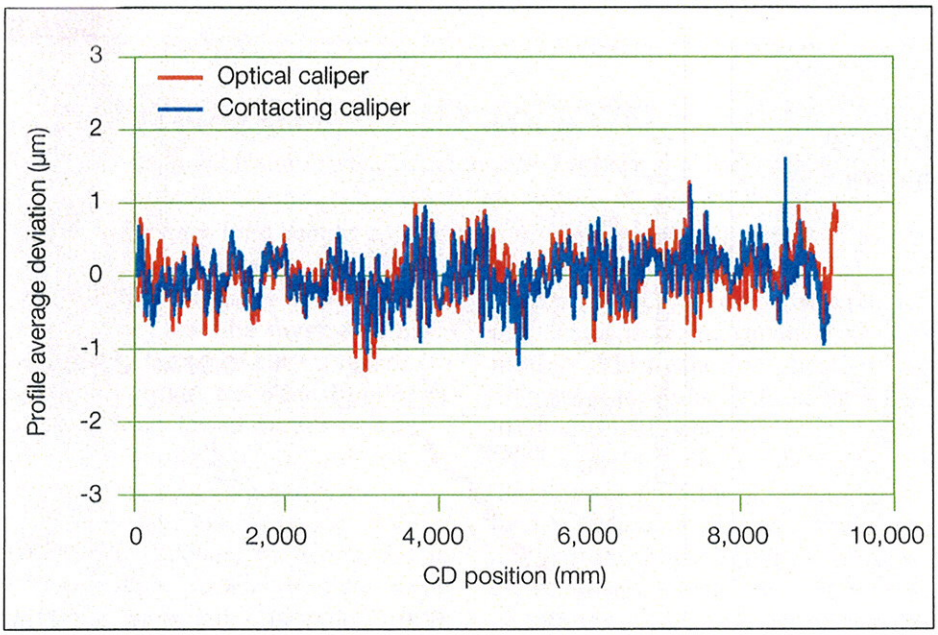

Fig. 6: Online performance on fully recycled newsprint grade

does not require any grade dependent calibration.

Sheet stabilisation

An accurately positioned and flattened sheet is also essential for any optical caliper measurement. This is achieved by a sheet stabiliser located in the head of one of the sensors. The stabiliser contains a ferrite target for the primary magnetic gap measurement and an optical target onto which the optics are focused. Sheet control is achieved by a very light vacuum, which gently smoothes the sheet and removes any wrinkles in the optical measurement zone without marking the sheet or allowing the buildup of coating or contaminants. As a result, the optical caliper sensor is applicable to demanding grades, such as newsprint, coated, super calendered, and fully-recycled grades.

The super smooth ceramic coatings and hard materials used in the sheet stabiliser plate prevent any buildup and sheet marking, and provide excellent wear resistance. The large vacuum zones are designed to prevent the accumulation of fillers and coating, thereby reducing or even eliminating the need for frequent maintenance cleaning.

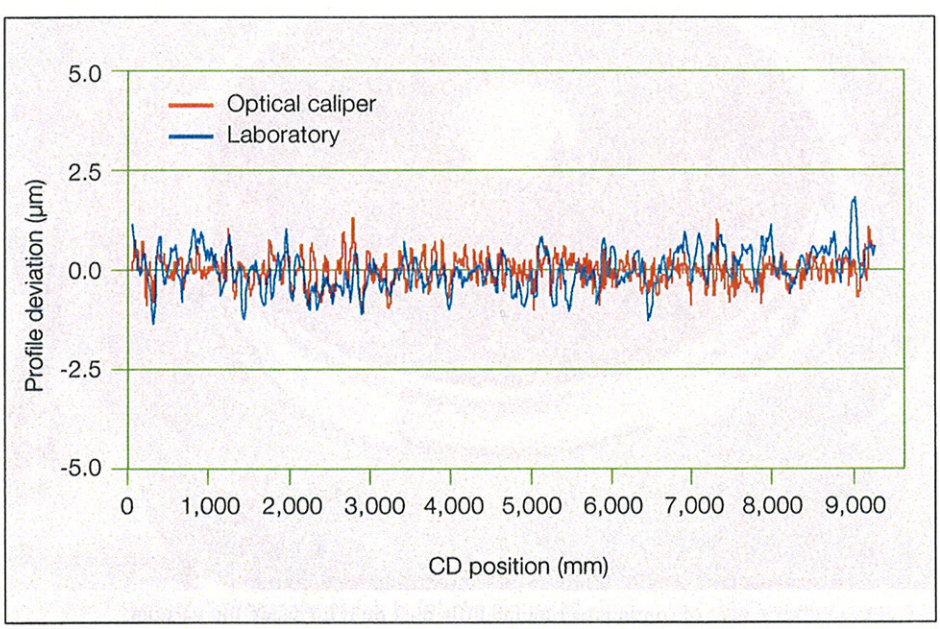

Fig. 7: Optical caliper performance on 100 % recycled newsprint

The simplicity of this sheet stabilisation technique avoids the complexity of a totally non-contacting sensor design whose measurement might depend on the synchronous combination of more than ten different measurements to compensate for the critical effect of paper tilt.

Results

The results on paper machines in the last year and a half are exceptional. The agreement between the optical caliper and the laboratory show deviations of less than ±1μm. In addition, amazing small-scale variability is now visible. With ABB's optical caliper sensor, one customer has experienced a 55 % reduction in caliper-related poor quality costs. The first permanent installation was on a large, 100 % recycled furnished newsprint machine that produces a 9.3 m wide sheet running at 1,700 m/min. This process can cause problems for contacting sensors, such as occasional buildup on the sensors or other mechanical factors that may cause measurement degradation, or even sheet handling problems.

The optical caliper was installed in December 2008 and has been used in the production process since January 2009. Just one month later it was used for live CD (cross direction) caliper control! Since then, the customer has reported improved reel building and a reduction in profile variation. Furthermore, the sensor requires little maintenance in this process – the sheet stabiliser plate is periodically cleaned only as a precaution.

The performance of the optical caliper is compared with that of the contacting caliper in Fig. 6. In this example, the profile deviation between contacting and optical measurement is better than 0.5 μm.

Sensor profile agreement with the customer's laboratory has also improved dramatically; Fig. 7 shows an agreement of better than ±1 μm.

The results of the optical caliper lead to significant reductions in off-quality paper due to caliper profile and reel building. The optical caliper has also been applied to several coated paper applications with the same excellent results. ■