New scanning combination caliper and moisture sensor ideal for board grades with high recycled fiber content

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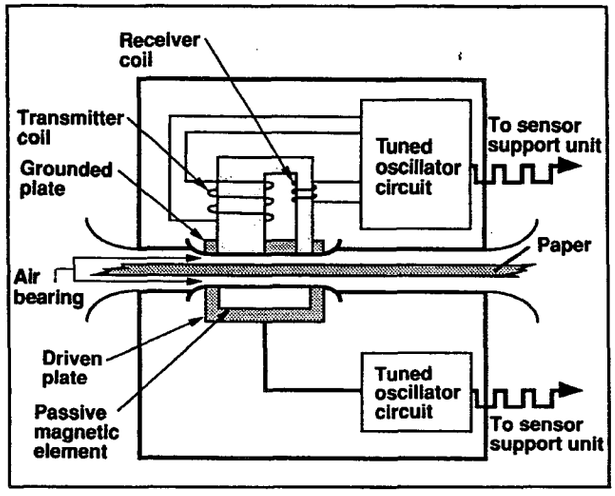
The search for both an accurate and cost-effective solution to the measurement problems posed by cylinder and other board applications with high recycled fiber content has been long and elusive. Moisture and caliper in particular have been difficult variables to measure—moisture because of the carbon black content that blocks (in the case of infrared sensors) IR transmission and caliper because of the buildup of recycled contaminants on the sensor head which prevent the sensor from providing accurate measurement data. Existing caliper sensors also have a limited measurement range, peaking at about 40 mils (1000 microns).

With the recycled content of these products likely to be increasing rather than decreasing, solving the problem of accurate moisture and caliper measurement for these applications is now more critical than ever. This paper first reviews some of the established techniques of measuring moisture and caliper, then it describes a new, patented method that resolves many of the outstanding measurement issues by combining, into one sensor head, measurement of both these variables.

1. A block diagram of the caliper and moisture sensor illustrates the principle of operation.



Conventional methods of measuring percent moisture

The most common means of measuring moisture in a moving web is to utilize a scanning-type moisture sensor based on the selective absorption of infrared radiation in paper. There are two types of IR sensors: reflective and transmission. Both types require a finely adjusted optical path as well as sophisticated electronics for standardization, and both are sufficiently accurate for most applications. However, cylinder and other board applications with a high recycled fiber content pose special obstacles for these sensors. Of particular concern for both the reflective and transmission IR sensors is the presence of carbon black in the sheet, which absorbs virtually all of the IR wavelengths these sensors are trying to measure, making calibration extremely difficult. The reflective type is also adversely affected by moisture stratification, which tends to be quite pronounced in board applications.

Two other types of scanning moisture sensors address the problem of carbon black: the radio frequency (RF) sensor and the microwave sensor. However, relative to the IR sensors, they have the drawback of reduced accuracy. Traditionally single-sided, both of these sensors must be in extremely close proximity to the sheet to be accurate, which subjects them to dirt and contaminant buildup on the sensor head.

Another type of moisture sensor is the double-sided, noncontacting microwave sensor. Because it is noncontacting, this sensor minimizes the problems of dirt and contaminant buildup. It is also transparent to many of the problems associated with cylinder board that afflict the previously mentioned sensor types. It is, however, very expensive, and it must normally be operated together with a basis weight sensor.

Because of the various limitations of these sensors, there exists the need for a cost-effective moisture sensor that can handle high basis weights and that is insensitive to such variables as carbon black content and moisture stratification.

Measuring caliper

There are basically two types of caliper sensors: contacting and noncontacting (air bearing). The advantages and disadvantages of each vary with the type of paper being

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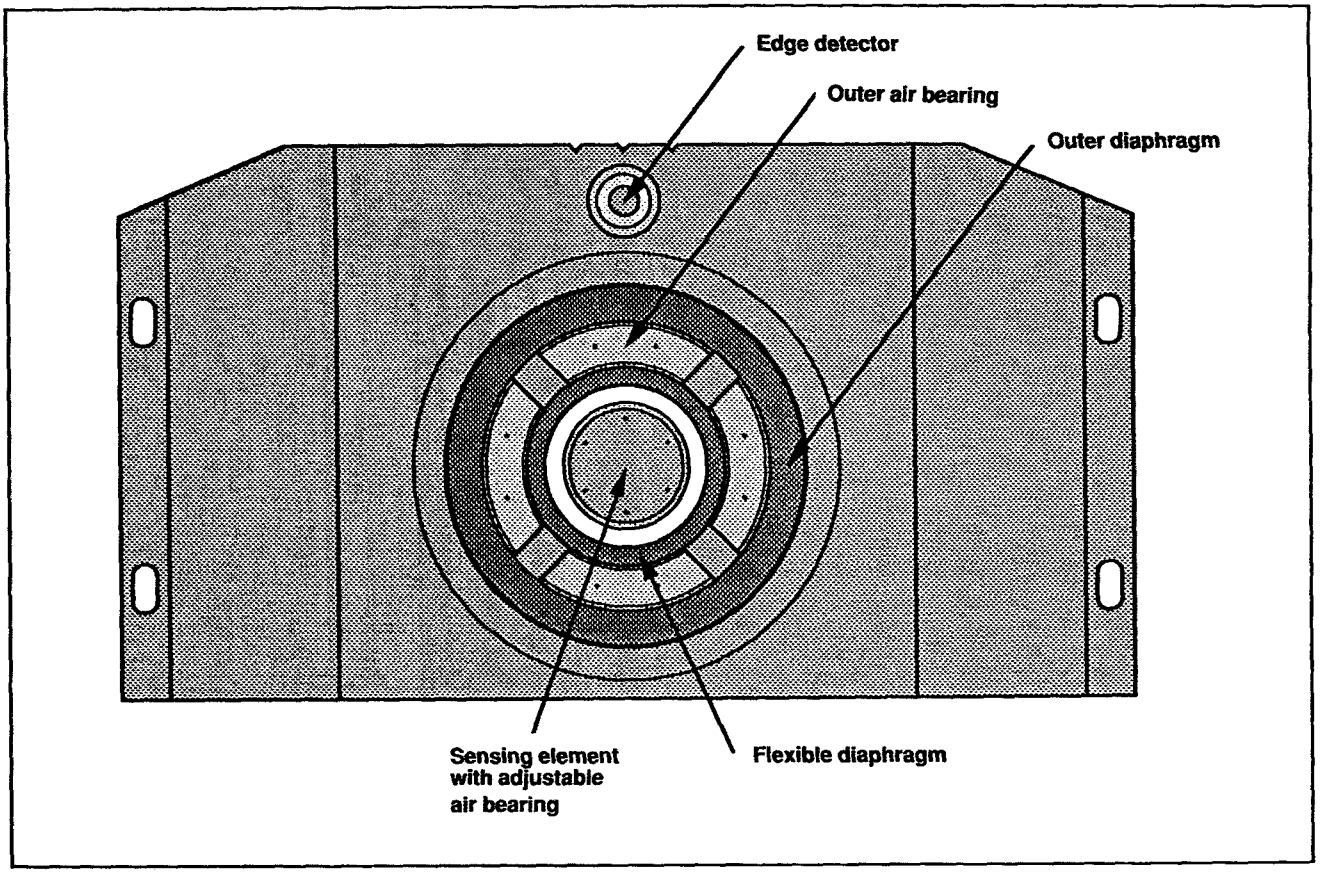
3. Diagram shows the dual air-bearing system utilized on both the upper and lower sensor head. Only lower sensor head is shown.



measured. For line sheets, contacting sensors, while extremely accurate, tend to tear the sheet. Noncontacting sensors, while eliminating the risk of sheet breaks, have traditionally been unsatisfactory because of inherently poor accuracy. This is due to the difficulty in keeping the air bearings stable in the face of sheet temperature variations, sheet flutter, and sheet irregularities.

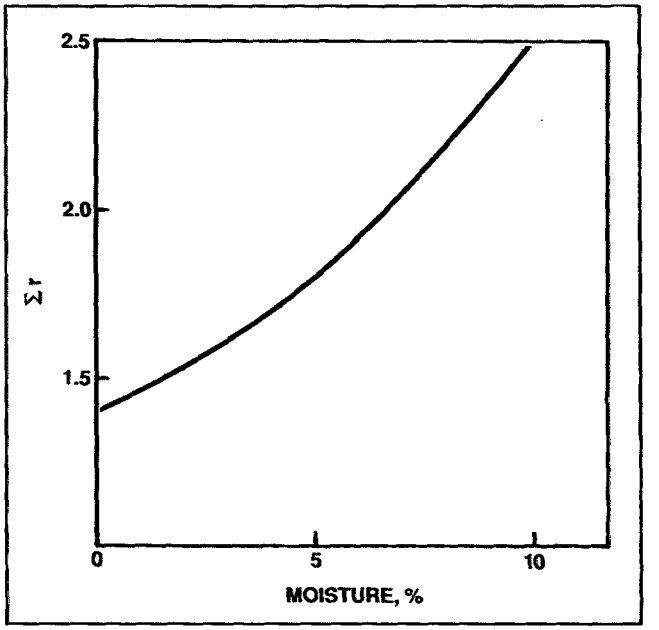
For cylinder board and other similar applications, a contacting caliper sensor poses almost no risk of tearing the sheet because of the sheet thickness. However, like the contacting moisture sensors, dirt and contaminant buildup on the sensor head reduces measurement accuracy. Taking the sensor off-line for frequent cleaning (as much as once every hour) is one solution, but it is time consuming and, over the long run, impractical.

Development of an air-bearing caliper sensor with an extended and accurate measurement range has therefore become an important requirement for these types of applications.

A new moisture and caliper sensor

A new sensor technology addresses the limitations of current moisture and caliper sensors for cylinder and other board applications with high recycled fiber content. Developed by Impact Systems of San Jose, Calif., this triple-patented technique combines the caliper and moisture sensor into one dual-sided, noncontacting sensor head (**Fig. 1**). Not only does this new design address the limitations discussed earlier, it also provides a more cost-effective solution compared to buying the sensors separately. The need for a basis weight sensor for moisture calibration is also eliminated.

2. The relative dielectric constant of paper as a function of moisture



At the heart of the new sensor is a pair of parallel conductive plates which are located on opposite sides of the moving sheet, forming a capacitor (Fig. 1). This

capacitance is proportional to both the moisture content of the sheet and its caliper. This is more specifically illustrated by the equation below:

$$C = E\,A/d$$

where

C = capacitance

E = dielectric constant between the plates

A = electrode area

d = caliper.

As shown in **Fig. 2**, the dielectric constant yielded by this equation is a function of the percent moisture. By measuring through the sheet in this way, the sensor is insensitive to both sheet flutter and moisture stratification, two problems associated with single-sided RF-type sensors.

The equation shows that capacitance has an independent variable, the caliper (d). To obtain the caliper measurement, one of the capacitor plates supports a magnetic core with two coils wrapped around it (Fig. 1). The capacitor plate on the opposite side is covered with a ferrite material, forming part of a magnetic circuit. Together, this arrangement forms a transformer. The coupling (or mutual inductance) between these two coils depends completely upon the size of the gap formed by the paper. By measuring this coupling, the thickness of the paper can be accurately calculated.

Like the primary magnetic reluctance principle used by standard caliper sensors, this patented (*1*) technique of mutual inductance yields a direct measurement of paper caliper, independent of composition, density, and sheet temperature. However, unlike the primary reluctance-type sensors, it also provides a wider measurement range. Recent tests show the sensor to be accurate from 100 microns to 3000 microns (4-120 mils). Current paper caliper sensors are accurate to about 1000 microns (40 mils).

Quad air bearings

The patented (*2*) dual-sided design of the caliper and moisture sensor provides the means for overcoming the problem of contaminant buildup on the sensor head. A patented (*3*) dual air-bearing system is utilized on both the upper and lower sensor head (**Fig. 3**), keeping the sensor from touching the sheet and avoiding dirt buildup on the sensor head. The dual air-bearing design also isolates the inner sensor element from all inertial sheet forces that can impact sensor accuracy.

The caliper measurement also is used to calibrate the moisture sensor to read percent moisture, a task commonly performed by a basis weight sensor.

Initial installation

The first installation of this new caliper and moisture sensor was at a board mill in California. The mill was installing an electric infrared moisture profiling system and felt that the added value of interfacing the new sensor technology with the profiling system would help them further reduce moisture profile variations.

The mill manufactures folding boxboard on a 72-in.-wide (1829 mm), nine-cylinder board machine. Product thickness ranges from 20 mils to 40 mils (500-1000 microns). The infrared moisture profiling system is installed on the last dryer can of the main dryer section.

The caliper and moisture sensor is mounted on an O-frame scanner, located after the dry calender stack just before the take-up reel. The sensor provides moisture and caliper profile measurements to the moisture profile control system via a local area network. Measurement displays and system controls are integrated into the operator station located at the backtender's control station. Using the moisture profile measurements, the infrared moisture profiling system automatically corrects the moisture profile by applying power to the areas of the web that require supplemental drying.

As a result of having installed the system, the mill has reduced its moisture profile variability by 40%, resulting in reduced moisture-related rejects and improved overall uniformity of the web. The mill has also gained some incremental drying capacity from the infrared moisture profiling system, providing a 3-5% production increase on dryer-limited grades. The mill also reports that the improved moisture profiles have, in turn, improved the uniformity of calendering and wet-finishing as well as made it possible for the mill to increase end target moisture for greater fiber and steam savings.

Several other mills have now installed the new caliper and moisture sensor, including an application where the sensor is "piggy-backed" onto a mill's existing measurement scanner and then linked to the host measurement computer for display. This provides a cost-effective, flexible solution for mills that already have a measurement system but do not have an adequate moisture or caliper sensor.

Summary

This paper has outlined the technology of a cost-effective new combined caliper and moisture sensor for board applications that equals the accuracy of dual-sided microwave sensors while effectively tripling the measurement range. Its insensitivity to sheet flutter, sheet temperature variations, carbon black, and contaminants makes it an ideal application for cylinder and other board applications that have a high recycled fiber content.□

Literature cited

1. Typpo, P., U.S. pat. 4,791,353 (December 1988).
2. Typpo, P., U.S. pat. 4,791,367 (December 1988).
3. Typpo, P., U.S. pat 4,929,895 (May 1990).

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