

ABB

Improving sheet dimensional stability to reduce paper rejects

By Shih-Chin Chen, corporate executive engineer QCS R&D

This article presents an application of a multivariable control on fiber orientation and weight profiles. With the online fiber orientation measurement and the multivariable control scheme, papermakers can reduce paper rejects due to sheet dimensional instability.

Fiber orientation is the inherent sheet property that determines the strength and dimensional stability (twist and curl) of a paper sheet. In papermaking processes, a number of process variables can influence the orientation of fiber distribution. Fiber orientation is strongly correlated with sheet strength and sheet dimensional stability.

Until recently, papermakers could only manually adjust process settings such as jet-to-wire speed difference, headbox slice opening, edge flows and headbox recirculation in order to keep fiber orientation within an acceptable range. If there is any process fluctuation, fiber orientation could drift away and it might not be easy for operators to manually compensate such drift.

An online laser-based FO sensor was invented in 1997 [1] and has been installed on numerous production machines. The online FO sensor shines polarised laser light on the sheet surface and measures the distribution of the reflected light. Depending on fiber distribution, the reflected light exhibits different distribution patterns. The fiber orientation is derived by measuring the reflected light patterns with three separate pairs of detectors as indicated in Fig. 1.

The tendency to twist and curl of paper sheet is associated with the two-sidedness of fiber orientation and sheet moisture changes [2]. Sheet dimensional stability (twist and curl) is correlated to the fiber angle and fiber ratio difference between the top and bottom sides of a

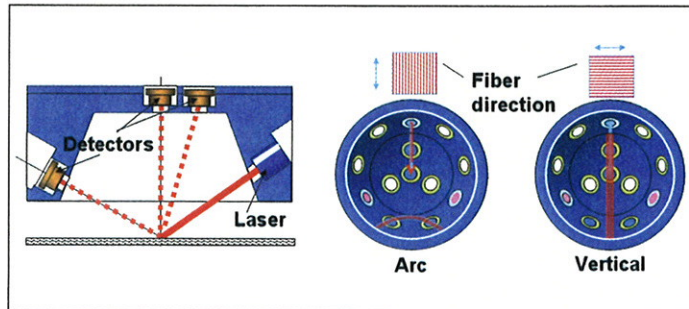


Fig. 1: Principle of online fiber orientation measurement

sheet. The twist index K_{xy} can be derived from online FO measurement using the following formula:

$$K_{xy} = (3H/t)(\bar{\beta}_2 - \bar{\beta}_1)(\alpha^w - \alpha^f) + c^o + c^d(r^w - r^f) + c^s(r^w + r^f)/2$$

H is the change of moisture content, t is sheet thickness, α is fiber orientation angle, r represents fiber ratio, and superscripts w & f indicate the wire and felt sides of the sheet, respectively. c^o , c^d and c^s are coefficients of fiber ratio influence. β_1 and β_2 are fiber hygroexpansivities aligned with the principal directions of fiber orientation. The above calculation can be applied point by point for the entire profile and produces a twist profile as indicated in Fig. 2.

When a bump test is performed on a slice screw, its responses on basis weight and fiber orientation profile can be detected. Fig. 3 illustrates such responses from a bump test that was performed on one zone of the top headbox. The weight response is symmetric with respect to

the bumped zone but the fiber angle response is anti-symmetric. Also, the width of the weight response is narrowly defined while the fiber angle response is extended significantly in cross-machine (CD) direction. Furthermore, as the jet-to-wire speed difference is reduced, the magnitude of fiber angle response to the slice screw change is also reduced as seen in Fig. 4. The response characteristics pose a great challenge for operators to control fiber orientation and weight profiles by manipulating each slice screw manually.

A multivariable CD (MCD) control technique is implemented for controlling both weight and fiber orientation profiles [3]. This control scheme is capable of taking in multiple profiles such as weight,

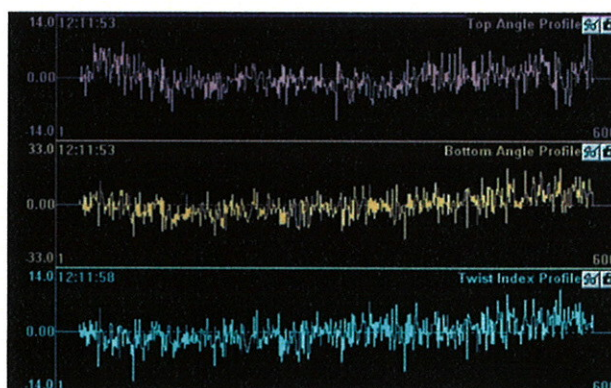


Fig. 2: Fiber angle profiles and the derived twist profile

fiber angles, fiber ratios and twist index to control multiple sets of CD actuators. Fig. 5 illustrates the application of this control scheme on a four-ply machine. On this machine, the slice screws of the middle headboxes only affect weight profile but the top and bottom headboxes affect both fiber angles and weight profiles. MCD control handles the coordination of all slice screw movements simultaneously to achieve the best weight and fiber orientation profiles automatically. Fig. 5(a) shows the profiles and slice screw settings before the control was turned on and Fig. 5(b) shows the result after the MCD has been applied. The top fiber angle is controlled to follow the shape of the bottom fiber angle profile so that the resulting twist is minimised. The effectiveness of the MCD control can be seen clearly in the resulting improvement in the twist index profile.

Benefits

Fiber orientation is the inherent sheet property that determines the strength and dimensional stability (twist and curl) of a paper sheet. With online fiber orientation measurement, the presented closed-loop multivariable CD control (MCD) is capable to control the combination of weight, fiber angles and twist/curl profiles to their selected targets. As the result of minimising the two-sidedness of fiber orientation, the twist and curl tendency of a sheet could be reduced. The application of online fiber orientation measurement and MCD control has proved to be an effective approach to improve sheet dimensional stability and reduce the associated paper rejects. ■

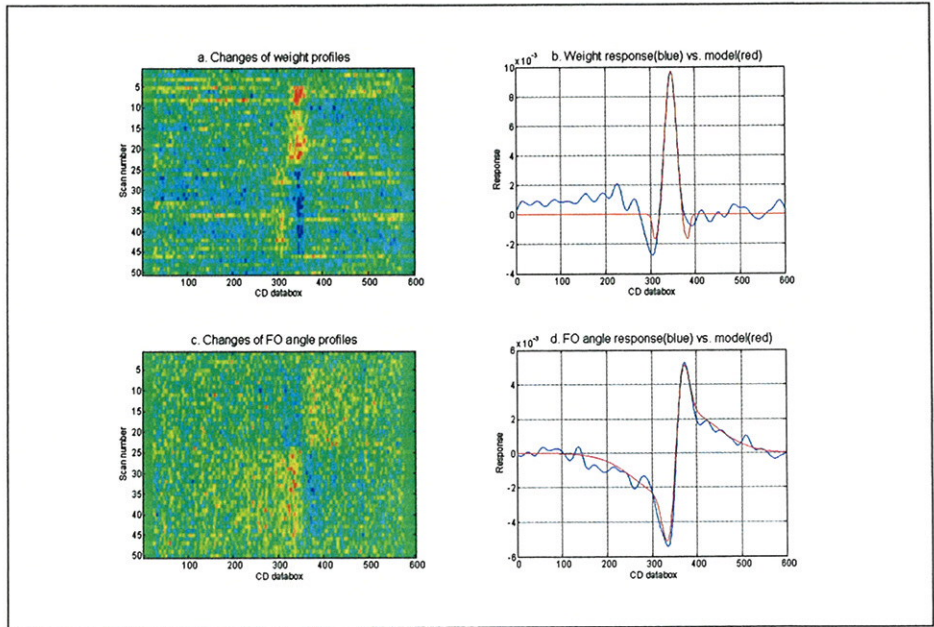


Fig. 3: Responses of weight and FO angle profiles with one slice screw bump test

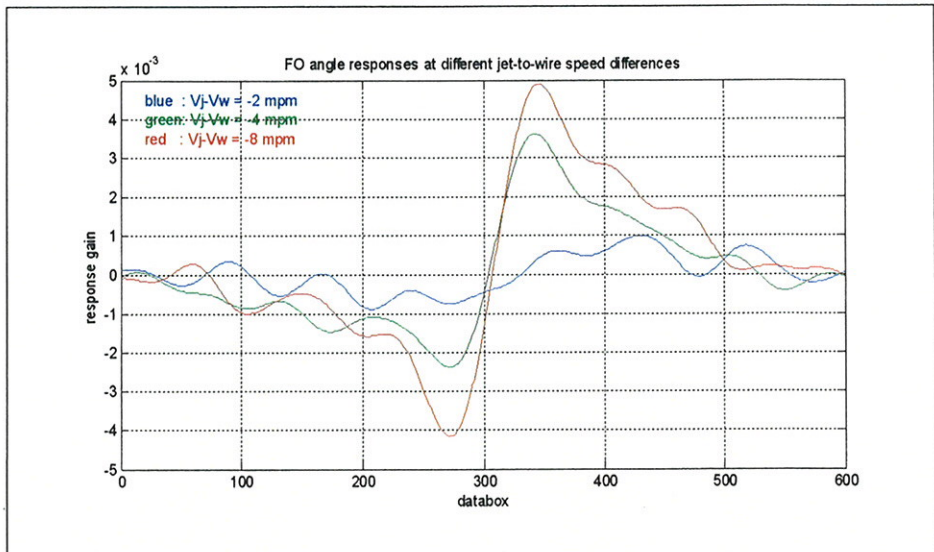


Fig. 4: FO response at various jet-to-wire speed differences

References

[1] Hellstrom, A.: Method and apparatus for on-line determination of fiber orientation and anisotropy in a non-woven web, U.S. Pat. 5,640,244 (1997)
 [2] Carlsson, L., et. al.: Curl and two-sidedness of paper, Svensk Papperstidning 7 (1980)
 [3] Berggren, J., Zehnpfund, A., Conway, D., Vasel, J., and Chen, S-C., "Multiple-input and multiple-output CD control applications - practical aspects", 2007 TAPPI Papermakers and PIMA International Leadership Conference, Jacksonville, FL, March 11-15, 2007

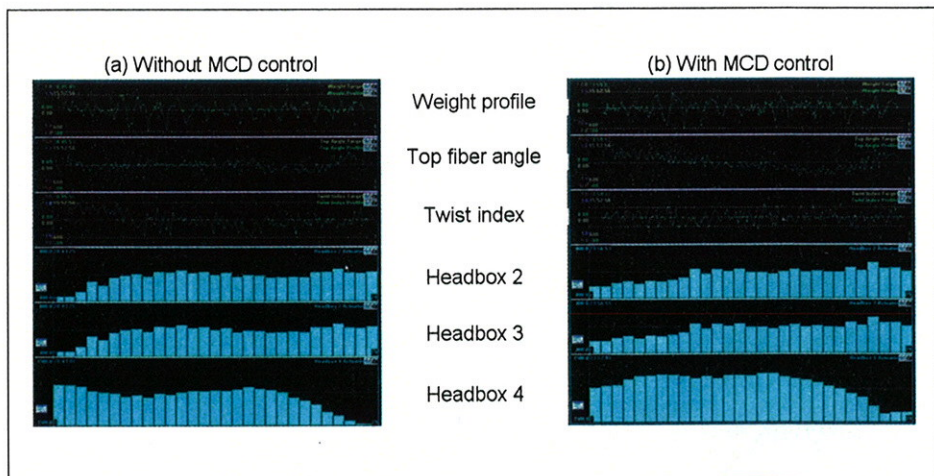


Fig. 5: Multivariable CD (MCD) control of weight and FO profiles