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TAPPI

Statistical process control - procedures for charting warp

Scope

This Technical Information Paper will concern itself only with statistical techniques used to measure and chart cross directional warp. Because there are no accepted procedures to measure the magnitude of end-to-end, "S," and twist warp, other statistical techniques must be used to record and chart the presence of these additional types of warp.

Safety precautions

If a paper knife or other cutting tool is used in sample preparation, proper safety precautions must be taken to avoid personal injury from knife cuts.

Content

In cross directional (CD) warp, the line of curvature (warp) moves across the corrugator; that is, the line of curvature is parallel to the flutes. In observing sheets as they are delivered from the corrugator, CD warp can be either "up" (normal) or "down" (reverse). The presence of even a slight amount of CD warp (either "up" or "down") can cause difficulties with efficiency, speed, and waste control, not only on a corrugator plant's own downstream production equipment, but on box users' automatic case setup, filling, and sealing machinery as well. Misfeeds, jam-ups, slot and print register variation, difficulties with vacuum handling equipment, and reduced operating speeds are typical results if warp is present.

Test methods

The Corrugated Industry Development (CID) group completed a major study in the early 1970s on warp. Warp was defined as a function of sheet width with the result called a warp factor. The formula to determine the warp factor (WF) is as follows:

Formula for measurements expressed in millimeters:

$WF = (14{,}650 \times \text{warp})/(\text{sheet width})^2$

Formula for measurements expressed in inches:

$WF = (576 \times \text{warp})/(\text{sheet width})^2$

The resulting WF is expressed in decimal form.
The CID group also defined “flat” board as having a WF of equal to or less than 0.25. For definition purposes, up
(normal) warp is positive and down (reverse) warp is negative. The nominal definition of flat board is board having 6.4

Time: Mark each sheet with the time of day when the sample was taken.
Trial number: The position “A” sample must always be identified with the trial number (if one is used) and “time.” Other positions need not have the trial number identification as long as “position” and “time” is identified.

Drawing warp profiles

A “warp profile” is drawn with sheets on end with the identification “up and away,” i.e., the DFL (doubleface
liner) side is toward you with the trailing edge contacting the profile strip. The profile is traced with a felt tip pen held
against the DFL side of the combined board.
The warp profiles should be drawn on white heavy-weight paper or bleached 42 lb liner strips. Cut strips about 10
x 12 in. wide by about 8–9 ft long. Support on a 4 x 8 flat piece of plywood or suitable table.
Trace profiles between time intervals of **5 min** and **10 min** after sheet delivery, i.e., do not start tracing before **5**
min has passed and be finished before **10 min** have elapsed. All “at corrugator” sampling should be done in this manner.
If time permits, sample and trace two or three profiles from each position and average the results.
Always use a felt tip pen with a broad rectangular type tip. Use two colors, alternating so that adjacent profiles
representing different samplings are of a different color. This makes it easier to record warp factors. Figures 3 and 4
illustrate this procedure.

Warp measurement

All warp values are reported as warp factors. Warp factor represents the inches[1] of warp, in decimal form in a **610-**
mm (24-in.) wide sheet. In other words, no matter what the width of the sheet, its warp is reported as if the sheet were
610 mm (24 in.) wide.
Warp measurement is made by placing a transparent plastic grid over the warp profiles and noting the type and
amount of warp present. The grid is marked in **6.4-mm** (1/4-in.) divisions with major marks at **63.5-mm** (2.5-in.)
intervals. To simplify measurement and conversion into warp factors, the plastic grid is marked to indicate spans of **305**
mm (12 in.), **432 mm** (17 in.) and **610 mm** (24 in.). For sheets near **432 mm** (17 in.) and **305 mm** (12 in.) in width,

double the reading for the **432-mm** (17-in.) span and multiply by 4 for the **305-mm** (12-in.) span to obtain warp factors.
Refer to “rule of thumb table” (Fig. 5).
When studying warp, it is desirable to look at four positions across the width of the corrugator. Most corrugators
have what is called a position effect, i.e., the operator's side may show up warp most of the time, the next position over
(operator center) may show some reverse warp, etc. By determining the predominant type of warp at each of the four
positions, it is possible to detect problem areas such as uneven adhesive application, perhaps uneven liner tension over
preheaters, etc. Both edges may have some tendency for S warp. This is easily detected with the plastic grid and may be
reported by warp factors such as 0.25/0.40*R*, which would indicate S warp with **6.4 mm** (0.25 in.) of normal warp at the
left and **10 mm** (0.40 in.) of reverse warp on the right portion of the sheet. When recording warp factors, *R* placed after
the number indicates reverse warp. If *R* is not present, the warp factor indicates normal warp. **The notation + = normal
warp and – = reverse warp have been added to facilitate use of warp factors with SPC.**

Keywords
Cross direction, Warpage, Charting, Process control, Statistical methods