LINERBOARD: THE RELATIONSHIP BETWEEN POLAR ANGLE PROFILE AND TWIST WARP

Project 2926-13

CONFIDENTIAL

to the

TECHNICAL DIVISION
OF THE
CONTAINER KRAFT PACKAGING GROUP
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INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY
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A Progress Report
to the

TECHNICAL DIVISION
OF THE
CONTAINER KRAFT PACKAGING GROUP
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By
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February 1, 1993
Linerboard: The Relationship Between Polar Angle Profile and Twist Warp

Irwin M. Hutten

The purpose of this presentation is to provide a simple explanation to linerboard manufacturers and box plant operators as to how fiber orientation in linerboard as measured by polar angle is related to twist warp. Hopefully, a better understanding of this relationship will provide better guidance to the solution of twist warp problems that now appear to be of such serious concern to the industry.

Two major causes of twist warp in a box plant are:

1. A moisture imbalance in the liners combined with a corrugator tension imbalance. This is a box plant controllable process condition.

2. Nonnormal orientation of fibers in the linerboard. This is a paper mill controllable process condition.

Twist warp of corrugated paper board sheets is a major quality concern to box plants and corrugated board users. It refers to the very condition where one pair of diagonal corners of the corrugated sheet twist up and the other pair of diagonal corners twist down. The resulting shape is similar to that as depicted in Figure 1. Twist warped corrugated structures, like this, can cause jams on high speed converting equipment and box set-up and packing equipment.

It has already been mentioned that twist warp is caused by the fiber orientation of the linerboard components of the corrugated combined board structure. Fiber orientation can be measured by ultrasonic techniques developed at the Institute of Paper Science and Technology. The result is called a polar angle. A polar angle can be perceived as being the average of all fiber orientations in the area of specimen being measured. A polar angle is referenced to the machine direction of the sheet. If the average fiber orientation is perfectly parallel to the machine direction, the polar angle is zero. If the average fiber orientation points to the right of the machine direction, the polar angle is positive. Conversely, if the average points to the left of the machine direction, the polar angle is negative.

If polar angles are measured at spaced intervals across the roll, a cross direction profile is developed. Figure 2 is an example of such a profile on a linerboard roll. Note in this particular case all the polar angles are positive and between $5^\circ$ and $10^\circ$. This is the
profile of a roll of linerboard on its way to the box plant to cause twist warp. Why this is so is explained below.

First, two characteristics of polar angle profiles are identified in Figure 2. The first characteristic is called rotation. Rotation is the slope of the best fit line drawn through the profile. It is measured by the angle this line makes with the horizontal. The second characteristic is called translation. Translation can be considered as the average polar angle of the profile. More specifically, it is the polar angle as calculated for the center position of the profile. In the case of Figure 2 the translation is calculated to be 8.51°.

Figure 3 is a schematic illustration of linerboard rolls having the polar angle profile or fiber orientation as depicted in Figure 2. The arrow on the single face (SF) roll is positive and represents the general nature of the polar angle profile diagrammed in Figure 2. The double face (DF) roll, from the same roll position, has the same polar angle profile as the SF roll. In combined board operation the DF is normally turned around so that the felt or smooth side on both sides of the subsequent combined board will be the outside surfaces. Note from Figure 3, the arrow representing fiber orientation in the DF roll and panel component is also turned around so that it is now diagonally opposite and negative with respect to the SF arrow. When the two panel components are combined as they would be in corrugated sheet the arrows crisscross. When the sheet is exposed to a change in humidity then the major dimensional change in each face will be along axes parallel to the diagonal arrows. Along each set of diagonal axes, one face will grow faster than the other. For the slower growing face to play catch-up, the faster growing face will have to curl around it. One set of diagonal corners will try to curl up, the other set will try to curl down. When this happens it is called twist warp.

Box plants experiencing twist warp problems often reverse one of the rolls as illustrated in Figure 4. This often corrects the twist warp problem, if it is polar angle related. However, this is at the penalty of exposing the less aesthetic wire side as an outside surface. Note from Figure 4, that when the DF roll is reversed, both SF and DF arrows point in the same direction. When the corrugated sheet so simulated undergoes exposure to a change in humidity, dimensional change in both faces will be the same in all directions. Twist warp should not occur. If it does, it will most likely be due to the combination of moisture imbalance and corrugator web tension differences.

Figure 5 is an example of another type of linerboard roll profile. The profile has negative polar angles on the left hand side of the sheet, positive polar angles on the right hand side and zero polar angle in the middle. The rotation of this profile crosses the zero line near the center of the profile, therefore the translation is zero.

The arrows in the SF and DF roll schematics of Figure 6 are representative of the polar angle profile plotted in Figure 5; negative angles on the left, positive angles on the right and zero angle in the middle. Because of symmetry, this arrow profile remains the
same when the DF roll is turned around. Note that when the two panel components come together in the combined board structure, the arrows in both faces all point in the same direction. Dimensional change due to a change in humidity and moisture content will be the same for all directions of the SF as it is for the DF. The combined board structure is not expected to exhibit twist warp due to polar angle.

The above examples illustrates that the critical factor in the box plant operation is translation and not rotation. More specifically, it is the difference in translation between the SF and DF liners. This has already been illustrated in Figure 3. When the DF liner was turned around, the translation of that liner as represented by the arrow was also turned around so that it went from positive to negative. Obviously, the negative translation of the DF liner when combined with the positive translation of the SF liner is going to result in a large difference in translation and a condition for possible twist warp. This difference in translation and condition for twist warp was eliminated when the DF roll was reversed as illustrated in Figure 4.

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Figure 1

TWIST WARP IN COMBINED BOARD
Polar Angle Profile of a Linerboard Roll

High Translation

Translation = 8.61 deg.
Figure 3

TWIST WARP
EFFECT OF HIGH TRANSLATION

Single Face Roll

Double Face Roll

Combined Board

Humidity Change

Twist Warp
Figure 4

TWIST WARP

EFFECT OF HIGH TRANSLATION
(Double Face Roll Reversed)

Single Face Roll

Double Face Roll (reversed)

Combined Board

Humidity Change

No Twist Warp
Figure 5

POLAR ANGLE PROFILE OF A LINERBOARD ROLL
Low Translation

Translation = 0
Figure 6

TWIST WARP
EFFECT OF LOW TRANSLATION

Single Face Roll

Double Face Roll

Combined Board

Humidity Change

No Twist Warp