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Statistical process control: friction – slide angle

Scope

Friction of corrugated board ensures that boxes made from that board will not slip from a load. Some newer methods of material handling rely on a certain friction between the boxes, so it is important for the boxmaker or his linerboard supplier to control the amount of friction. The angle of inclination at which one box on top of another will just begin to slide is a measure of the coefficient of static friction between the two surfaces of the two boxes in contact. Derivation will show that the coefficient of friction is equal to the tangent of the angle of inclination from the horizontal. The coefficient, hence the angle itself, is independent of the force applied between the two surfaces. Therefore, the coefficient of friction or slide angle is not dependent on the weight of the box and its contents.

The test covered in this technical information paper was devised to measure the coefficient between two box surfaces. It can also be used to measure the coefficient of friction between two paper surfaces prior to fabrication of the box. The test can be applied to linerboard before corrugating, to corrugated board after combining, and at any point up to and after box fabrication. Subsequent treatment, rubbing, or abrasion of that surface can alter the coefficient significantly. This is especially true if frictionizing materials have been applied to the surface. Subsequent processing could remove the frictionizing material, thereby lowering the coefficient.

To determine conformance to specifications, the test should be made after all the fabrication steps have been completed. It is advisable to simulate the same point in the distribution cycle at which the customer is performing the test and setting specifications. For control, slide angle measurements should be made as early in the process as possible. When frictionizing materials are being applied at the corrugator, the test should be made after the take-off in order to be able to adjust the application.

The slide angle created by the addition of nonskid on corrugated boxes will tend to decrease as blanks come into sliding contact with other boxes (including processing over flexo-folder-glue and automated case erecting and filling machinery). Because of this, studies may have to be undertaken to determine the higher target necessary at the corrugator to meet a customer's final use requirements.

Safety precautions

There are no safety precautions.

Content

Test methods

The test to determine surface friction (slide angle) is TAPPI Test Method T 815 "Coefficient of Static Friction of Corrugated and Solid Fiberboard (Inclined Plane Method)." Alternatively, TAPPI Test Method T 816 "Coefficient of Static Friction of Corrugated and Solid Fiberboard (Horizontal Plane Method)" can be used. When trying to compare data from the two different tests, the conversion table in Table 1 can be used to convert from "coefficient of static friction" to "Slide Angle" or vice versa. T 815 calls for measuring the angle at which motion just starts on the third slide. However, experience has shown that there is little difference between the first and third slides.

Sampling and charting

For incoming materials: Obtain samples of the linerboard from the rolls. Normally, linerboard is uniform in friction across the roll width, but can vary significantly from roll to roll. To begin, a single $\bar{X}$ ($\bar{X}$ -bar) and R chart is recommended. Obtain samples from five rolls per car, perform testing, record the data, and plot the average and range. The supplier, grade, and car and roll numbers should be carefully recorded. When sufficient data have been collected (usually 20 – 25 sample lots), control limits can be calculated. Analysis of the chart will provide clues pointing out suppliers or grades that may be causing problems. It may be decided that more selective charting is necessary to get facts or audit supplier compliance on a per-supplier or per-grade basis. Figure 1 is a sample $\bar{X}$ and R chart.

If you have completed a process capability study and determined that the process natural variation falls within your requirements for slide angle, action is warranted if tests indicate a shipment has a coefficient of friction lower than the control limit. This could result in rejection of the shipment or at least a warning issued to the supplying mill. The shipment could be tagged for special treatment. It could be used for inside of doublewall (middle liner) low C. O. friction may cause handling problems in plant if used as inside liner. For use on less critical orders, or used only when frictionizing material is to be subsequently applied. Some incoming liners may be too low in coefficient of friction to meet a specification, even with frictionizing.

On rarer occasions (and this may be the case with mottled white liners) the coefficient of friction may be too high, resulting in a drag on the corrugator. Again, the supplier may be warned, but in this instance, friction can be reduced by applying a lubricating agent at the corrugator hot plates.

For control of frictionizing application: Slide angle can vary across the web due to nonuniform application. Take samples from at least three positions across the web at the take-off. Depending upon the type of applicator, more may be required. Make measurements of slide angle with the appropriate apparatus on each sample. Record the average and range for each set of samples. At a minimum, a set of samples should be taken at the beginning of a run and for each roll of linerboard subsequently used at the doublebacker.

For compliance with specifications: In the case where an absolute minimum slide angle specification for a given customer is established, a simple individual and moving range X and MR chart should be used. A single reading is recorded and plotted along with the moving range. Because the X and MR chart is a chart of so-called individuals, the reject limit may be shown on this chart as well as a somewhat higher action limit. If nonskid is being applied, then more can be applied if the action limit is reached. If the run does not have nonskid and the action limit is reached, then either the doubleface liner can be changed or nonskid application can be initiated. Figure 2 is a sample X and MR chart.

The control chart

The control chart is designed to detect the presence of assignable causes of variation. By allowing a range for test values that accounts for the normal variability of a process in control, tests out of that range are considered to be caused by some change in the process that can presumably be corrected. An $\bar{X}$ and R control chart (Figure 1) shows sampling of incoming roll stock and an X and MR control chart (Figure 2) shows sampling off of a corrugator run.

Calculations: Determine the grand average, $\bar{\bar{X}}$ ($\bar{X}$ for X and MR charts) and the average range, $\bar{R}$ (average moving range for X and MR charts) for the first 20 or 25 lots of either incoming material, sets from corrugator runs, or individual measurements when frictionizing material is being applied. The control limits for the control chart will be as follows:

For $\bar{X}$ and R

$$UCL_X = \bar{\bar{X}} + A_2 \bar{R}$$

where $A_2 = 1.023$ when $n = 3$
and 0.577 when $n = 5$

$$LCL_X = \bar{\bar{X}} - A_2 \bar{R}$$

$$UCL_R = D_4 \bar{R}$$

and $D_4 = 2.574$ when $n = 3$
and 2.114 when $n = 5$

$LCL_R = D_3 \bar{R}$ and is “none” because D_3 has no value for sample sizes less than 7.

For $\bar{X}$ and MR

$UCL_X = \bar{X} + 2 (\bar{R} / d_2)$ where $d_2 = 1.128$ when $n = 2$)

$LCL_X = \bar{X} - 2 (\bar{R} / d_2)$

$UCL_R = D_4 \bar{R}$

where $D_4 = 3.268$ when $n = 2$

$LCL_R = D_3 \bar{R}$ and is “none” because D_3 has no value for sample sizes less than 7.

Corrective measures

Corrective measures for incoming materials that are out of allowable limits were discussed earlier in this TIP. Where frictionizing material is being applied, corrective action can be initiated when the process is out of the control range.

The first step would be to:

1. Use indicator spray to ensure the test specimen has been coated. If there is no indication, check the application equipment. If there is indication, check:
 - a. Initial slide angle of untreated liner or board.
 - b. Dilution of the frictionizing agent. (The concentration of the agent may be increased.)

Only when all of the above is within the norm is it worthwhile to change lots of the frictionizing agent.

Keywords

Statistical methods, Slide angle, Friction factor, Container boards, Corrugated boards, Process control

Additional information

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