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Utilizing statistical process control techniques to assist in meeting specification at finishing crush process control points to the paper and paperboard industries

Scope

Caliper is an indirect measure of the compression stacking of corrugated boxes. Low caliper usually results in corrugated box performance below specifications. Caliper is maximized by (1) proper flute formation and bonding, and (2) minimizing crush after formation.

The intent of this Technical Information Paper will be to discuss the benefits of SPC techniques and the application of these techniques to finishing machine crush.

Discussion on box plant quality measurement TAPPI TIP 0304-02 “Box Plant Quality Measurement: Why Test?” and corrugated box plant quality targets TAPPI TIP 0304-03 “Corrugated Box Plant Quality Targets” review questions and answers regarding quality and testing. TAPPI TIP 0304-04 “Corrugated Caliper: Why Is It So Important?” details the importance of corrugated caliper in corrugated container construction.

Safety precautions

There are no safety precautions.

Content

Test Methods

TAPPI T 411 “Thickness (Caliper) of Paper, Paperboard, and Combined Board” discusses test methods to obtain thickness (caliper) of combined board. Motor-operated micrometers will not normally be found in the box plant environment. Therefore, attention should be drawn to the Appendix of TAPPI T 411 where there is a discussion on use of manually operated, dead-weight actuated, dial-type micrometers.

Sampling

Opportunities for flute crush exist in the box plant at any point combined board passes through the nip of two rolls. Examples of finishing equipment nip points are flexo folder gluer or rotary die cutter feed rolls, impression at print stations, pull collars, slotter heads, and rotary die drum impression.

Beginning caliper is that recorded from combined board arriving from the corrugator. The amount of crush at the finishing operation would be the difference between the caliper recorded on the board that has completed the path through the finishing equipment and the caliper of the arriving board.

Samples of board should be taken from the exit side of finishing equipment. Feed roll crush and print cylinder crush should be areas of major concern. Samples should be taken at two to four positions across the blank and use the average of those readings as the $\bar{X}$ value. If there is more than a 0.002 m variation in the readings, consideration should be given to having separate $\bar{X}$ and MR charts for each position.

Frequency of sampling would be at the discretion of the user plant. However, usually a check would be made at the beginning of each order. Frequency of checks during the running of an order would depend on the tightness of control desired.

Measurements

Operating personnel should be taking and recording measurements. For detailed analysis, any specific area of crush should be recorded separately such as feed roll crush or print roll crush. Occasional detailed analysis of specific areas can provide information concerning machine condition such as feed roll wear, bearing wear, printing die wear, etc., operator habits, and shift variations.

Each measurement will be the result of averaging three caliper readings in a triangle in an area approximately 0.152 m² or 152.4 mm² (6 in²).

Several options exist for control charting. Separate charts could be established for the drive side and the operator side. This may be desirable if feed roll wear or bearing wear is suspected. A single chart can be set up which charts the average of the caliper readings from the positions checked.

Statistical process control

Statistical process control techniques can be used to establish many things. Previously mentioned points would be feed roll wear, bearing problems, and operator habits. The most applicable chart to plot the area of finishing crush is the $\bar{X}$ and MR chart (see Fig. 1 for a blank; see Fig. 2 for an example of a completed chart). The $\bar{X}$ and MR chart permits operators or supervisors to be able to plot the latest reading and compare the value to a central line and to control limits. The determination of control limits requires knowledge of process variability. Control limits, developed over a period of time, could also be published on the control chart.

Many computer software packages are available that will allow rapid statistical calculations and quickly generate completed charts.

Individual and moving range ($\bar{X}$ and MR) chart

Uses for this chart (see Figs. 1 and 2) include the following: (a) adhesive quality measurement (gel point, batch temperature, and viscosity); (b) caliper loss during a converting operation; and (c) possible for warp measurement.

Formulas involved are as follows:

- (1) Individual X readings are plotted.
- (2) The average $\bar{X} = \Sigma X / N$.
- (3) The moving range (MR) values are determined by finding the difference between the current measurement and the next most recent measurement.
- (4) The average $\overline{MR} = \Sigma MR / (N - 1)$.
- (5) Control limits for MR :

$$UCL_{MR} = D_4 (\overline{MR})$$

Since our sample size is always two, D_4 will always be 3.267. There is no LCL because the formula for the LCL contains D_3 which, for a sub-group of two is zero.