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Short-run statistical process control: a basic charting method

Scope

This Technical Information Paper describes a method of using short-run SPC techniques to measure process variation where production runs are too short to employ classic SPC techniques. Short run SPC techniques are particularly well suited to the job-shop order patterns that characterize the corrugated box industry. While the statistical techniques described in this TIP are somewhat sophisticated, the method described is valuable in that different characteristics can be measured on each series of order items (see Fig. 4 – example). This TIP assumes that the reader/user has a basic understanding of $\bar{X}$ -Bar and R control charts.

NOTE 1: The statistical technique describe in this TIP is not recommended when a single characteristic (e.g. caliper off the corrugator) is plotted over time for several order items. For single characteristic statistical charting, plotting “Deviation from Nominal” on standard $\bar{X}$ -Bar and R charts is recommended. It is a less complicated and very descriptive statistical method that is superior to the short run statistical method described in this TIP for this application.

Safety precautions

No additional safety precautions are required other than the normal safety precautions that should be taken for working around machinery and paper while gathering samples for evaluation and while operating testing equipment.

Definitions

LCL :	Lower control limit
UCL :	Upper control limit
$\bar{R}$:	The average range
D_3 and D_4 :	Statistical constants used to calculate LCL and UCL for Range Charts
A_2 :	Statistical constant used to calculate LCL and UCL for $\bar{X}$ -Bar Charts
Order Item:	A box, die cut shape, sheet or other corrugator product
Order Item	
Characteristic:	A characteristic of an order item (e.g. caliper of corrugated board)

Materials

No special materials required.

Content

The manufacturing environment has undergone many significant changes since Dr. Shewhart of Bell Labs first developed control charts in the 1920s. The increasing implementation of just-in-time (JIT) inventory control systems, which container manufacturers and their associated suppliers are experiencing, demands smaller lot sizes with shorter production runs. This means more frequent setups or changeovers to accommodate many different part numbers with different specifications, all run across the same equipment.

One approach to process control in this type of situation is to have separate control charts for each order item characteristic. This method, while valid for each order item characteristic, is not very effective in evaluating the continuous performance of the process or equipment. Hundreds of different containers could be run on a particular piece of finishing equipment, meaning dozens of control charts would be required for each machine. If separate charts were kept, it would take a long time to collect data and calculate control limits. Also, plotting data on separate charts means that any time-related changes affecting consecutively run models would be impossible to detect.

Another traditional approach is to record all measurement data for a given characteristic on the same control chart with one large scale. However, this can send misleading signals to the operator, because each measurement may be at a different absolute level for different order item characteristics making the chart appear out of control. (See Note 1 to manage these situations.)

There is a charting method (developed by the International Quality Institute) that addresses this situation. This chart is designed for monitoring the output of a process running small lot sizes. It allows data from different order items and order item characteristics to be plotted on the same chart, thus eliminating the need for many separate traditional charts. Since the data taken from different order items are plotted in chronological order on one chart, time-related process changes become easier to detect.

Basic Theory

This technique is accomplished by using special data transformation that scales all process output data to a common distribution. Subgroups from different order items run over the same machine can be plotted on one standardized chart, with the same set of control limits for all models.

The data transformation for the short-run range chart is derived as follows. The traditional Shewhart range chart is in control when the subgroup range, (R), falls between the control limits as follows:

$$LCL_R < R < UCL_R \quad (1)$$

or

$$D_3 \bar{R} < R < D_4 \bar{R} \quad (2)$$

If the $\bar{R}$ for gap width changes from one box to another because of different box specifications, then so do the control limits, since they are a function of $\bar{R}$. This means separate charts must be maintained.

But if the above inequality is divided by $\bar{R}$, the result is control limits that are independent of $\bar{R}$ as follows:

$$(D_3 \bar{R} / \bar{R}) < R / \bar{R} < (D_4 \bar{R} / \bar{R}) \quad (3)$$

When eq. 3 is divided by $\bar{R}$, the result is:

$$D_3 < R / \bar{R} < D_4 \quad (3A)$$

If the range of a sample is divided by the historical $\bar{R}$ value for that order item characteristic, one can plot the result on a range chart with D_3 as the lower control limit, D_4 as the upper control limit, and the number 1 as the centerline.

Therefore, the range plot point for order item characteristic A is calculated as follows:

$$R \text{ (plot point)} = R_A / \bar{R}_A \quad (4)$$

where R_A is the target value for part A , which can often be derived from the historical average.

NOTE 2: Control limits are independent of $\bar{R}$ and are constant for a given subgroup size. This is because the data transformation (scaling) makes the plot point a dimensionless number. Refer to Fig. 1.

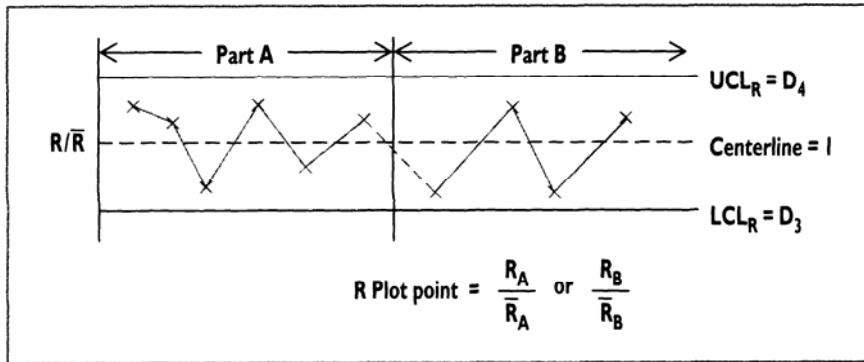


Fig. 1 Range plot point and centerline.

The control limits of the $\bar{X}$ -bar chart are also a function of R -bar as well as $\bar{X}$ -double bar (the grand average). For a given part number, the $\bar{X}$ -bar chart is in control when all of the $\bar{X}$ -bars fall between the control limits. This is represented by:

$$UCL_{\bar{X}} = \bar{\bar{X}} + A_2 \bar{R} \quad (5)$$

$$LCL_{\bar{X}} = \bar{\bar{X}} - A_2 \bar{R} \quad (6)$$

Therefore, control is indicated by:

$$LCL_{\bar{X}} < \bar{X} < UCL_{\bar{X}} \quad (7)$$

or

$$\bar{\bar{X}} - A_2 \bar{R} < \bar{X} < \bar{\bar{X}} + A_2 \bar{R} \quad (8)$$

If $\bar{X}$ -double bar is subtracted from the inequality, the result is:

$$-A_2 \bar{R} < \bar{X} - \bar{\bar{X}} < A_2 \bar{R} \quad (9)$$

But in this state, the limits still depend on R -bar, if R -bar changes, the $\bar{X}$ -bar control limits also change. To remedy this, the data are scaled by dividing by R -bar. The result is:

$$-A_2 < (\bar{X} - \bar{\bar{X}}) / \bar{R} < A_2 \quad (10)$$

Now the limits are independent of R -bar; therefore, order item characteristics with different averages and different ranges can be plotted on the same chart, as follows:

$$\bar{X} \text{ (plot point)} = (\bar{X}_A - \bar{\bar{X}}_A) / \bar{R}_A \quad (11)$$

where

$\bar{X}_A$ = the average of the current subgroup for order item A 's characteristic being measured