How statistical process control works in a corrugated box plant

David A. Carlson

Most of the SPC work in the corrugated industry is really a form of statistical quality assurance. This is a prerequisite to true SPC, which involves control of machine settings to reduce variation in product quality.

Every industry believes that it is unique and that application of statistical process control (SPC) will lead to special difficulties and peculiar problems. The corrugated box business is no different, and corrugators often invoke the following litany of peculiarities to explain the absence of SPC in their plants.

We're a job shop. Each incoming order is unique with regard to a combination of factors, including dimensions, printing, board combination, and quantity. Nothing is manufactured until an order is received from a customer. The amount of time that any given order is on any particular machine may range from a few minutes up to a few hours, after which we proceed with a new setup, changing all of the settings, printing plates, scores, slitting knives, and so forth.

We only do short runs. Because any particular order is being run on a given machine for a relatively short period of time, we don't see variation during that particular run on many of the quality characteristics that we and our customers consider to be important. Board caliper, box dimensions, and printing are either 100% correct or we have made a major mistake with our setup.

We're on track as long as we meet minimum requirements. We frequently deal with characteristics that have a specified minimum, such as bursting strength, flat crush, basis weight, box compression, and caliper. We don't worry about how much in excess of the minimum we have gone.

We have a wide range of quality requirements from our customers for products that are essentially similar. Take the situation where two customers are buying a similar sized box made from the same board grade and flute and run over identical equipment in a corrugated box plant. The first customer with automatic packing equipment and high-bay warehousing would demand excellence at the manufacturer's point and careful control of caliper for good compression performance. The other customer is hand packing his product and has no compression requirements. The second customer may find boxes with crooked manufacturer's points, with some points even slightly stuck together and with significant caliper losses acceptable to him. With both orders of boxes fit for the particular customer's use, how can the boxmaker set common internal standards?

Implementation of the SPC process requires commitment. Consider a situation where a company feels compelled to chart a single characteristic, such as variation in the manufacturer's joint gap on a flexo folder gluer. The supervisor and work crews who were involved in the project would need to receive some minimum amount of instruction, and the local plant's production management team would have to be involved enough to ensure continuation of the effort. The commitment to proceed in this matter would not be great. The company might keep a customer at bay for a while, but customers who are knowledgeable about SPC would seriously question its motives.

The entire concept of SPC really implies a significant change in management style. Implementation of SPC shifts the focus of the quality improvement process from the supervisor level (inspection/detection mode) to the operator level (prevention mode). When management asks operators to be responsible for the quality of their output, management must, in turn, eliminate any obstacles that might prevent the operators from producing top-quality products. This implies a significant amount of trust between management and operators. It also implies that management will respond when operators bring problems to their attention. This philosophy is intertwined in several of W. Edward Deming's 14 points (*1*):

1. Create consistency of purpose for improvement of products and service with a plan to become competitive and stay in business.
2. Adopt the new philosophy of no longer accepting delays, mistakes, defective materials, and defective workmanship.
5. Find problems and fix them. Adopt the philosophy of continual improvement.
7. Institute modern methods of supervising.
8. Break down barriers between departments.
9. Drive out fear among employees.
12. Remove barriers that stand between the hourly worker and his or her right to pride of workmanship.
13. Institute a vigorous program of education and retraining.

These are only eight of Deming's fourteen points, but they do provide an idea of his managerial philosophy.

Carlson is manager of quality assurance at Stone Container Corp., 150 N. Michigan Ave., Chicago, Ill. 60601-7568.

Requirements for implementation of SPC

What is required for implementation of the SPC process within a corrugated box plant? The following considerations should be taken into account.

Management commitment. SPC can be used to enhance productivity, safety, quality, and to reduce waste. But regardless of its function, there is no way an SPC system will work unless the general manager and the rest of the management team are fully committed to making the system work. It is one thing to say that you are committed to quality. Your employees will remain skeptical unless they find a consistent message in everything that is spoken, written, and done.

Training and education. Each location needs to have someone with expertise in SPC. This ensures that the correct charts will be used for each characteristic measured and that the mathematical calculations will be done properly. This person would also provide training to the sales force, hourly workers, and office employees. If implementation is done correctly, we are talking about a substantial portion of one individual's time. Another part of the training process would involve providing some formal education in statistical methods for the general manager and the other members of the management team at each location.

Participation extended to the office. Studies have shown that between one-third and one-half of all mistakes and errors in the typical box plant originate somewhere other than the manufacturing department (*2*).

Quality as a process and not as a program. Employees have seen quality programs come and go for years. They remain skeptical. It is highly desirable that a company have a broad statement outlining the philosophy supporting the way that the corporation is going to conduct its business. The quality process is developed to support the company philosophy and to fit within the corporate culture. Employees can see a common thread from the corporate philosophy through the quality process and their involvement in that process.

Quality as a never-ending process. There are always additional problems to solve and additional customer requirements to be met.

SPC as a tool and not as an end. Taking measurements and charting those measurements cannot change a single thing with regard to how a particular process is operating. Measuring and charting can help identify the magnitude of a problem, but the problem must be solved before improvement is noted. Creating the climate to solve problems and actually doing so, whether through the use of engineering solutions or input from employees, is a management responsibility. Once a solution has been implemented, statistical tools can be used to evaluate the action taken.

Employee involvement techniques. Employee involvement activities or the use of quality circles is a key element of any quality improvement process, and one that is essential for effective problem solving in any plant. Management has been reluctant to tap the vast body of knowledge within our employee group. Who knows more about the problems on a particular machine than its operator? Would not that operator be quite capable of offering constructive suggestions on solving problems? What better way is there to align the goals of management and the hourly work force than to listen to, and implement, the problem-solving suggestions of those hourly employees? Ninety-five percent of all hourly employees want to do a good job. It is management's responsibility to create the climate to achieve the full benefits of our employees' talents. The employee involvement concept is a unique tool to achieve employee participation (*3*). It may well be more influential in the success of quality improvement than the adoption of SPC techniques. Indeed, a strong case can be made for starting the process of quality improvement with employee involvement. Once the employees are confident that management is receptive to their ideas, SPC can be implemented as another tool for use by the employees.

The quality manager

The appointment of a quality manager at each local box plant is critical to the successful implementation of the quality improvement process. The quality manager, who serves as the focal point for the commitment to quality improvement, should be thought of as an extension of the other managers (plant manager, sales manager, controller, and even the general manager) and as their peer. The quality manager needs the freedom to discuss problems with the sales manager, controller, and general manager without the potential constraints imposed by the traditional practice of having the quality department report through the production group. Without that freedom, the quality manager cannot interact effectively with customers or address the quality problems that occur outside the manufacturing environment. The quality manager should report directly to the general manager.

The quality manager must also be a leader with the initiative and the ability to communicate with hourly employees, other managers, and customers. Quality managers should have extensive training in group dynamics, employee involvement skills, and SPC techniques. The individual appointed to this position should be "promotable." Our industry cannot afford to treat the quality function as one of inspection and of thinking of the quality manager as one who can do no more than inspect.

A plant is ready to begin using statistical tools in a quality improvement process when there is:

- Plant-wide commitment to an operating philosophy and to a quality improvement process
- Strong and active backing on the part of the local general manager and the rest of the management team
- A competent and respected quality manager
- A successfully implemented program of training and education for the quality manager, the management team, and the rest of the employees
- A successfully implemented employee involvement program.

Implementation of SPC

It is often the case that pressure from a key customer forces a plant to utilize statistical techniques before completion of the recommended prerequisite activities. In such cases, it may be necessary to appoint a quality manager and perform some minimal SPC activity to satisfy immediate customer demands while the balance of the quality improvement process moves forward.

Several questions must be answered before using statistical techniques in a corrugated plant:

- What are the product specifications?
- Will early efforts be concentrated on internal processes or will supplier quality also be initially considered?
- What characteristics should be studied first?
- What are the appropriate statistical methods for each characteristic?
- How can we measure success?

Establishing specifications

Almost all of the practitioners of SPC relate quality to established specifications. Quality is not referred to as either "goodness" or "badness." A typical commitment to quality can be stated as follows:

> Each product shipped or service provided shall conform to realistic and documented specifications that will provide fitness for use by the customer. These specifications shall be exactly complied with or caused to be officially changed to what we and our customers agree is really needed.

Specifications can be imposed by regulation, as in Rule 41; they can be imposed by customers; or they can be requirements of our own downstream operations. Each plant should establish its own list of specifications and the nominal values attached to those specifications.

The next step is to perform a process capability study on each operation to determine how well each piece of manufacturing equipment can meet its list of requirements. Data must be gathered, and then averages and standard deviations must be calculated to determine the level of conformity. In some cases there will be few, if any, problems. In other cases, maintenance or other problem-solving activities will have to be undertaken to bring the process within required specifications. In still other cases, it may be necessary to renegotiate specifications with customers, acknowledging realities of process limitations.

The end result of the exercise should be a plant-wide list of specifications that apply to everything that is produced. This should be done even though some customers may not care whether certain characteristics meet specific requirements. The creation of a single, realistic, but high-standard value for each characteristic within a box plant will go a long way toward convincing employees that management is serious about achieving excellence in quality.

In gathering data and treating it statistically, you can calculate a central tendency (an average), control limits, and the estimated standard deviation (σ) of the process. The process average and process standard deviation tell you how the process is behaving, not how you would like it to behave. Put another way, the process average and $\pm 3\sigma$ variation may or may not bear any relation to your specifications or engineering tolerances.

The process capability study is the technique used to determine how well the central tendency and natural tolerance match the engineering specifications. There are four possible conditions:

1. Centered and capable. The process average is close to the specification average (centered), and the process limits are within the specified tolerance (capable).
2. Centered but not capable. The process average is close to the specification average, but the process variation exceeds the engineering tolerance.
3. Capable but not centered. The process variation is within the engineering tolerance, but the process is so far off specified center that significant amounts of product are out-of-spec.
4. Not centered and not capable. The process average is off specified center and the natural tolerance exceeds the engineering tolerance.

Condition 1 is obviously the desired state of affairs. If any of the other three conditions is present, management action is required to change the process so that a satisfactory state of control (condition 1) can be achieved.

Internal vs. external

The underlying concepts behind SPC require that we examine both our own internal process and the quality of raw material and supplies being delivered to our system. The large amount of work necessary to begin the SPC process may encourage a plant to look first at its internal processes. After gaining experience in applying statistical techniques to machines within the plant, management can initiate discussions with suppliers.

When SPC is discussed with suppliers, the same ground rules should apply as those used in establishing your own internal specifications. Each plant must determine what characteristics are important to the successful use of each raw material or supply item within the plant. The typical list of raw materials includes paper, starch, ink, resin adhesive, and a host of other items that may be lower in priority.

Each plant will also have to think about the realities of its own supply situation. For integrated companies, individual box plants may not have the flexibility of an independent converter when establishing realistic but ironclad mill specifications. For other raw materials, corporate policy may dictate central purchasing instead of local plant purchasing.

Establishing specifications for raw materials and then complying with those specifications are essential aspects of SPC. If paper supply and the purchase of other raw materials is handled centrally, then the central group must listen to its individual plants with regard to specifications, just as the local plant must listen to its customers in establishing finished corrugated product standards.

Establishing priorities in gathering data

When pressure is applied by customers, there is a strong temptation to run onto the floor of the box plant and begin to chart everything. Proceeding in this manner will doom your efforts to failure. Employees will quickly see that measuring and charting is being required without regard to any plan and will then conclude that management is only interested in seeing charts on the wall, not in using the information to identify problems for solution.

Several tools are available for identifying priorities among the characteristics to be measured and charted. Process capability studies can identify those processes that are in need of the most attention. A Pareto analysis of customer complaints, returned goods, and internal errors can also establish a priority list of characteristics for measurement and charting.

One approach is to look at characteristics that are already routinely measured in your plant. Charting measurements that are already being taken and recorded imposes less of a burden on your employees than starting the process with a characteristic that the employees are not currently measuring at all. Almost everyone measures combined board caliper off the corrugator. This, then, is a characteristic that can be handled statistically without too many problems.

Each plant establishes its own list of basic characteristics for the routine application of SPC. The plant should be realistic in establishing this list. In our industry, there are not a huge number of characteristics that lend themselves to measurements, although we do have quite a few that can be considered visual in nature. Once a plant has established a basic list of characteristics, additional characteristics can be studied either as they become problems or as the need for special one-shot studies arises.

A key point to remember is that the quality improvement process should be dynamic, not static. The sequence of (1) statistical analysis, (2) problem solving, and (3) additional statistical analysis to verify the achievement of improved levels of quality eventually (4) results in all measurements for the particular characteristic being well within the specified tolerance. The frequency of measurement should then decrease and may, in some instances, be eliminated altogether. Other problems will become more critical. This never-ending work to improve quality is Deming's process of continued improvement (*1*).

There is one thing that is true of almost every kind of charting. When management asks employees to measure, record, and chart a characteristic, particularly on a continuous basis, that characteristic will improve. Call it the "Hawthorne effect," or whatever. People want to do a good job, and when management focuses its attention on a characteristic or situation, provides guidance for the employees, and then gives them the responsibility of helping out, the employees will respond.

I. Selected corrugated characteristics with suggested SPC charting techniques

Corrugating adhesive	
Viscosity	X & MR (Individual moving range)
Batch temperature	X & MR
Gel point	X & MR
Adhesive pattern photographs	
High-Low	X & MR
Double-face dry streaks	X & MR
Double-face excessive adhesive	X & MR
Single-face finger lines	X & MR
Single-face excessive adhesive	X & MR
Caliper loss at press (including flexo folder gluer & rotary die cutter	X & MR
Corrugator caliper	$\bar{X}$ & R
Warp	$\bar{X}$ & R
Pin adhesion	$\bar{X}$ & R
Slide angle	$\bar{X}$ & R
Manufacturing joint skewness (fishtailing)	$\bar{X}$ & R
Die cutter length variation	$\bar{X}$ & R
Score lineup at manufacturing joint	$\bar{X}$ & R
Slot depth variation	$\bar{X}$ & R
Visual characteristics	Special "U" chart*

*From Ref. (*4*).

Choosing appropriate statistical methods

The suggested SPC charting techniques listed in **Table I** are not the only techniques applicable for the listed characteristics. An individual with knowledge of both the corrugated box business and statistical techniques is certain to modify this list. For instance, it is possible to consider five consecutive batches of adhesive as a sample lot and use the $\bar{X}$ and R technique instead of the X and MR technique. Other individuals might prefer to use the "median and range" chart in place of the $\bar{X}$ and R chart. The "median and range" chart has some advantages in simplicity and ease of training with hourly people.

Comments are in order concerning the adhesive pattern photographs. To successfully evaluate glue patterns of sheets which have been soaked apart on an objective basis rather than a subjective one, three sets of five photographs each were prepared. The photographs were selected to represent various quality levels for the characteristics being evaluated.

A "number" rating was assigned to each of the five photographs, with excellence being given a "4" rating and numbers declining on the other four photographs down to a "0" rating for the photograph which represented totally unacceptable quality. A set of photographs was prepared for the characteristic "high-low." A second set of photographs was prepared showing "dry streaks," which is used to evaluate both dry streaks on the double-face side and finger lines on the single-face side. A third set of photos was prepared showing various degrees of excess adhesives. This third set is applicable for either the single-face or double-face side. **Figure 1** shows the three sets of photographs permanently mounted above a soak tank with good lighting for work and with space available to post charts.

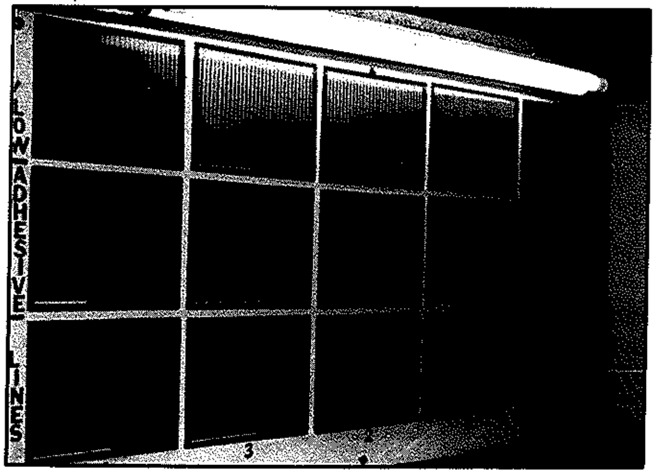
Many possibilities exist for the "visual" chart. Typically, a chart of this nature is used at the finishing machines, either flexo folder gluers or rotary die cutters. A Pareto analysis of customer complaints and internal errors can be performed to identify those characteristics most in need of attention. Any number of characteristics that fall into the category of "go/no-go," "present/not-present," or "good/bad" can be classified as a visual characteristic. Even some characteristics which can be measured, such as slot depth, can also be considered as a visual characteristic. The chart seems to work well with five characteristics observed.

Most SPC work in the corrugated industry involves the measurement of production characteristics. This approach might better be thought of as statistical quality assurance (SQA). To proceed toward process control, work should be done in relating machine settings or machine conditions to finished product quality. Control of machine settings to either improve finished product quality or to reduce variation in finished product quality is much closer to true SPC.

Measuring success

Tools for measuring quality are not easy to establish, and customer acknowledgement is often slow in coming. One possible measuring tool is the calculation of a "cost of quality" or a "cost of non-quality." While the list of quality costs can be extensive, a plant should easily be able to calculate the costs for returned goods, less any products rebilled, gather the costs of freight for returned goods and for rework labor, and place some value on the pounds of waste generated internally by errors that are caught before they reach the shipping dock. These costs can be gathered on a monthly basis and related to some constant figure such as \$/million ft^2 sold or as a percentage of sales dollars. As a plant gets more sophisticated in its efforts, additional costs

1. Visual chart mounted above a soak tank. This chart, which is used to evaluate glue patterns, has three sets of five photographs. Each set represents a different glue-pattern characteristic, and the five photographs represent various quality levels for each characteristic.



can be included in the cost of non-quality.

Conclusion

The quality improvement process, which includes employee involvement and SPC, is not a quick fix. The process requires a plant-wide commitment to a new kind of operating philosophy that regards quality improvement as a never-ending process. Full implementation of the process to the point where success can be seen can take anywhere from three to five years. Initial benefits may be difficult to measure. Ultimately, plants will see a reduction in the amount of process variation, a reduced cost of quality, improvements in employee attitude and performance, and customer awareness of significantly improved quality.

Literature cited

1. Deming, W. E., Out of the Crisis, Massachusetts Institute of Technology Center for Advanced Engineering Study, 1986, pp. 23, 24.
2. Vander Heyden, G. and Wilcox, J., Statistical Studies at Stone Container Corporation, unpublished work.
3. Tewksbury, R., Tappi 69(4): 65(1981).
4. Grant, E. L. and Leavenworth, R. S., Statistical Quality Control, McGraw-Hill, New York, 1980, p. 268.

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