Putting SPC to Work in Manufacturing: Reducing Variability and Increasing Productivity

White Paper
John Clemons, Director of Manufacturing IT
MAVERICK Technologies, LLC
Introduction ................................................................................................... 3
From Data to Diagnostics ............................................................................... 3
Gaining Control by Setting Limits .................................................................. 4
The Rules of Fine Tuning ................................................................................ 5
Real-time SPC: Batch by Batch ...................................................................... 7
Historical SPC: Reducing Variability ............................................................... 8
Assessing Improvement ............................................................................... 10
Adding SPC to Your Toolkit ........................................................................... 11
Take Control of Your Process ........................................................................ 11
Introduction

With a 90-year history of helping streamline manufacturing processes, statistical process control (SPC) has become increasingly sophisticated in its ability to identify opportunities for process improvement. By using existing data, SPC can perform real-time or historical analyses to focus on root causes of failure or trends in batch variability, allow for real-time corrective actions and measure the effectiveness of adjustments.

Though SPC methods were pioneered by Bell Labs in the 1920s, SPC's actual application is rooted in the war efforts of the '30s and '40s, when pen-and-paper SPC analysis helped boost munitions production. As technology advanced, so did SPC. The advent of the personal computer in the '80s eliminated pen-and-paper SPC in favor of SPC software, which today can be found in virtually every manufacturing industry — often right on the shop floor.

Its user-friendliness contributed to SPC's popularity with shop floor operators, but its effectiveness in reducing variability and increasing productivity cemented its spot as a manufacturing mainstay in both immediate and continuous improvement initiatives.

From Data to Diagnostics

SPC is not for everyone, but it can be a powerful and extremely valuable tool when applied to targeted areas in manufacturing. SPC makes the most sense in scenarios where manufacturing processes are generally stable and consistent but could benefit from fine tuning. Of course, sometimes instability is only revealed with SPC analysis.

The most fundamental component of SPC is the data it uses to help prevent and correct process issues. Most commonly, the data used by SPC resides in a database and / or historian. Two different types of data are required: process data and descriptive data. Process data is collected directly from the process itself and may include variables such as temperature, pressure, speed, flow, weight and volume. This data needs to be captured frequently and consistently to be useful. Descriptive data describes the batch and gives the process data context; it may include information such as the batch number, product, material, manufacturing order, process order, supplier, source and / or destination.

Figure 1 shows four real-time charts of process data. Providing this data to shop floor operators in real time allows them to see what's actually going on so they can diagnose problems effectively and discover what's causing the process to stray from its expected parameters.
Gaining Control by Setting Limits

Once the data is available, the next step is to apply specification limits (indicated by the dotted red line in two of the charts in Figure 1). Specification limits set the acceptable operating range for the process so operators can identify when the process is trending high or low and make adjustments accordingly.

But staying within specification limits doesn't necessarily mean that the process is under control. Many companies set specification limits as wide as possible, which means even products that appear to be within limits can still have a significant amount of variability.

This is where SPC really starts to pay off — with the SPC control chart. SPC doesn’t use the specification limits for this but instead mathematically analyzes the process data to determine upper and lower control limits. These limits are usually much, much tighter than the specification limits, but as the process stabilizes, the specification limits can be finely tuned to match the control limits.

Figure 2 illustrates the tighter constraints of control limits as well as the variability that violates them.

In addition to showing operators when and how long a process is out of control, the SPC control chart also documents the subsequent expediency and effectiveness of any adjustments made. It can even reveal over-adjustment or over-steering problems.
The Rules of Fine Tuning

Working together with the control chart, pattern rules establish data-based rules that determine which adjustments should be made to keep the process within the control limits. These rules work well when a controlled process is trending close to the center line. For example, a pattern rule might say to make a small downward adjustment when three or more successive data points are above the center line.

When pattern rules are used, warning limits are often added to the SPC control chart as well. Set between the center line and the upper and lower control limits, warning limits indicate when the process is starting to become uncontrolled. They’re used as part of the pattern rules to flag necessary adjustments when the data nears or goes beyond the warning limits.

A real-world example of using control limits and pattern rules to monitor key variables is shown in Figure 3.

In the application illustrated by Figure 3, an aseptic process was used to sterilize the product and containers and then seal the containers. Because the process is very sensitive, when sterilization was lost it could take up to an hour to clean everything out and regain sterilization. SPC was applied and real-time warnings were triggered when underlying variables such as pressure, temperature, speed or flow started to trend in the wrong directions; that way, operators could take corrective action before losing sterilization. This cut downtime from sterilization losses by 50 percent, which increased our total throughput by about 20 percent.
In another actual application, shown in Figure 4, vacuum pressure had to reach a specific level very quickly and then remain there for the entire batch. To monitor the process, SPC was applied to the final vacuum pressure and to the initial curve. If the vacuum pressure didn’t get to the desired level or if there was a change in pressure that indicated a potential problem (seen toward the end of the batch in Figure 4), operators could adjust the process in real time. This reduced losses due to vacuum pressure problems by more than 75 percent, which increased productivity by 5 percent.
Real-time SPC: Batch by Batch

The examples above rely on real-time, open-loop SPC, which is typically used by shop floor operators. As a new data point is captured, the data is displayed immediately to provide a real-time picture of the process. When violations occur, the SPC control chart provides notifications to the operators in real time so they can make necessary adjustments manually.

Real-time SPC is a very powerful way to control a process. It focuses on keeping the currently running process under control by examining a single batch at a time. Figure 5 shows a real-time SPC control chart with two control limit violations.
Open-loop SPC, whereby the operator manually adjusts the process to keep it within control limits, is the most commonly used type of real-time SPC, but closed-loop SPC can be valuable in situations where the fundamental process is already well controlled. With closed-loop SPC, when a pattern rule determines that an adjustment is needed, instead of notifying the operator and having him make the adjustment, the alert is sent directly to the control system (HMI, PLC, DCS, etc.) and the control system makes the adjustment.

Closed-loop SPC is not intended for every application, however. It requires sophisticated control logic to avoid over-correcting or over-steering and works best in high-speed, high-volume situations where fine tuning keeps the process tightly controlled. But even with closed-loop SPC, the operators can view control charts and the adjustments being made, and they can still be called upon to deal with problems beyond the control system’s capabilities if necessary.

**Historical SPC: Reducing Variability**

Historical SPC looks at multiple batches and compares them over the last week, month, year or even longer. With historical SPC, operators can see long-term trends and detect problems and patterns that are not evident when examining a single batch in real time.

Figure 6 shows a historical SPC chart with multiple batches and drill-down capability. The issue being investigated here is the differences in the ramp down to the vacuum pressure as seen on the left side of each chart.
SPC is at its most valuable when used to reduce batch variability. Historical SPC helps identify the “golden batch” so it can be compared to other batches to improve consistency. Operators can also use historical data to compare different equipment, lines, products or product families, shifts, etc.

Even when there are no process failures, there can still be a wide range of variability in the process, which can lead to batch inconsistencies. Sometimes, supposedly stable processes turn out to be just the opposite. By allowing operators to examine processes more closely over time, historical SPC helps them uncover sources of variability and instability that need to be addressed.

In Figure 7, a control chart shows a real-world situation where SPC analysis revealed an opportunity for significant process optimization. In this application, pressure was expected to rise as the batch was processed, but the process length was defined by time rather than pressure. When SPC was used to analyze the pressure, it was discovered that the pressure didn’t rise throughout the batch as was thought; at the end of the batch, it actually plateaued.

By changing the process so that the batch was processed until the pressure plateaued instead of just running for a prescribed amount of time, the manufacturer was able to reduce batch times by an average of 10 minutes per batch and increase productivity by more than 15 percent.
Assessing Improvement

Most manufacturing companies have some type of continuous improvement program underway, such as Six Sigma or lean manufacturing, but it can be difficult to assess the program’s real impact without SPC. Sometimes process improvement initiatives may even hit a plateau, and SPC can be a good way to get them rolling forward again. When it comes to analyzing the effectiveness of continuous improvement initiatives, historical SPC is key. With it, operators can determine what’s working, what’s not and how long it takes for efforts to yield results.

SPC identifies opportunities for improvement and helps pinpoint what specific types of improvements are needed the most. Then, analysis determines if the steps being taken to improve the process are actually working. By reducing variability in the manufacturing process, SPC helps improve product consistency and reduce product variability as well.

Figure 8 shows a real-world application where historical analyses revealed a number of process inconsistencies worth investigating. Historical SPC was set up to examine and compare various batch parameters simultaneously, on the same chart. This allowed operators to get to the root cause of many process failures and target batches that were close to failing. This not only gave the continuous improvement program a boost; it also helped increase overall throughput and productivity by about 10 percent.
**Adding SPC to Your Toolkit**

Historical SPC looks at multiple batches and compares them over the last week, month, year or even longer. With historical SPC, operators can see long-term trends and detect problems and patterns that are not evident when examining a single batch in real time.

**Take Control of Your Process**

SPC has been around for many years because it continues to be one of the most powerful applications available to manufacturers. Today there are lots of commercially available SPC software packages that are powerful and very easy to use.

Integrating SPC into daily operations can help companies avoid process failures, reduce variability and bolster continuous improvement initiatives simply by gaining better access to real-time data and comparative analysis tools. SPC provides operators with what they need to control the process and gives managers what they need to control the business.

**A NOTE FROM MAVERICK**

MAVERICK Technologies recently partnered with Northwest Analytics Solutions to offer our partners access to integrated SPC solutions. We hope that this white paper, developed in support of our partnership, will help educate manufacturers on the powerful benefits of statistical process control.

To learn more about SPC and what it can do for you, check out related posts on our blog at mavtechglobal.com/ideas