The Implementation of SPC for the Shot Peening Process

by Charlie Mason

It seems that every time we pick up a quality magazine, we see an article written by a manager or engineer. These are the people who supervise or organize the production programs. What about the people who actually perform the work? At Menasco Aerospace Ltd., shop floor personnel are not only involved in the organizing and running of such programs, they are also directly involved in problem solving and corrective actions.

The Process Improvement Team, which I lead in the Shot Peening Department, has achieved excellent quality advancements using AQS tools (Table 1). This article is an overview of our experiences while implementing SPC/DOE into our shot peening operations.

In my eight years in the industry, I have come across many people who still think shot peening is simply a cleaning process. Perhaps many years ago it wasn't realized that propelling steel shot to clean metal surfaces actually cold worked the material. Today, by controlling such parameters as air pressure, wheel speed, shot size and hardness, we have developed a process to increase fatigue life and reduce stress corrosion cracking of metal components. The process of shot peening is used extensively throughout the aircraft and automotive industries.

Before we could start our SPC program at Menasco, we needed to identify the main measurable output variables directly related to...
Our first step prior to formal experimentation was to use a standard SPC rule, "Center the Process". This was accomplished in the development of the shot peening techniques (wheel speed, air pressure, shot flow, peening time and cycle settings, etc.). We focused on achieving the nominal intensity and consuming a minimum amount of the engineering tolerance. Process parameter settings that resulted in intensities near specification limits were disqualified. This was done to avoid the risk of rejections during production runs.

The histogram seen in Figure 1 illustrates the intensities from an old technique card used to process the outer cylinder for the 737 Main Landing Gear. The intensities consume all the lower end of the engineering tolerance, and the C_p and C_pk have very low values of 0.66 and 0.53, respectively.

Our present 737 outer cylinder technique is shown in Figure 2. It can be seen that by taking the time to apply standard SPC rules, the intensities are now centered around the nominal, as well as consuming much less of the engineering tolerance. The success of this exercise is reflected in the improved C_p and C_pk values of 1.3 and 1.26 produced in this non-production, test environment.

Again, the above examples indicate the intensities achieved when generating shot peening techniques under controlled circumstances. What is really happening during production? The histogram shown in Figure 3 illustrates the intensities of actual production runs using our new technique and parameters. The intensities consume more of the engineering tolerance, resulting in lower C_p and C_pk values. The current change is due to process variation and reducing this variation was the next step in controlling the process.

We began by plotting the intensities for each lot of parts processed. Individual X charts were used to examine the extent of variation and display control limits. After the control limits were established, special cause variation was identified and corrective actions such as nozzle break-in cycles and daily visual checks were incorporated. Operators were advised about the importance of plotting all results obtained, including values out of specification. Once the problems were identified, corrective action was taken.
A recent study involved charting the defective or deformed shot count. We found that the shot in the machine was unacceptable because the upper control limit was over the specification. Adjustments were made to the shot separators and a daily maintenance program was incorporated with very little success. At this point management approved a request to upgrade our present separation system. A spiral separator was installed and along with our daily maintenance program, our defective shot count is now in control. New data was collected and the control limits were recalculated (see Figure 5).

Now that we had established basic machine standards it was time to look at our key process parameters. Again, a brainstorming session was conducted with the team and the following key process parameters were identified: shot flow, wheel speed, air pressure, shot quality and blast pattern. We felt that these parameters had the greatest impact on the main output variable, "intensity". To date we have established control limits on our wheel speeds, shot flow and shot quality based on SPC calculations. Programmable alarms have been installed on the machines to warn us immediately of out of control situations.

As time progressed we noticed a consistent upward trend of the intensities charted. Something in the machine was changing and we had no control over it. Further brainstorming was conducted with the team members and it was concluded that the blast pattern was changing due to wear on the blast wheel components. This forced us to take a step backwards and establish basic machine setup standards. Blast pattern intensity charts, test run procedures and control limits were implemented. Almen intensity test strips were strategically located across the peening (working) zone and standards were determined for each wheel separately (see Figure 4). Variable control charts with control limits were developed for each test strip and regular verification runs were performed to detect changes in the blast pattern. These standards enabled us to replace worn components and maintain consistent operating conditions. This was a major step in reducing variation in our process.

As a result of this project, we have been able to improve the quality of our products and reduce the variation in our process. This has led to increased customer satisfaction and decreased costs.

An Almen Gage repeatability and reproducibility study (Gage R&R) was performed to ensure our measurement system was not a source of excessive variation. The maximum percentage of variation found in the gage was 9.4%. We concluded this was acceptable as it does not consume more than 10 percent of the engineering tolerance.

To further understand the parameters of our process, a statistically designed experiment (DOE) was performed. Specifically, our goal was to determine the optimum settings to achieve an intensity of .016 A (i.e., .016 inch on an A type Almen test strip), as this reflected the nominal intensity required to peen the new Boeing 777 Nose Landing Gear.
process parameters to achieve the required intensity. Using the Main Effect Plot it was determined that a wheel speed of 1600 R.P.M., shot flow of 75/0, and a peening time of 4 minutes would yield an intensity of .016A. Our conclusions were justified with four verification runs producing the following intensity results: .0164A, .0163A, .0163A, .0162A. SUCCESS! We had achieved our goal. The results also indicated that we required tight controls on our wheel speeds and shot flows, but something as simple as an "idiot light" to monitor the table drive.
Figure 6. D.O.E. indicated which parameters had the most effect on intensity.

Once the team gathers all the necessary information, we plan to produce a Process Control Document (PCD) that demonstrates our shot peen process is in control. This document will contain a procedure to monitor the machine’s capability instead of verifying individual setups for each lot of parts. When this is the only requirement to verify the machine’s capability on a periodic basis, the amount of test runs during production will be notably reduced. This PCD is an option outlined in the Boeing Shot Peen Specification BAC5730.

As a result of AQS implementation, the team is now much more knowledgeable and proficient in the art of shot peening. The quality improvements that have been made thus far would not have been possible without the encouragement and resources provided by top management. With their continued support those who work on the shop floor feel they can make a major contribution to Continuous Quality Improvement here at Menasco. The ongoing challenge to optimize our process offers an exciting outlook for the future.