

Quality Shot Peening Using SPC

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Editor The Shot Peener

This article is adapted from a presentation made by Charlie Mason of Menasco Aerospace during the 2nd Annual Workshop on Shot Peening in Cincinnati, Ohio.

In the last issue of *The Shot Peener*, I described how to conduct a gage study for the Almen gage. This procedure is necessary in order to recognize the variation contributed to the process by the Almen gage. Once this variation is known to be 10% or less, then the peening process itself can be evaluated. In this article, I will describe how to evaluate the variations that occur in the peening process.

If you can't monitor it, then you can't control it. The shot peening process can be monitored, and it can be controlled. One of the best tools to maintain consistent shot peening quality is referred to as SPC or Statistical Process Control.

SPC is a procedure frequently associated with the Japanese manufacturing process. In 1931 Dr. William Shewhart published a book called "Economic Control of Quality of Manufactured Product", which laid the foundation for SPC. Today SPC is more closely associated with one of Dr. Shewhart's colleagues, Dr. W.E. Deming, who is credited by the Japanese for much of their productivity and quality improvement success.

The main objective of SPC is to improve productivity and competitive position through quality improvements by defect prevention and variation reduction. Defect prevention is the use of statistical evidence to prove that quality is built-in; and it eliminates the need for inspection on a mass basis. Variation reduction will limit the variation of process parameters to a manageable level.

Shot peening specifications, or procedures, state the desired areas to be peened and the peening intensity level. A tolerance is usually stated for the intensity. If no tolerance is stated, then a spread of 4 points is assumed. For example, for a 10A intensity the spread would be from 8A to 12A.

Most shot peening procedures specify the repeat frequency of intensity measurements, usually every four hours or at each shift change. Historically, these readings would be recorded and, if within the tolerance spread, forgotten. It is much better to chart their value onto an SPC graph to observe the tendency for the intensity to respond in trends. The intensity should cluster closely around a center line. If it tends to deviate (up or down), then a special cause is present and must be addressed.

Before starting any SPC program you must identify the measurable main output variables. For shot peening, these would be intensity and coverage. However, other system

variables, such as broken shot content, dust collector "fines" removal, wheel pattern "hot-spot", etc., can also be analyzed using SPC techniques.

The first standard rule of SPC practice is to center the process by aiming for the nominal intensity. This can be accomplished by focusing on achieving a nominal intensity and consuming a minimal amount of the peening tolerance. **DO NOT ACCEPT INTENSITIES NEAR THE PEENING TOLERANCE AS THEY MAY GO OUTSIDE OF THE SPECIFICATION DURING PRODUCTION.** Centering the process will allow room for natural (inherent) process variation during the regular production runs.

One of the simplest ways to display variation in a product or process is done by use of a histogram. By plotting a collection of peening intensities on a histogram you can determine its capability. This will also show how well the intensity is centered within the peening specification limits. The frequency of occurrence of any given value is represented by the height of the bars. The construction of a histogram is done through the collection of measurements (variable data) from a process. In our case we will use the peening intensity measurements. Thirty (30) or more measurement points are preferred. The intensities are grouped into bins and the number of measurements within a bin is counted and plotted on the graph. A bin may be any width. You should have between three and five bins for a histogram.

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What can be charted using SPC ?

- Intensity
- Wheel Speed
- Air Pressure
- Shot Hardness
- Shot Broken Content
- Dust Collector "Fines"
- "Flooded" Wheel Amperes
- Separator Screen Take-out
- Shot Elevator Motor Amperes
- Shot Additions (replenishment)
- Dust Collector Static Pressure
- Air Pressure Drop Along Blast Hose
- Shot Size (sieve screen or image analysis)
- Almen Gage Repeatability and Reproducibility (Gage R&R)
- Wear/Parts Lifetime (orifice plates, wheel blades, nozzles, protective liners)
- Coverage %
- Shot Velocity
- Shot Flow Rate
- Target (hot spot)
- Tracer Removal %
- Nozzle Wear (erosion)

The examples shown in Figure 1 represent histograms for a) Old Setup, b) New Setup, and c) New Production.

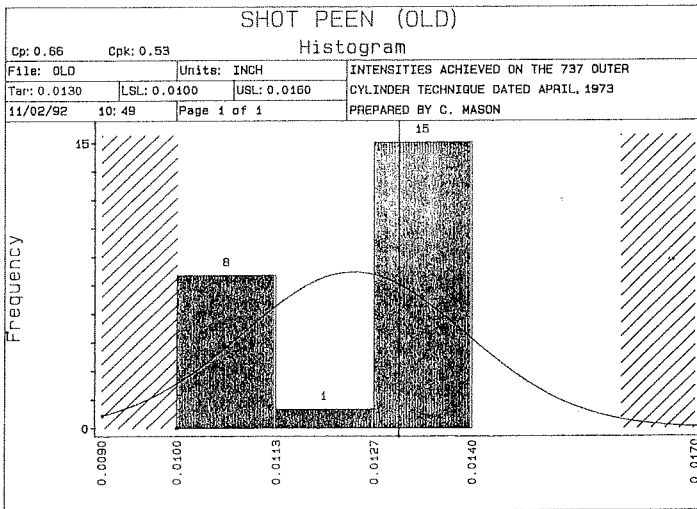


Figure 1a.

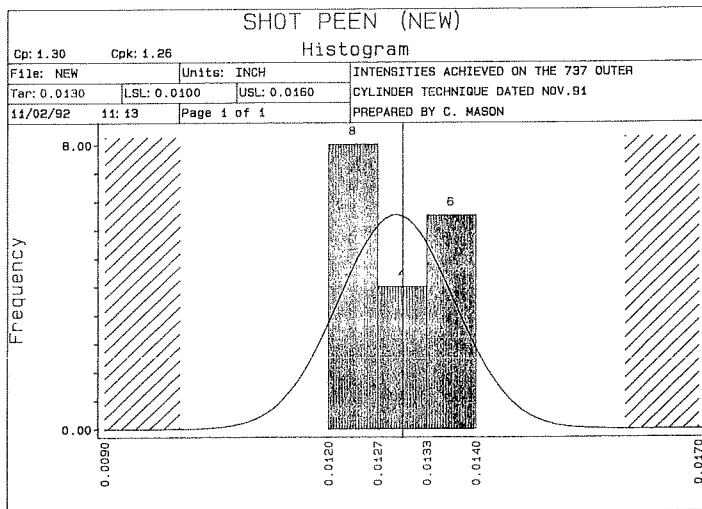


Figure 1b.

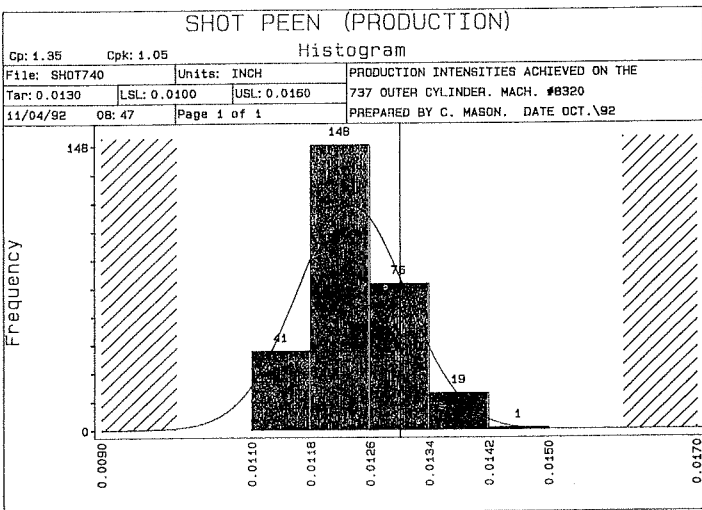


Figure 1c.

Control Charts are used in SPC to present the data in a meaningful manner. Before any improvements can be made to a process we must first identify the sources of variation. To do this we start by monitoring the output of the process (intensity and coverage) over a period of time and plot the data onto control charts. The two most common control charts associated with short-run SPC are the individual point (or IX) and the moving range (or MR) charts.

The individual IX control chart is used to track process variation from one point to the next. The centerline for this chart is the average value of all the individual measurements (called X bar). Control limits are then calculated from information gathered from both the individual IX and moving range MR control charts. These limits will separate the special cause variations from the common cause variations.

The moving range is simply the range between neighboring subgroups. The centerline is the average of all moving range values (called MR bar).

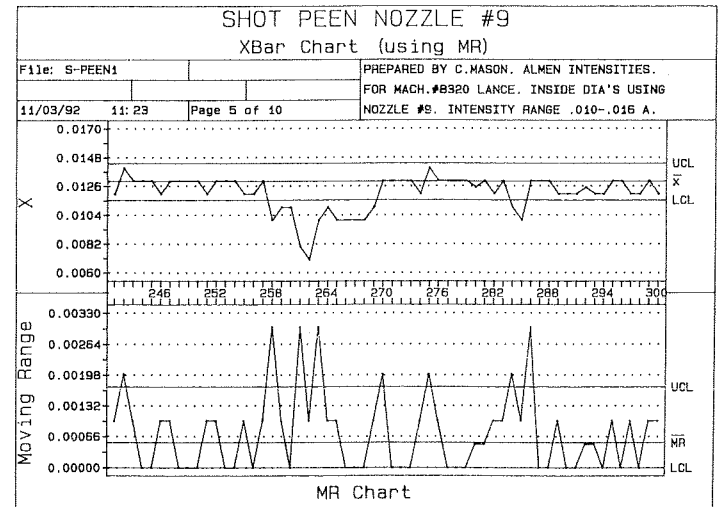


Figure 2.

There are two types of process variation that are of concern: common cause and special cause. Common cause consists of the combined effect of several sources of variation that are inherent to the process. The collective influence of common cause variations defines the natural process fluctuation.

Special cause variations are not inherent to a process, but these generally cause a large change in the variation. Determination of the source of this impact makes its cause "assignable". Power surges, mechanical breakdowns, a plugged hopper or leak in the shot flow system are all examples of special cause variation. REMEMBER: If you do not identify the problem, then you cannot correct it.

SPC control limits, also called upper and lower control limits, demonstrate the natural variation within the process. If variation is excessive, then corrective action must be taken to bring the process back into control.

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Once corrective action has been implemented, then new data must be collected and the SPC control limits must be re-calculated. For example, suppose the broken shot count proves to be excessive. The air-wash separator could be adjusted, or the screen separators can be checked. Perhaps a spirolator must be included to eliminate the non-round shot particles, or you might select a new vendor for shot. New data must be collected to demonstrate the efficiency of any of these remedial steps and to ascertain whether the process (acceptable broken shot count) is brought into control (to within limits). Figure 3a (before adjustments) and 3b (after adjustments) show defective shot count using the individual X (or IX) chart techniques. Notice that new values for UCL and LCL are shown in figure 3b. Not only has the number of defective shots been reduced, the variation in count (UCL - LCL) has also been reduced from (approximately) 22 to 10.

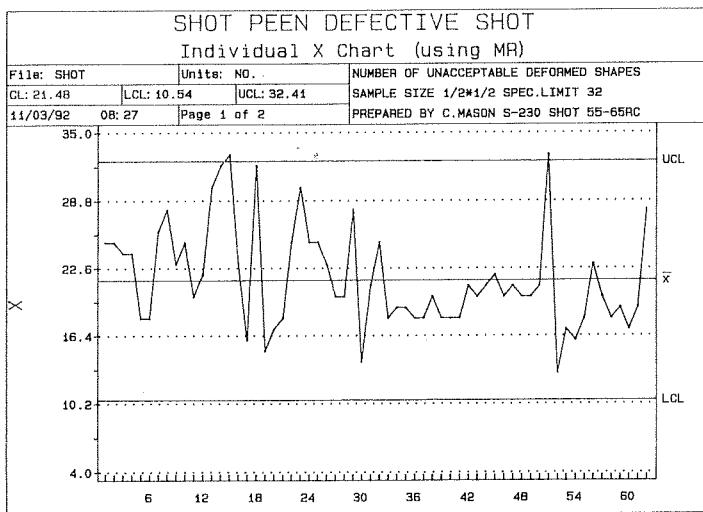


Figure 3a.

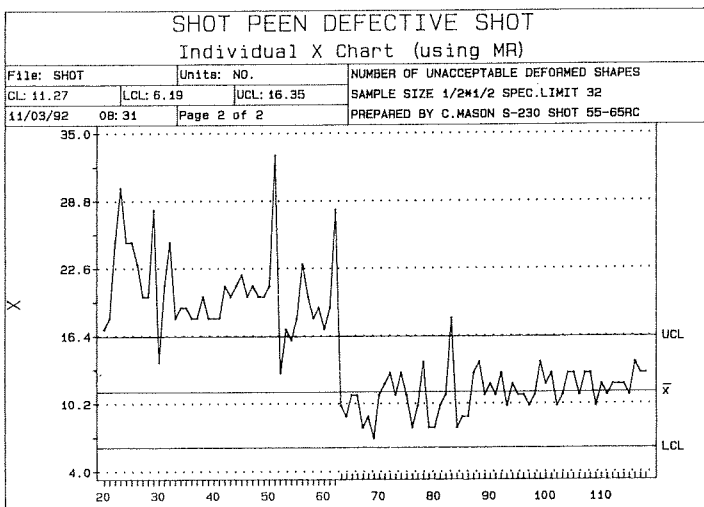


Figure 3b.

Peening intensity can also be shown on the Individual X chart (using MR). Figure 4 shows a wheel peening intensity with LCL of .0147 and UCL of .0165. The bottom of the graph is used to show calendar dates and notes about process adjustments.

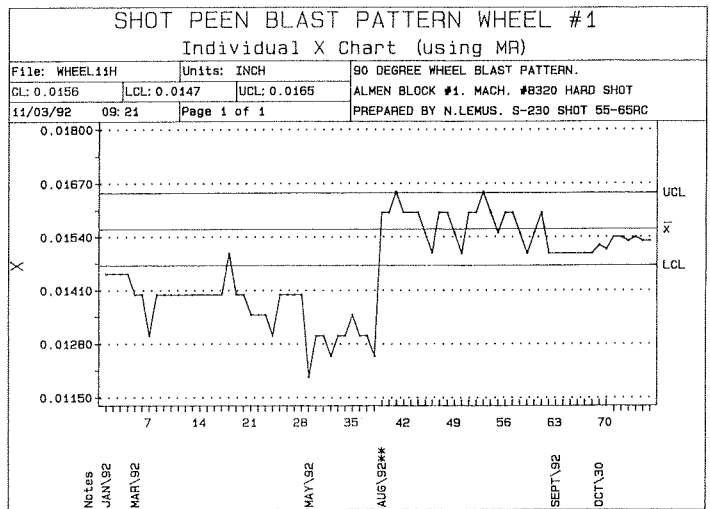


Figure 4.

Occasionally other process parameters are charted to help show process consistency. Figure 5 shows shot flow rate for an air type peening machine. The LCL is 14.89 and the UCL is 15.36 pounds per minute shot flow rate.

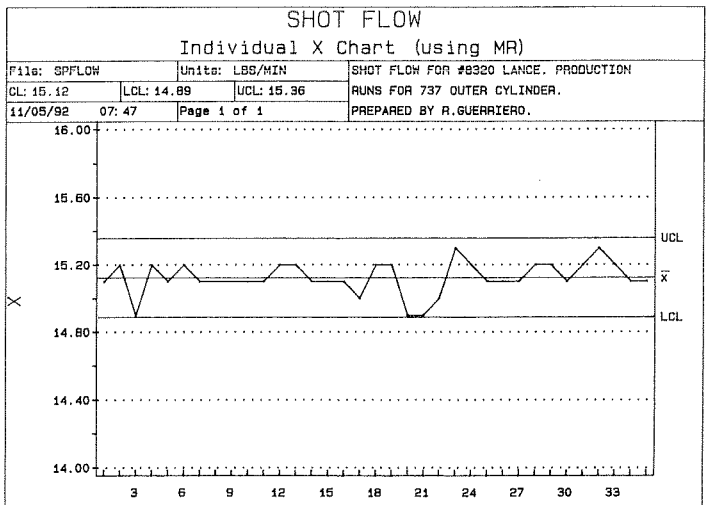


Figure 5.

Once the peening specifications have been established (usually by product design), and the natural variability of the process determined, the process potential CP can be calculated. The term CP is a measure used to indicate whether the process variation is acceptable. That is, if the process were centered correctly could it produce all the product within the specification? The term CPk indicates whether the process variation is acceptable and if the process is properly centered.

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First determine the standard deviation = S

- 1). Add up all of the values in the sample
- 2). Divide the total by the number of values added together. This is the average value.
- 3). Subtract the average value from each of the individual values from the sample.
- 4). Square the difference.
- 5). Add up all of the squared differences.
- 6). Divide this value by the number of values in the sample minus one
- 7). Calculate the square root of this amount. This is the standard deviation.

Next, calculate the process potential where
 USL = Upper Specification Limit
 LSL = Lower Specification Limit
 S = Standard Deviation

$$CP = \frac{(USL - LSL)}{6S}$$

Next, calculate CPk where Xbar is the average intensity
 CPk = $\frac{Xbar - \text{Nearest Spec Limit}}{3S}$

Next, calculate the control chart limits, for the individual X chart where

- MRbar = Moving Range Average
- UCL = $Xbar + (2.660) MRbar$
- LCL = $Xbar - (2.660) MRbar$

Next, calculate the control limits for the moving range chart

- UCL = $(3.267) MRbar$
- LCL = 0 (Always set to zero)

An example of a data collection and chart form is shown in Figure 6.

Individual X and Moving Range Chart (IX-MR)

Part #: _____ Description: _____ Characteristic: _____ Date: _____

Source: _____ Operator: _____ Inspector: _____

Gage: _____ Zero Value: _____

Upper Spec: _____ Resolution: _____ Unit of Measure: _____

Lower Spec: _____

UCL X: _____ X: _____ SX: _____

LCL X: _____ LCL R: _____ R: _____ SR: _____

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Measurements																										
MR																										
Notes																										
IX																										
MR																										

Figure 6.

As a reminder of how to approach the process, the following flow chart should be helpful. Notice that once you start, there is no ending. You must, therefore, continue the quest to constantly reduce variability. That's what a good quality program is all about.

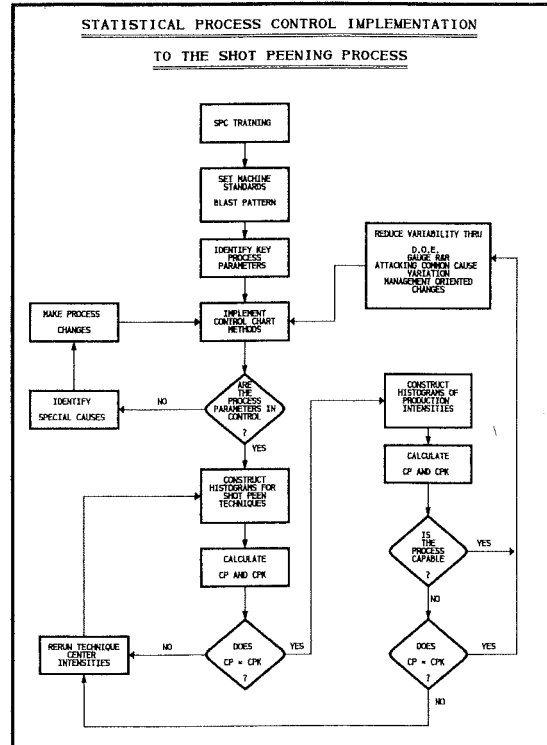


Figure 7.

In the next issue, we'll discuss how to control some of the parameters that contribute to process variation: shot velocity, shot flow rate, coverage. Methods of regulating these parameters to obtain process capability will be described. In the meantime, remember to keep your shot dry.

TSP