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Small-Lot SPC…Really!

By Robert A. Dovich, ASQ, Fellow, CQE, CRE, Quality Manager, Field Fastener Supply Company

There have been many attempts in the past - in seminars, books and articles, including this column -to present methods of using statistics for small production runs. For the record, small production runs are those (in my opinion) of 25 to 50 pieces or less. You guys who produce 500 are high volume compared with the short-run companies.

Quite by accident, while on a business trip, I ran into a colleague who was taking a class on short-run SPC. I expected to hear the same story of "nice, but not realistic." Now, for the rest of the story (sorry, Mr. Harvey). The course is given under the auspices of the International Quality Institute, Inc. (IQI), in Northville, Mich. It is three days in length, running about 20 to 24 hours.

I did not attend the course, but purchased a copy of the handbook to review some of the techniques for validity. One must always remember that the smaller the sample size, the less confidence one has in the results. There's no free lunch. But the techniques shown do allow you to use control-chart concepts on short runs, with control limits calculated by the (somewhat) traditional methods.

The first chart discussed here will be the NOM-I-NAL chart. (Be aware that I am briefly discussing the concepts, and one will not become proficient in this topic by just reading this column.) This chart allows one to plot several part numbers on the same chart. It is preferable, when working with this chart, that the operations be similar, because the control limits will be based on an assumed equality of range values between part numbers.

A brief example adapted from the manual follows:

Part Number	Specification	Tolerance	Nominal Value
Part A	30-40	10	35
Part B	40-60	20	50

Part A

Subgroup 1	Nominal	Variation from Nominal
31	35	-4
33	35	-2
32	35	-3
		Sum -9

$\bar{X} = -3$ R = 2

Part A

Subgroup 2	Nominal	Variation from Nominal
34	35	-1
36	35	1
32	35	-3
		Sum -3

$\bar{X} = -1$ R = 4

Part B

Subgroup 1	Nominal	Variation from Nominal
47	50	-3
45	50	-5
46	50	-4
		Sum -12

$\bar{X} = -4$ R = 2

Part B

Subgroup 2	Nominal	Variation from Nominal
48	50	-2
47	50	-3
49	50	-1
		Sum -6

$\bar{X} = -2$ R = 2

When enough data is obtained, plot the average deviations from nominal and the range values on the control chart. The following example is for purposes of illustration only and does not really have sufficient data points:

$$\bar{\bar{X}} = \text{Sum of } \bar{X}/k = -10/4 = -2.5$$

$$\bar{R} = \text{Sum of } R/k = 10/4 = 2.5$$

$$UCL_{\bar{X}} = \bar{\bar{X}} + A_2\bar{R} = -2.5 + (1.023)(2.5) = 0.058$$

$$LCL_{\bar{X}} = \bar{\bar{X}} - A_2\bar{R} = -2.25 - (1.023)(2.5) = -5.058$$

$$UCL_R = D_4\bar{R} = (2.575)(2.5) = 6.438$$

Constructed charts, with control limits, are shown in Fig.l.

The NOM-I-NAL chart can be adapted to many types of parts or situations. One caution: Avoid placing the results of hole boring and shaft grinding on the same chart; the expected variation would be dissimilar.

Target X-Bar and R Chart

In situations where process tolerance is unilateral; the NOM-I-NAL chart will not suffice. The IQI training manual covers this with the Target Chart. It is similar in principle to the NOM-I-NAL chart, but works with the design target or historical average instead. The manual also provides some slick techniques that make choosing the proper chart to use an easy task.

The 3-D Control Chart

Have you ever been involved with a study when there is so much variation within the part, that part-to-part variation is greatly affected by the location of the measurement? If not, you are luckier than most. Prior to reading this manual, I performed these studies in a similar manner, but did not chart all the characteristics indicated by IQI. Its answer to this situation is the 3-D Control Chart (no special glasses required). This chart allows the user to measure and plot the within-piece variation, determine an average size per part and use the average-size information to determine piece-to-piece variation. An example of how the data is collected is shown in Fig. 2, which represents the measurement, in four places, of a symmetrically shaped part (it is shaped like a washer, with no visible means of orientation). As can be seen in the illustration, data variation is separated by within-part variations R wand part-to-part variations Rp. One can then construct an average and two range charts, plot the points on these three groups and calculate their respective control limits for comparison. Using this method, it is easy (relative term) to determine the major source of variation, be it within-piece or piece-to-piece. This is analogous to performing Gage R&R studies to identify the major sources of variation.

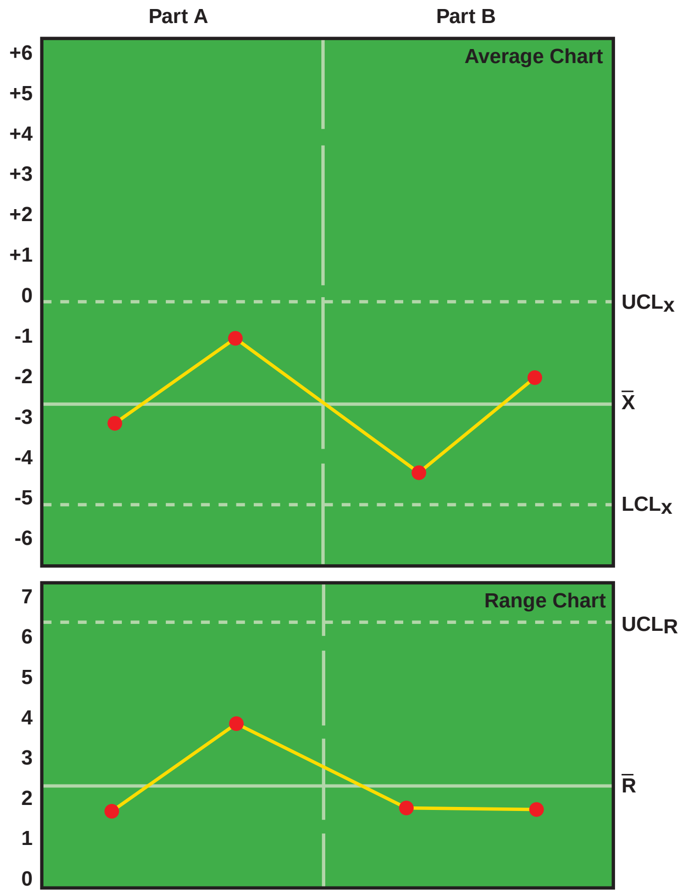
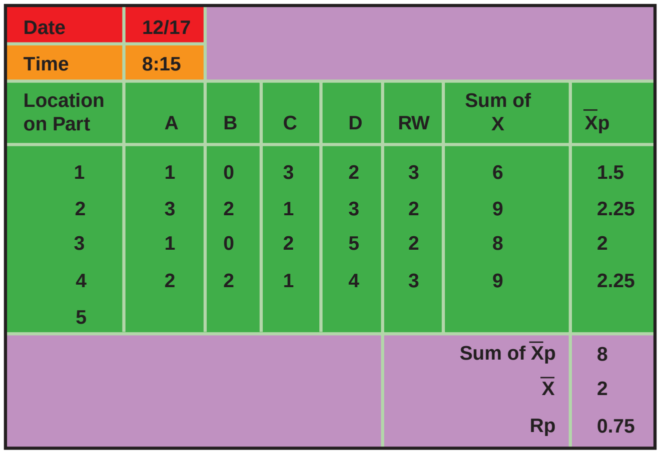


Fig. 1. Nominal and range values, with control limits, are plotted on control charts.



Date	12/17						
Time	8:15						
Location on Part	A	B	C	D	RW	Sum of X	$\bar{X}$p
1	1	0	3	2	3	6	1.5
2	3	2	1	3	2	9	2.25
3	1	0	2	5	2	8	2
4	2	2	1	4	3	9	2.25
5							
						Sum of $\bar{X}$p	8
						$\bar{X}$	2
						Rp	0.75

Fig. 2. Suggested means of collecting data for 3-D Control Chart. Measurement is being made in four places on asymmetrically shaped part,

The 3-D chart is an excellent problem-solving tool, allowing personnel to focus their efforts on reducing the major contribution of variation. This chart provides more information (in a statistical sense) than the extremely useful (but pictorially oriented) Multi-Vari chart. I'm not saying that this should be used in lieu of the Multi-Vari chart, but rather as an alternative in specific situations.

Sequential Range Test for Process Potential

The sequential range test for process potential (though the authors call it capability) is also shown. The values given are designed to accept a process potential of less than, or equal to, 60 percent of tolerance, or reject a process potential of greater than, or equal to, 100 percent of tolerance using the range values from a minimum number of samples. If the sample range divided by the tolerance is somewhere between the table values, another sample is taken.

Basically, samples of eight are drawn and the calculated value is compared to the table values. If the sample range divided by the tolerance is less than the lower table value; the process is accepted as having a process potential that is acceptable. If the range divided by the tolerance is greater than the upper table value, the process potential is considered to be unacceptable. The method used by the authors ends at a total of 50 samples, and then converts to a more classical method of calculating the process potential. This method provides an earlier truncation point than many sequential sampling plans. As always, there is an increased "statistical" risk due to smaller samples, but if small lots are all you have, there really isn't 't any other choice.

Some other concepts discussed in the training manual are group control charts that make charting multicavity dies - or other dimensions that are repeated several times on a part, such as with crankshaft journals-practical. Once again, a seemingly impossible charting task is made possible by this technique.

In a conversation with one of the authors, no claims were made of inventing all of these methods, So if you've seen these techniques elsewhere, don't be surprised.

Small-lot SPC can be accomplished. One more excuse has been taken away. No longer can small lot sizes be used as a defense. Lot sizes of three or more can now be charted. It may not be classical SPC, but it is effective.