How do I Implement SPC for Short Production Runs (Part I)?

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Traditional SPC methods were developed to support high volume production and long production runs. However, with the trend toward product specialization, product diversity, and flexible manufacturing, short production runs have become more common. Applying SPC in the traditional manner presents challenges in short production runs, because by the time enough data is collected to establish valid control charts, the production run may be over!

An approach to deploying control charts with short production runs is to utilize charts of common *characteristics* across different products. The chart pertains to the characteristic of interest (e.g. diameter) rather than for the diameter of a specific design.

A single chart can monitor the characteristic even though the nominal values (and specifications) are *different*. This is accomplished by standardizing the data before plotting it. A common chart that performs this is called the **Deviations from Nominal (DNOM) chart**. Essentially, the value that is plotted is the *difference* between the part measurement and the nominal value (Note: The nominal value refers to the value that is typically specified on an engineering drawing as the desired value and is often halfway between the lower and upper specification limits). Once the differences are computed, the control limits may be established in the normal way.

An Example:

A machining process produces in inner diameter of a check valve. Depending on the type of unit produced, the nominal value of the diameter is 17.400 mm, 12.700 mm, or 10.500 mm. Here, 10 samples (of size 3) are produced and measured for each part type.

For each unit measured, a deviation from nominal is calculated by subtracting the relevant nominal value from it. For example, for a part that measures 17.408 mm, the deviation from nominal is:

$$17.408 - 17.400 = 0.008$$

For a part that measures 17.387 mm, the deviation from nominal is:

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17.387 – 17.400 = -0.013

The following table illustrates the calculations for the Deviations from Nominal Chart. Essentially, each measured data value is transformed by subtracting off the nominal value ($x_i = m_i -$ Nominal). The deviations are then used in the usual manner to construct the desired control chart (e.g. Xbar/S Charts, Xbar/R Charts).

			Measurements			**Deviation from Nominal**			**Chart Statistics**		
Sample	**Part Type**	**Nominal**	**m_1**	**m_2**	**m_3**	**x_1**	**x_2**	**x_3**	**xbar**	**R**	**S**
1	A	17.400	17.408	17.404	17.407	0.008	0.004	0.007	0.0062	0.003	0.0016
2	A	17.400	17.403	17.404	17.414	0.003	0.004	0.014	0.0068	0.011	0.0063
3	A	17.400	17.392	17.393	17.375	-0.008	-0.007	-0.025	-0.0135	0.018	0.0101
4	A	17.400	17.387	17.400	17.387	-0.013	0.000	-0.013	-0.0090	0.013	0.0074
5	A	17.400	17.400	17.399	17.420	0.000	-0.001	0.020	0.0063	0.022	0.0123
6	A	17.400	17.408	17.400	17.399	0.008	0.000	-0.001	0.0022	0.010	0.0053
7	A	17.400	17.409	17.396	17.395	0.009	-0.004	-0.005	-0.0001	0.014	0.0075
8	A	17.400	17.411	17.418	17.402	0.011	0.018	0.002	0.0102	0.016	0.0082
9	A	17.400	17.397	17.403	17.387	-0.003	0.003	-0.013	-0.0043	0.015	0.0078
10	A	17.400	17.415	17.400	17.389	0.015	0.000	-0.011	0.0014	0.026	0.0130
11	B	12.700	12.698	12.702	12.686	-0.002	0.002	-0.014	-0.0046	0.016	0.0084
12	B	12.700	12.697	12.704	12.687	-0.003	0.004	-0.013	-0.0036	0.017	0.0086
13	B	12.700	12.698	12.713	12.708	-0.002	0.013	0.008	0.0062	0.016	0.0081
14	B	12.700	12.720	12.687	12.698	0.020	-0.013	-0.002	0.0014	0.033	0.0170
15	B	12.700	12.696	12.702	12.707	-0.004	0.002	0.007	0.0017	0.011	0.0056
16	B	12.700	12.709	12.702	12.702	0.009	0.002	0.002	0.0044	0.007	0.0039
17	B	12.700	12.695	12.686	12.712	-0.005	-0.014	0.012	-0.0022	0.026	0.0133
18	B	12.700	12.695	12.691	12.696	-0.005	-0.009	-0.004	-0.0061	0.005	0.0028
19	B	12.700	12.685	12.693	12.695	-0.015	-0.007	-0.005	-0.0090	0.009	0.0049
20	B	12.700	12.712	12.695	12.700	0.012	-0.005	0.000	0.0024	0.016	0.0085
21	C	10.500	10.487	10.499	10.494	-0.013	-0.001	-0.006	-0.0067	0.012	0.0060
22	C	10.500	10.502	10.508	10.496	0.002	0.008	-0.004	0.0023	0.012	0.0059
23	C	10.500	10.504	10.498	10.510	0.004	-0.002	0.010	0.0038	0.012	0.0060
24	C	10.500	10.500	10.496	10.490	0.000	-0.004	-0.010	-0.0051	0.010	0.0050
25	C	10.500	10.485	10.481	10.485	-0.015	-0.019	-0.015	-0.0163	0.003	0.0020
26	C	10.500	10.526	10.516	10.494	0.026	0.016	-0.006	0.0121	0.032	0.0164
27	C	10.500	10.519	10.501	10.508	0.019	0.001	0.008	0.0093	0.018	0.0092
28	C	10.500	10.520	10.503	10.504	0.020	0.003	0.004	0.0090	0.017	0.0096
29	C	10.500	10.512	10.486	10.512	0.012	-0.014	0.012	0.0030	0.026	0.0152
30	C	10.500	10.494	10.508	10.479	-0.006	0.008	-0.021	-0.0064	0.028	0.0141
									0.0001	0.0159	0.0083
									xbarbar	rbar	sbar

Xbar and S charts constructed from the "Deviation from Nominal Data" follow.

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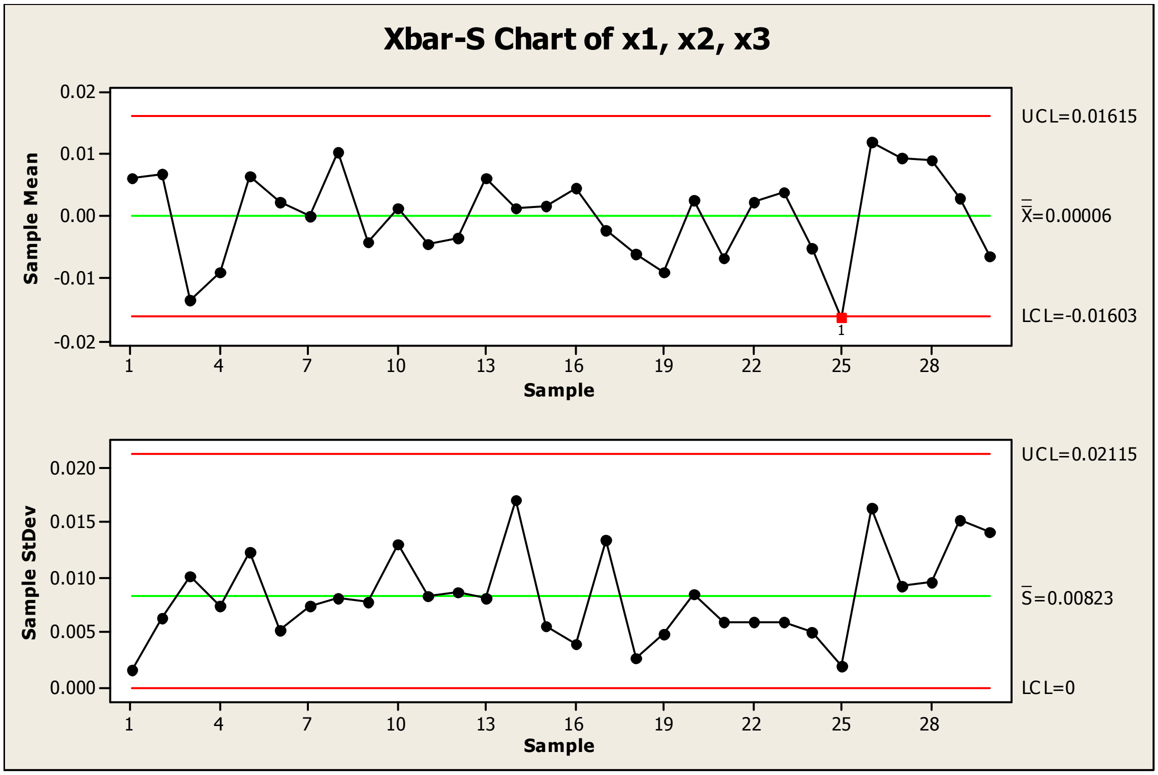

Important Assumptions and Considerations

Several important assumptions and considerations apply to the DNOM approach and example above.

1. It is assumed that the process standard deviation for the various part types are statistically the same. Often parts with larger nominal measurements will also have larger standard deviations. If the standard deviations are not the same across all part types, the above approach is invalid (and Standardized DNOM charts should be used). Since the standard deviation is used to compute control limits, a single set of control limits would not apply if the variation differed across part types. The solution to this potential problem is to further standardize the deviations before charting to account for the differences in variation. The standardized DNOM charts and methods to test for equal variances will be covered in next month's newsletter.

2. The DNOM chart assumes that the same sample size is used for each part type.

3. The DNOM chart is most intuitive when the nominal specification is the desired target for the process and the process average is "on target." However, often it is desirable to center the process at a value that is closer to one specification limit for cost reasons. Furthermore, many characteristics have only a one-sided specification (e.g. strength,

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hardness, roundness) so no nominal value exists. In these cases it may be desirable to change the "deviation from nominal" to either:

a. Deviation from Target (where there is a strong desire to keep the process at the target value)

b. Deviation from Historical Average (where we are mainly looking to detect process *changes* from the historical mean for that specific product type).

Summary

This article explains the use of DNOM charts, which may be used to monitor process characteristics over time even when the units being controlled have varying nominal values. When the process variability differs significantly by part type, Standardized DNOM charts should be utilized and these will be described in Part II of this article.

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