

Process Capability Analysis Using MINITAB (I)

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Abstract

The use of capability indices such as C_p , C_{pk} , and “Sigma” values is widespread in industry. It is important to emphasize that there are certain crucial assumptions, which allow the use of such values to have a meaningful interpretation, which are frequently overlooked. It is the aim of the author to address such issues by the use of discussion and case studies, and to provide some useful guidelines and insights when performing capability analysis using Minitab®. Procedures when dealing with non-Normal data will be considered in the following edition of EXTRAOrdinary Sense.

Assumptions

There are two critical assumptions to consider when performing process capability analyses with continuous data, namely:

1. The process is in statistical control.
2. The distribution of the process considered is Normal.

If these assumptions are not met, the resulting statistics may be highly unreliable. One finds in practice that, typically, one or both of these assumptions are disregarded.

1. Control Status

If the process is not in statistical control we are unable to reliably use our estimates for spread and location, hence our formulae are redundant. In order to assess whether or not a process is in statistical control, quality practitioners use control charts. The most frequently used form of control charts in operation today are those which have their derivation from the pioneering work of Dr. Walter Shewhart in the early 1920's. In their basic form, these charts (e.g. Xbar-R, Xbar-S) are sensitive to detecting relatively large shifts in the process, i.e. of the order of 1.5 standard deviations or above.

Two types of charts are primarily used to detect smaller shifts, namely Cumulative Sum (CUSUM) charts and Exponentially Weighted Moving Average (EWMA) charts. For more information on these charts, the interested reader is referred to Montgomery¹ and an example by Bower².

¹ Montgomery, D.C. (1996). *Introduction to Statistical Quality Control, 3rd Edition*. John Wiley & Sons.

² Bower, K.M. (October, 2000). “Using Exponentially Weighted Moving Average (EWMA) Charts”, Asia-Pacific Engineer.

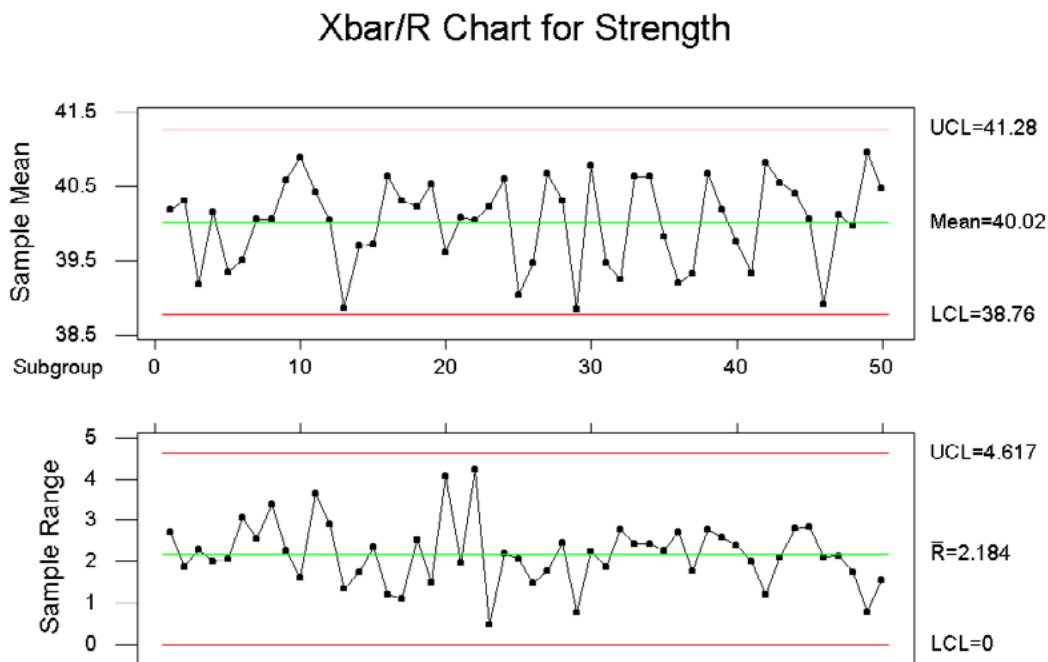
2. The Normal Distribution

One should note that there are an infinite number of distributions which may show the familiar bell-shaped curve, but are not Normally distributed. This is particularly important to remember when performing capability analyses. We therefore need to determine whether the underlying distribution can indeed be modeled well by a Normal distribution. If the Normal distribution assumption is not appropriate, yet capability indices are recorded, one may seriously misrepresent the true capability of a process.

Example

Consider the following simulation. Suppose the LSL = 37, the USL = 43, and our target for this process is midway between the specs, i.e. at 40. Firstly, considering the \bar{X} -R charts in Figure 1, we see that the distribution is stable over the period of study (this may also be reported via Minitab's Capability Sixpack™).

Figure 1

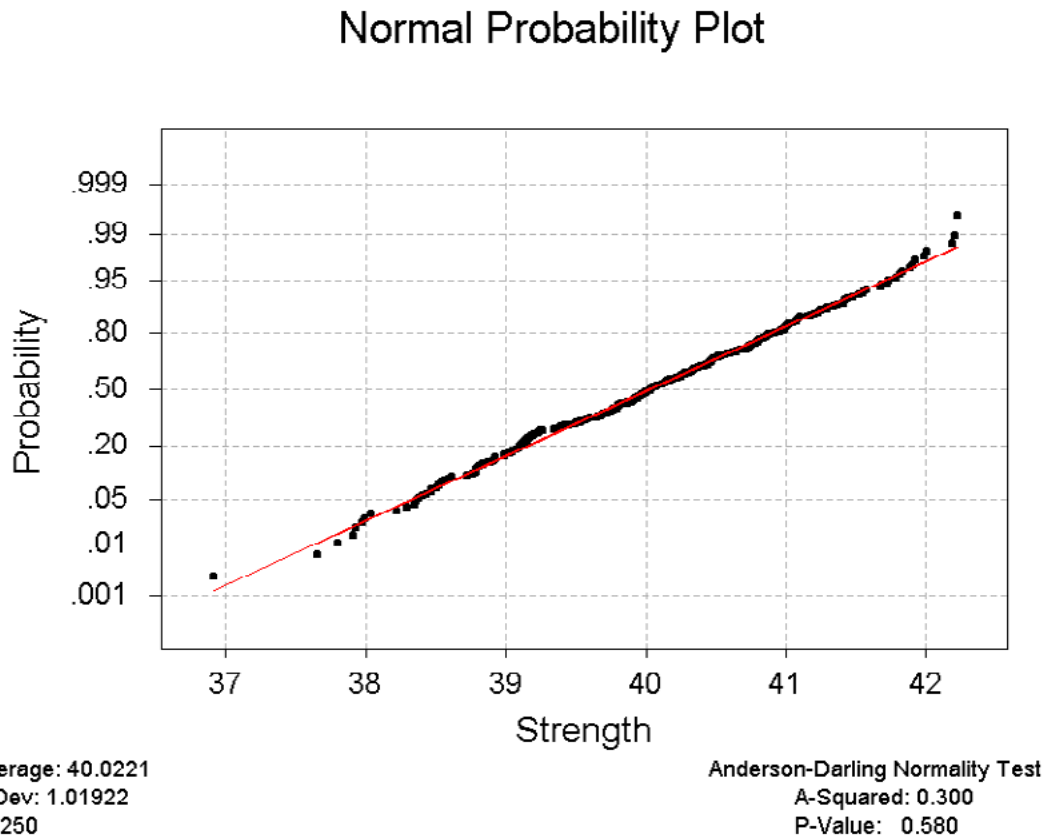


As the \bar{X} -R charts indicate stability, even using all of the Western Electric rules³, we have some justification to use estimates of the overall process mean (μ) and the within-subgroup (short-term) standard deviation (σ_{within}) from this course of study. Many practitioners mistrust the estimate of the overall standard deviation (σ_{overall}) as they question whether this window of inspection could truly estimate all of the possible realizations of special causes in the long term.

³ Western Electric (1956). *Statistical Quality Control Handbook*. Western Electric Corporation, Indianapolis, IN.

From the Normal probability plot graph in Figure 2, the Anderson-Darling (A-D) Normality test shows that we are unable to reject the null hypothesis, H_0 : data follow a Normal distribution vs. H_1 : data do not follow a Normal distribution, at the $\alpha = 0.10$ significance level. This is due to the fact that the p-value for the A-D test is 0.580, which is greater than 0.10 - a frequently used level of significance for such a hypothesis test, as opposed to the more traditional 0.05 significance level.

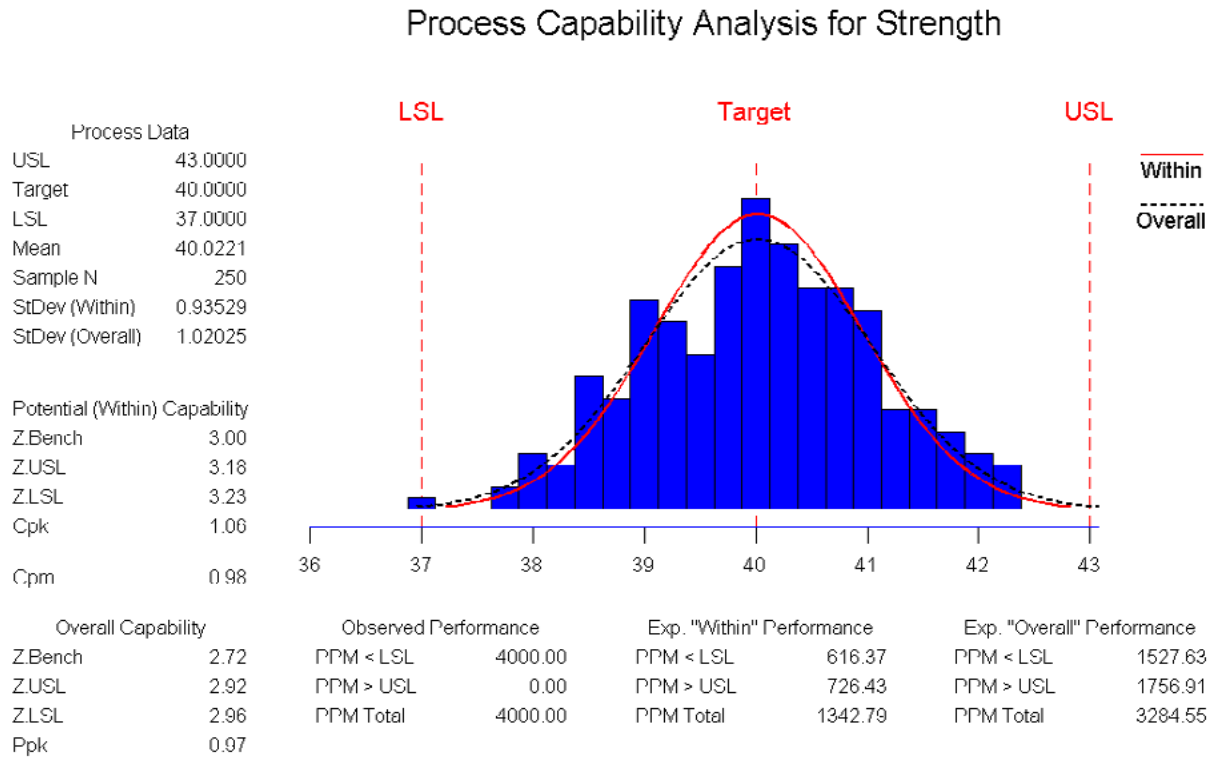
Figure 2



It is worth emphasizing that one would be advised to use a Normal probability plot along with the p-value associated with A-D test as such p-values are very much sample-size dependable. For large samples, very likely, you will reject the Normality assumption, though the underlying distribution may in fact be well modeled by the Normal distribution.

The capability analysis in Figure 3 shows that with the LSL = 37 and USL = 43. Shortterm (and long-term) performances are also indicated, namely that approximately 1343 parts per million (ppm) would be nonconforming if only common causes of variability were present in the system, and approximately 3285 ppm in the long-term.

Figure 3



The corresponding Z-Bench values, from which one may obtain a “Sigma” value may also be reported in the output.

“Six-Sigma” Capability

In practice one may find differing advice with respect to reporting the actual process sigma. There are 2 options, which this author will consider, namely:

- (i) Adding 1.5 to the overall benchmark Z, hence taking the “long term” performance, and adding the shift and drift factor to result in the “short term” assessment.
- (ii) Taking the within-subgroup benchmark Z and reporting that value as “Sigma.”

This is discussed in further detail in a future edition of the Minitab newsletter, “KeepingTAB”. In this author’s opinion, having obtained justifiable rational subgroups, which are supposed to represent solely the common causes of the process (the inherent variation), option (ii) may be preferable. I welcome practitioners’ comments on this.

Conclusion

Capability analyses are frequently reported as part of an ongoing quality program though, in many instances, statistics are merely reported and an insufficient amount of consideration for the technical issues surrounding these statistics may take place. It is the hope of this author that consideration and validation of these aspects, as indicated in this article, may be of some use to quality practitioners in order to perform capability analyses in a more valid manner. Procedures when dealing with non-Normal data will be considered in the following edition of EXTRAOrdinary Sense.