CAPABLE, STABLE, IN CONTROL – IS THIS REALLY COMMON PRACTICE?

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While discussing the issue of process capability, we always have to face the three terms given in the title of this article. However, isn't it all the same or are there really some differences?

Our first article "Process Capability – a Simple Illustration" published on April 2016 explains the basic principles of process capability analysis. This new technical contribution ties in with the first article and focuses on the terms mentioned above. Our previous article about process capability talked about the normal distribution model and illustrated how to calculate capability indices based on this type of distribution. We also touched the topic of a series of processes whose output actually approaches the "bell curve" quite well in reality, at least in a short observation period. This information lends some empirical insight into many typical production processes – turning, milling, drilling, trimming, grinding and many more.

However, we also mentioned that normal distribution does not apply to processes analysed over a longer period because they will show smaller or larger deviations in most cases. Almost every real process is subject to various influences outweighing the random variations illustrated in the previous article. Just think about temperature fluctuations between day and night or summer and winter, different batches of material, tool wear or even operator influences. There might be a random and/or systematic change of distribution parameters. The total variation of all values, however, will increase at any rate. The distribution of all individuals might have a different shape, e.g. flat, steep, skew, multimodal but even normally distributed. The graphic below gives an example of one of the numerous possible versions.

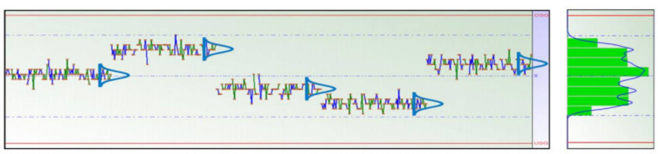

Figure 1 Value chart and histogram of a process including e.g. major shifts in average depending on the respective batch

The process is clearly not stable; however, if the shifts in average remain tolerable, the process is obviously capable. In the 1980s, the German DIN 55350-11 standard already offered a kind of answer to the problem and provided the definition of a “process characteristic in a state of statistical control”.

Translated from DIN 55350-11:2008-05

3.11.1

Process characteristic in a state of statistical control

Process characteristic for which the parameters of the distribution of characteristic values do not change, or only change in a known manner or within known limits.

This definition shows that the authors of the standard knew that they had and wanted to accept certain process instabilities as long as they met the requirements of the definition above. This is even the very reason why the method of Six Sigma considers a maximum “shift” of +/- 1.5 σ. This empirical insight accommodates the fact that real processes are subject to additional variations.

For technical reasons and based on the empirical insights provided before, certain types of characteristics can be assigned to other typical shapes of distributions – provided that their parameters are constant, especially in short-term observations. Such a classification is e.g. documented in the Daimler guideline LF 1236. The technical reason for this classification is given in the TEQ training “013-STM Process Capability Analysis”.

Characteristic		Evaluation method	Characteristic		Evaluation method
Form tolerances			**Location tolerances**		
Symbol[1]	Tolerated property		Symbol[1]	Tolerated property	*)
⏤	Straightness	B1	//	Parallelism	B1
▱	Evenness	B1	⊥	Perpendicularity	B1
○	Roundness	B1	∠	Inclination	B1
⌭	Cylindricity	B1	⌖	Position	B2
⌒	Line shape	B1	◎	Coaxiality/ concentricity	B2
⌓	Surface profile	B1	⌯	Symmetry	B1
			↗	Runout/ total runout	B1/B2
			⌰	Axial runout/ total axial runout	B1
			Other		
*) N =	normal distribution		Rz	Roughness	B1
B1 =	folded normal distribution		⨀	Imbalance	B2
B2 =	Rayleigh distribution		↔	Linear sizes	N

Figure 2 Translation of table A-1 from Daimler guideline LF 1236

* Symbols according to ISO 1101 “Geometrical Tolerancing”

The following graphics show examples of the folded normal distribution and Rayleigh distribution.

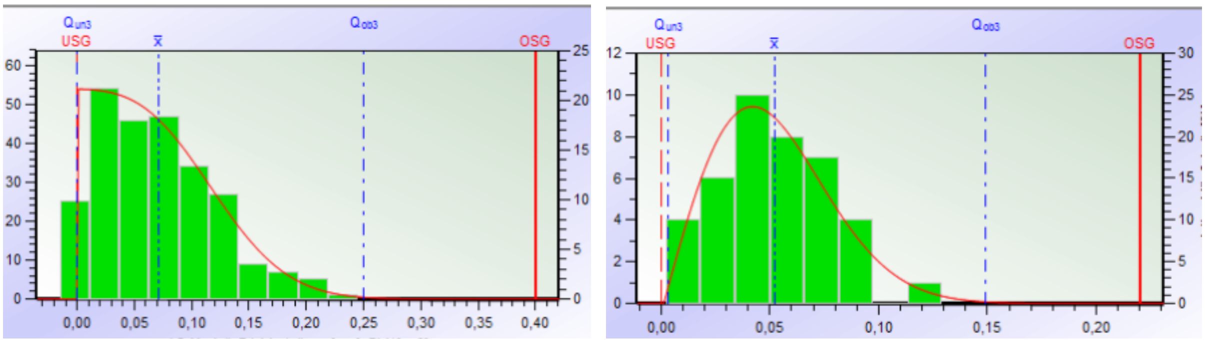

Figure 3 Examples of a folded normal distribution and a Rayleigh distribution

Due to numerous influences affecting the process, the mathematically mapped distributions are expected to vary over time which leads to smaller or larger deviations from the assigned distribution.

Besides these realities, Anglo American standards (AIAG SPC manual, IATF 16949) always assume a stable process (in a state of statistical control). Their definition of a stable process is almost the same as the one given in ISO 22514-1.

3.1.21
stable process
process in a state of statistical control
<constant mean> **process** (3.1.2) subject only to **random causes** (3.1.19)

Note 1 to entry: A production in control is a production with processes in control.

Note 2 to entry: A stable process will generally behave as though the samples from the process at any time are simple random samples from the same population.

According to the respective guidelines (standards, company guidelines and standards of technical associations), you are not allowed to indicate capability indices C_p and C_{pk} for processes that are not stable based on this definition. In this case, you may only provide performance indices P_p and P_{pk}. The capital P stands for performance.

The fact that the limitation to a hypothetical stability is not applicable in practice was confirmed in 1997 by an analysis of Daimler that is also known as “Nowack study“ among quality experts. Only about 2% of 1000 inspected processes were stable according to the definition given above. A specialist article published in the German Magazine QZ (1999) also talked about this study, headlined “Only Seems to Be Unstable” and proposed to extend the definition of “stable” basically to the definition of “in a state of statistical control”.

A German standardisation project was based on this idea and this project led to the release of DIN 55319 in March 2002. This standard defines two additional terms accommodating this fact.

Translated from DIN 55319:

3.16.1

Inherent process variation

Variation of values of a process characteristic in a state of statistical control

NOTE You may apply different measures of variation e.g. standard deviation or range.

3.16.2

Total process variation

Variation of values of a process characteristic consisting of the inherent process variation and variations due to any further admitted influences.

Based on the two basic distribution models – normal distribution and unimodal non-normal distribution – the standard examines possible combinations of varying location and variation parameters. The following matrix illustrates the classification. It is an extract from the current version of the ISO 22514-2 standard.

<table>
<tr><th rowspan="2">Process-standard deviation $s(t)$</th><th colspan="8">Process average $\mu(t)$</th></tr>
<tr><th colspan="3">Constant</th><th colspan="5">Not constant</th></tr>
<tr><td rowspan="5">Constant</td><td rowspan="2"></td><td colspan="2">A</td><td rowspan="2"></td><td colspan="4">C</td></tr>
<tr><td>A1</td><td>A2</td><td>C1</td><td>C2</td><td>C3</td><td>C4</td></tr>
<tr><td rowspan="3">Short time distribution</td><td rowspan="3">Normal distributed</td><td rowspan="3">Not normal distributed – unimodal</td><td>Location</td><td>Random</td><td>Random</td><td>Systematic (e.g. trend)</td><td>Systematic and random (e.g. lot to lot)</td></tr>
<tr><td>Short time distribution</td><td>Normal distributed</td><td>Normal distributed</td><td>Normal distributed</td><td>Normal distributed</td></tr>
<tr><td>Resulting distribution</td><td>Normal distributed</td><td>Not normal distributed – unimodal</td><td>Any shape</td><td>Any shape (e.g. multimodal)</td></tr>
<tr><td rowspan="2">Not constant</td><td rowspan="2">Resulting distribution</td><td colspan="2">B</td><td rowspan="2">Resulting distribution</td><td colspan="4">D</td></tr>
<tr><td colspan="2">Any shape – unimodal</td><td colspan="4">Any shape</td></tr>
</table>

Figure 4 Table 1 from ISO 22514-2 classification of time-dependent distribution models

The standard provides different calculation methods for the quality CAPABILITY indices of stable processes depending on the resulting distribution time model.

At the same time as the German standardisation project started, an international standardisation project dealing with the same topics was initiated. On the international level, however, the advocates of "stable" processes had their way and the international standardisation introduced the differentiation between "process capability" for stable processes and "process performance" for unstable ones. The result was published in the form of ISO 21747. The terms "stable" and "in control" became synonyms and the separate definition of "in a state of statistical control" did no longer apply. ISO 21747 was translated from English to German in 2007 and published as DIN ISO 21747 while DIN 55319 was withdrawn. From then on, you were only allowed to indicate capability indices (C_p, C_{pk}) when the process was stable based on the definition (3.1.21) given above. Still today, capability indices only apply to process models A1 and A2 of Figure 4. In any other case, you may only specify performance indices (P_p, P_{pk}), even in cases where the process is not stable based on 3.1.21 but in control according to 3.1.20. C_p and C_{pk} should actually become collector's items being of a rarity now.

This fact still poses a difficult dilemma. It has been common practice to consider additional variations of real processes and to monitor processes "in control" by applying quality control charts with extended limits or acceptance charts (whose targets and principles we will explain in a different article) – at least in Germany. As long as the processes do not violate the corresponding control limits, process capability is established. This procedure, however, is contrary to ISO 21747. Some German manufacturers like Daimler, VW and Bosch have kept this procedure all the same which seems like an act of civil disobedience. Even though company guidelines distinguish between C and P – which complies with standards – the evaluation strategy in qs-STAT calculates C-values even for control charts with extended control limits. The good news is that these settings do not affect the calculated results of C and P at all.

While ISO 21747 was revised to publish ISO 22514-1, the German representatives of the responsible ISO committee TC 69 insisted on the differentiation between "in control" and "stable" since they wanted to include the former definition again. Even though both definitions became part of the revised standard once again, the terms are subsequently not applied in the document at all. The German version at least includes a footnote informing about this development.

3.1.20
product characteristic in control
product characteristic (3.1.7) parameter of the distribution of the characteristic values of which practically do not change or do change only in a known manner or within known limits

Translation of the German footnote: In ISO 21747:2006, 3.1.1.6, the English terms "stable process" and "process in control" were synonyms. ISO 22514-1:2014, 3.1.21, however, only refers to the behaviour according to ISO 21747:2006, 3.1.1.6, note 1 to 3, as "stable process" and "process in control". But ISO 22514-1:2014, 3.1.20, specifies the behaviour as explained in ISO 21747:2006, 3.1.1.6, note 4, as a "product characteristic in control". This change of meaning has not been considered yet in ISO 3534-2:2013-12, 2.2.7.

Let's return to the question we asked in the heading. "Is this really common practice" or just splitting hairs? Our conclusion: Many processes are approximately normally distributed in the short term. Additional variations, especially variation in the location of averages, lead to smaller or larger deviations from the normal distribution model. This restriction of capability analyses to stable processes as given in ISO 22514-2 is only a theoretical one and cannot be applied in practice. Real processes most frequently correspond to process model C (C1 to C4) of the standard. The definition of a "process in control" as provided by ISO 22514-1, 3.1.20 applies to most of them. The acceptance of these additional variations is virtually always reasonable for economic reasons. Quality control charts with extended control limits or acceptance charts are functional tools to "control" a process. The debate about "process capability" and "process performance" is rather negligible since, as mentioned before, the terms do not have any impact on the meaning of the numeric value.

The following graphic shows some representative constellations of stable, in control and capable. Please contact us in case of any questions arising in your company.

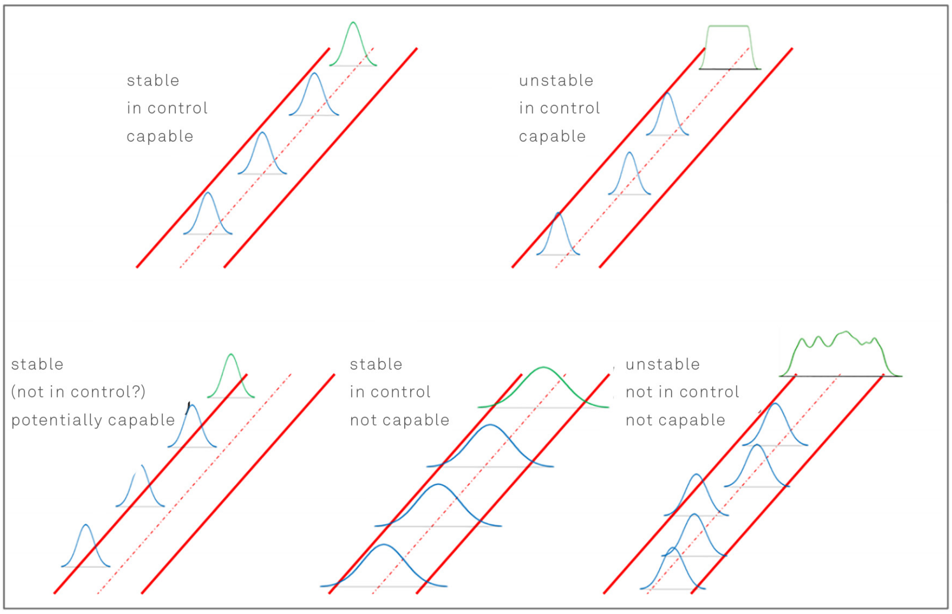

Figure 5 Representative examples of in control, stable and capable ($C_{pk} > 1.33$)

Interested in this topic?

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