MEASUREMENT PROCESS CAPABILITY - PART 2

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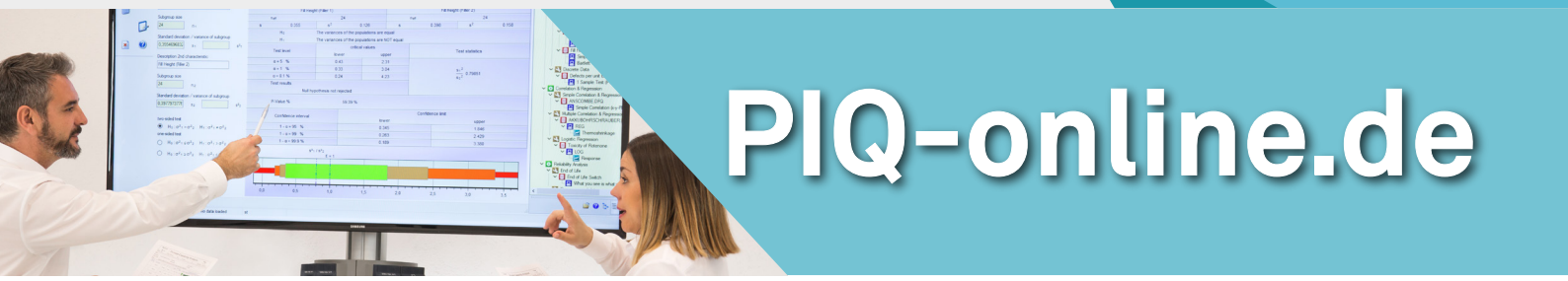


There is still need for discussion – a working paper

Nowadays, measurement process capability according to VDA Volume 5 and/or ISO 22514-7 is well-established. The Volkswagen group (VW, Audi, Seat, Skoda…) adapted their VW 10119 guideline years ago, the LF5 Daimler guideline is already based on the latest edition of VDA Volume 5, BMW modified the group standard 98000 accordingly, Bosch updated booklet 8… however, this fact alone does not answer all the questions. This article discusses some current aspects that leave room for interpretation since they are not based on any "official" regulations. Read part 2 of this series of articles.

ONE-SIDED TOLERANCES

VDA Volume 5 only contains few information about one-sided tolerances. To avoid confusions, we have to distinguish between different kinds of "one-sided tolerances".

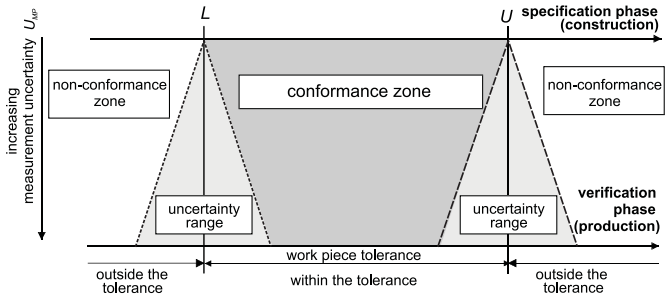
- One-sided tolerances having only one defined specification limit and are unlimited to the other side. Examples are pull-off forces and minimum breaking force.

- One-sided tolerances having a defined specification limit and a natural limit for natural/physical/technical reasons. Examples are measures of form and location such as roundness, evenness and rectangularity. The natural limit frequently equals zero and often refers to the target measure.

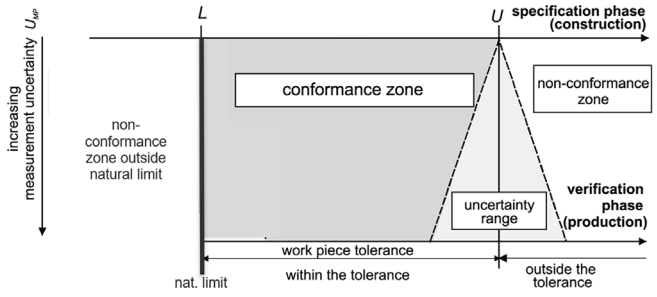
VDA Volume 5 does not yet offer a solution to the first case of a so-called tolerance unlimited to one side. The problem is that you require a tolerance T to calculate capability ratios; however, you cannot specify a tolerance in this case.

In the second case, the natural/physical/technical limit can be considered as a specification limit; you are thus able to calculate the tolerance T. This approach is common practice in measurement system analysis.

However, there is one fact in the debate about conformance zones that is worth mentioning. According to VDA Volume 5, the specification has to be extended by U at the upper and at the lower limit, at least from a supplier's perspective.

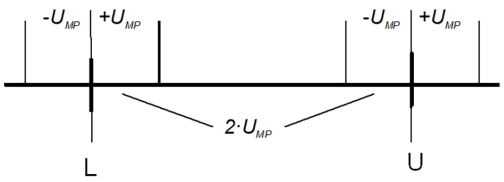


This reduction, of course, does not apply to natural/physical/technical limits. You only have to consider the measurement uncertainty at the set specification limit.



However, VDA Volume 5 includes the following note.

Note: According to ISO/TS 14253 [13], the tolerance zone is reduced on either side by the expanded measurement uncertainty U_{MP}. For this reason, the ratio of $2 \cdot U_{MP}$ is used as the tolerance TOL for the capability ratio.

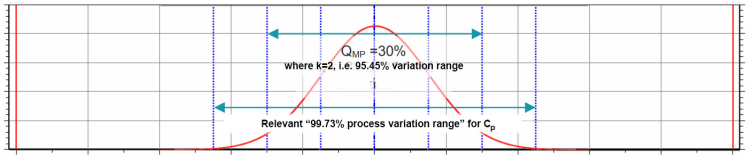


This might lead to the conclusion that only have to consider the expanded measurement uncertainty once in case of "one-sided specifications". You thus have to calculate the capability ratio only based on 1·U. This leads to the following formula for the capability ratio:

$$Q_{M*} = \frac{U_{M*}}{T} \text{ (where * refers S or P)}$$

This is, of course, a misinterpretation of the real facts; when consistently applied to a limit of $Q_{MP} \leq 30\%$, the results will be disastrous. As part 1 of this series already described, we try to find out how this result affects a machine/process capability analysis.

If $Q_{MP} = U/T = 30\%$, the expanded measurement uncertainty will amount to U=0.3·T. The 95.45% variation range (referring to 4s) of the measurement uncertainty is thus 2·U=0,6·T.



Applying this "noise floor" of the measurement process as a kind of variation to calculate process capability, you have to consider the 99.73% variation range (referring to 6s), i.e. 1.5 times the 95.45% variation range (simplified form of the normal distribution). The "noise floor range" thus amounts to 1,5·2·U=0,9·T and thus leads to C_p=1/0.9=1.11 even before you measured any part. No matter what you do now, there is definitely no more chance of reaching the target value of $C_p \geq 1{,}33$.

In the end, this is nothing but a misinterpretation of the note given in VDA Volume 5. The authors' intention was to discuss two aspects. Does the capability ratio have to be stated as U/T, which is similar to historical specifications based on "half" the variation ranges U and which was even included in the first edition of VDA Volume 5? Or is the total variation range of 2U always supposed to serve as a basis, similar to the results of measurement system analysis? The decision

to apply $Q_{M*} = \frac{U_{M*}}{T}$ was reasonable, for sure, since it does not confuse users of similar procedures completely. This is why we consistently relate the total variation range to the total specification since then.

MEASUREMENT PROCESS CAPABILITY AND RESTRICTED SPECIFICATIONS

There is a second misapprehension hidden in the background. The associated conversation is often as follows.

Question: "When my capability ratio amounts to Q_{MP} = 26%, my measurement process is capable, and I can use it to perform my process capability analysis. However, when I skip process capability, do I have to calculate a capability index C_{pk} that relates to the reduced tolerance?"

Answer: "No, you always have to relate machine performances and process capabilities to the specified tolerances. The existing measurement uncertainty already affects the results by increasing the observed process variation. You must not include it in the calculation twice, which will be the case when you reduce the tolerances."

Question: "And when do I have to restrict the tolerances?"

Answer: "You always restrict them when you assess conformity. i.e. when you inspect a part and want to decide whether the measured value of this very part falls within the specification.

Question: "I see! So, when I assess conformity based on Q_{MP} = 26%; I will reduce each specification limit by 13%, won't I?"

Answer: "Yes."

Question: "And when the capability ratio of my measurement process only amounts to Q_{MP} = 32%, I will reduce each specification limit by 16%?"

Answer: "Yes, that is correct."

Question: "Well, but this will not work because it means that the measurement process is not capable at all..."

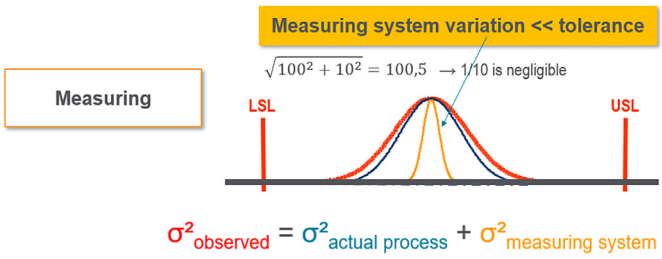
Answer/counter question: "Capable of what?"

At least by now you will start to brood and then it becomes clear that we like to mix up two very important activities. In general, it is all about "measuring" and "testing".

- A capability analysis always refers to a specific task which is, however, NOT a conformity assessment in our case. Typically, we need to establish the capability of a measurement process that helps us establish the capability of machines and processes or control processes (SPC). What we mainly observe are variations, especially variations of process location and process dispersion. The measuring system thus serves nothing but measuring purposes, you just use it to gain information.

  In this case, the measurement uncertainty affects the variation and increases it. And variations are calculated using quadratic addition. Increasing the process variation σ_p by a measurement process variation of 10% of the process variation ($\sigma_{MP} = 0.1 \cdot \sigma_p$), the total variation σ_{total} rises to $\sigma_{total} = \sqrt{(\sigma_p^2 + 0.1^2 \cdot \sigma_p^2)} = 1{,}005 \cdot \sigma_p^2$.

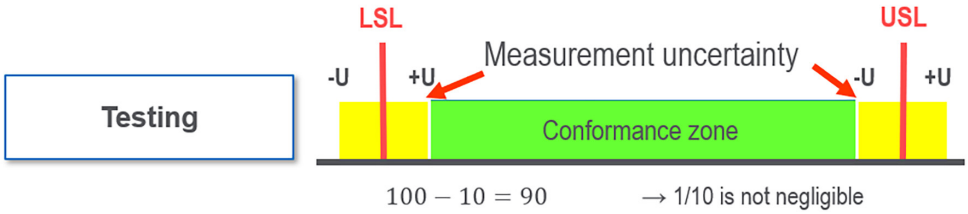
  The total variation thus increases by 0.5%, which is negligible. Even if we raise the process variation by a measurement process variation of 30%, the total variation will only increase by 4.4%. Conditions like these let us assume that the measuring system is capable, and you do not need to take any further corrective action.



- A different application is the conformity assessment of single parts. We pick one measured value of each part, compare this very value to the specification and make a test decision. We thus use the measurement process to gain a piece of information about a part and compare this information later on to the specified limits for analysis purposes.

  In this case, the measurement uncertainty becomes effective in the form of an uncertainty as to the true value of the part. We thus need a safety distance to the limits and have to reduce the specification to "acceptance limits".

If the uncertainty amounts to U=5%T, we will have to restrict two-sided tolerances by 2·U = 10%T; what remains is 90% of the tolerance. Provided that U=10%, only 80% of the tolerance are left. There is not any uncertainty that can be assessed as “ok, let’s drop it”. The capability index is irrelevant in this case.



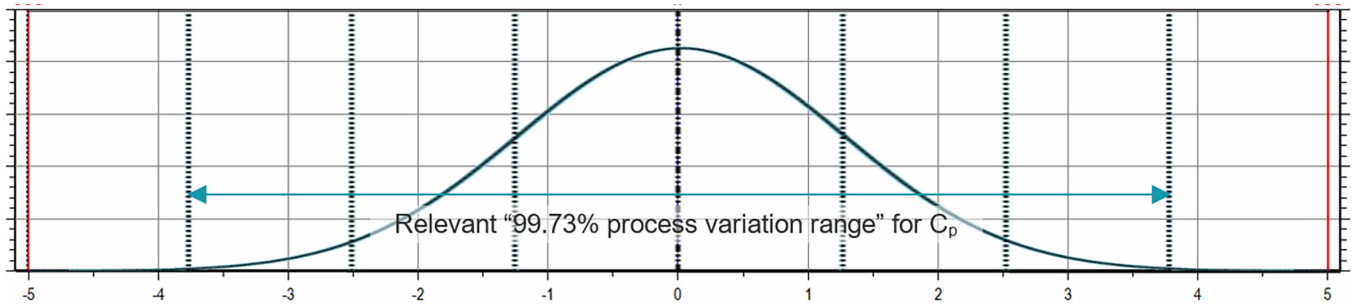
In the end, the term “capable” referring to the requirement of $Q_{MS} \leq 30\%$ is, above all, relevant to measurement processes (machine performance, process capability, SPC). “Capability” is only conditionally reasonable for test processes (conformity) since the expanded measurement uncertainty U is always considered at the specification limits.

There is only one “special case” – if the process capability is very high and the uncertainty is very low, there will be only few parts in the uncertainty range around the specification limits. The risk of making the wrong decision is thus negligible and you thus do not need to restrict the tolerance.

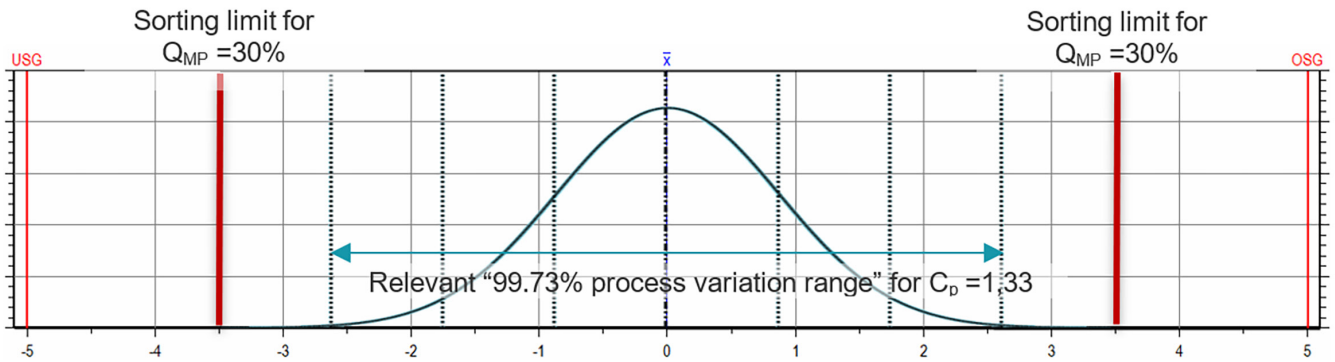
PROCESSES NOT CAPABLE – NEVER MIND, WE PERFORM 100% INSPECTIONS!

This is a statement that is worth endless discussions. My assertion: There is hardly any other mistake you will pay more dearly...

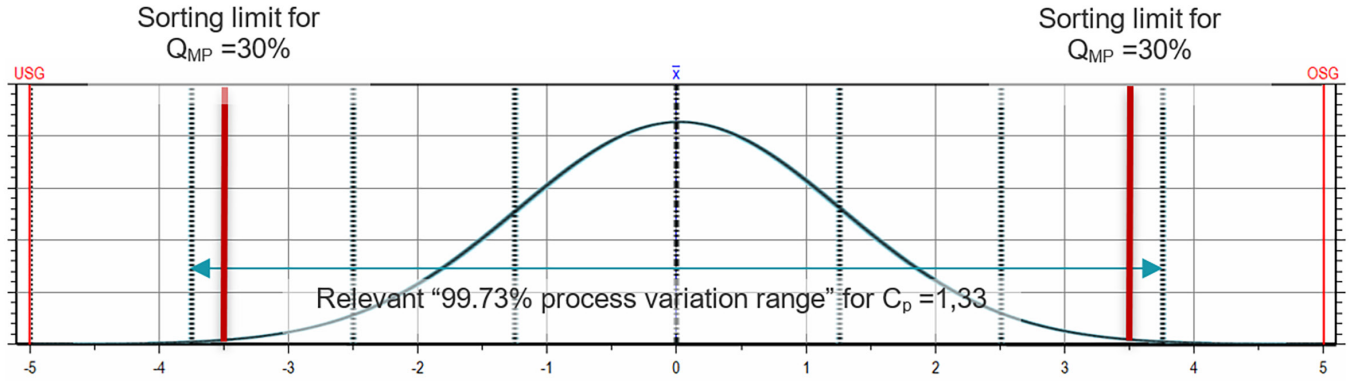
Let’s start with a rough estimate. Demanding a process capability index of $c_p \geq 1.33$, the 99.73% process variation range may occupy exactly 75% of the specification. This leads to an excess proportion of about 63 ppm (provided that the process is centred and normally distributed).



If we permit the capability ratio to amount to $Q_{MP} \leq 30\%$ and stick to the 100% inspection, we may only release parts within a 70% zone of the tolerance. In case the declared excess proportion is now also supposed to be less than 63 ppm, 99.9957% of all values (”8s“) need to be within the 70% zone, e.g. your processes must have a capability index of $C_p = 1.9$. Does this make sense? Rather not.

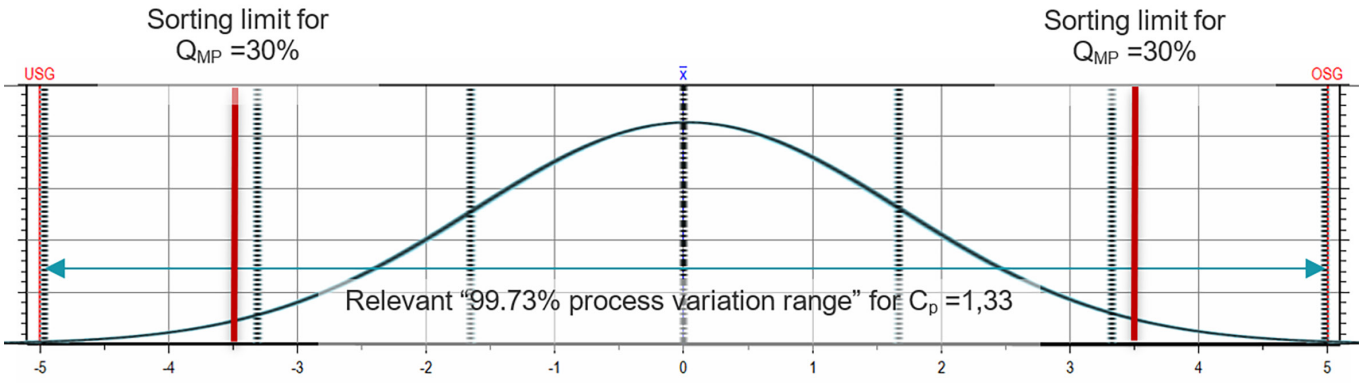


So let's leave our process at C_p = 1.33 and apply SPC instead of performing a 100% inspection. We increase our number of "controlled" SPC rejects from 63 ppm to a number of 100% inspection rejects of 5110 ppm. Is this supposed to make sense? 5110 ppm will, of course, contain a huge proportion to pseudo rejects; however, we are not able to distinguish these pseudo rejects from "real" ones.



What makes things even worse is that 100% inspections only require a capability index of C_p = 1. The produced number of rejects amounting to 2700 ppm thus increases to an "inspected" number of rejects of 35730 ppm.

It is true, of course, that the customer "is not provided with any defective part", however, I leave it up to you, my dear readers, to calculate the reject costs. In your individual case, you thus have to calculate these values based on your actual measurement uncertainty.



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