

CONSIDERING THE EXPANDED MEASUREMENT UNCERTAINTY IN 100% INSPECTIONS

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How to apply the second edition of VDA Volume 5 in practice

Customer requirements are easy (to understand): zero defects in all parts. Since a 100% inspection is usually not economical, companies frequently apply statistical process control (SPC) in industrial production. Even though, realistically viewed, this method does not guarantee that 100% of the parts are free from defects, it leads to a proportion of defects within a range that can only be measured in parts per million (ppm).

Being a major industry, automotive manufacturers demand a minimum process capability C_p/C_{pk} of 1.67 from their external suppliers; this equals a theoretical maximum share of rejects of 0.6 ppm. In case they meet this requirement, quality control charts control the process based on subgroups. When they are not able to satisfy this requirement or a sample indicates a process failure, the parts produced (since the last subgroup o.k.) become subject to a 100% inspection before they can be supplied to the customer. This is why it is not recommended to choose a subgroup size that is too large. Especially in series production, a subgroup n.o.k. quickly causes a 100% inspection of several thousand parts.

This article describes how measurement uncertainty affects 100% inspections. It provides you with background information and explains how to consider the expanded measurement uncertainty at the specification limits in practice.

ISO 3534-2 defines statistical process control (SPC) in chapter 2.1.8 as [activities focused on the use of statistical techniques to reduce variation \(2.2.1\), increase knowledge about the process \(2.1.1\) and steer the process in the desired way.](#)

The German Society for Quality (DGQ) is more specific about these terms and provides explicit control charts and process capability analyses.

The main steps to implement SPC typically are

1) PROCESS AND CHARACTERISTIC SELECTION

- Which product characteristics are important or relevant to customers? Are there any associated specifications available?

2) MEASURABILITY OF PRODUCT CHARACTERISTICS

- Is the measurement system/measuring equipment capable of recording the measured values of the product characteristics with sufficient accuracy? (measurement system analysis)

3) FEASIBILITY OF PRODUCTS

- Are the machines/facilities capable of producing products of appropriate quality? (machine performance)

4) PRODUCIBILITY OF PRODUCTS

- Is the process capable of maintaining the product quality for a longer period? (process capability)

5) CONTROLLABILITY OF PROCESSES

- Do we know the process behaviour sufficiently well to react to changes in an appropriate way? (quality control charts)

After identifying the characteristics relevant to the respective customer, you have to qualify the measurement system customer and supplier agreed on in the control plan for the respective application.

To find out whether the measurement system is suitable for this characteristic in the respective application, the second step is to perform a measurement system analysis according to type-1 or type-2 study – in case there is not any operator influence available – or according to type-1 and type-3 study under real conditions. When the analysis confirms the capability of the measurement system for the intended characteristic, you may use this measurement system to inspect the produced parts in the third, fourth and fifth step.

If you ideally have a process with a high capability index, the second edition of VDA Volume 5 Measurement Process Capability e.g. says on page 43:

[If the capability of the production process reaches a sufficiently high value \(e.g. \$C_p, C_{pk} \geq 2,0\$ \) that was established by an adequate measurement process, a separate observation of the expanded measurement uncertainty at the specification limits is not required because the evaluation of the process already includes the variation of the measurement process.](#)

In any other case requiring a conformity assessment, especially in case of 100% inspections, you have to consider the following rules.

Applying a 100% inspection, you must not consider the entire tolerance to make a good/bad decision. You have to consider the uncertainty according to ISO 14253-1:2013 at the tolerance limits instead.

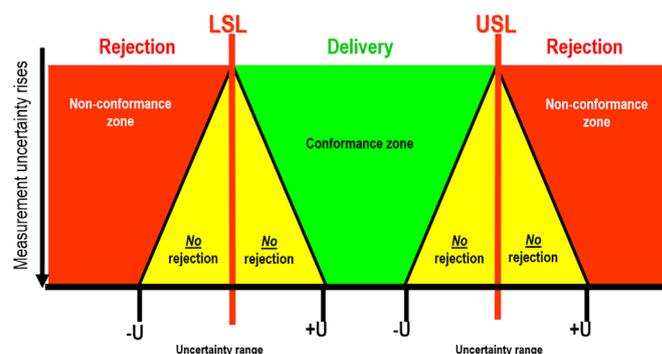


Fig. 1: Acceptance zone and rejection zone based on ISO 14253-1:2013

This uncertainty is expressed in the form of the expanded measurement uncertainty U_{MP} . The applicable tolerance thus becomes tighter and only parts in the acceptance zone may be supplied to the customer.

$T' = T - 2 * U_{MP}$ where T is the tolerance given in the drawing and T' is the acceptance zone for 100% inspections. The expanded measurement uncertainty UMP is calculated according to the 2nd edition of VDA Volume 5.

The following example illustrates the effects of considering measurement uncertainty. The example is based on the following data:

- part = cylinder bore
- characteristic = inside diameter
- USL = 30.008 mm
- LSL = 30.003 mm
- T = 0.005 mm
- measuring instrument = bore gauge with resolution RE = 0.0001 mm

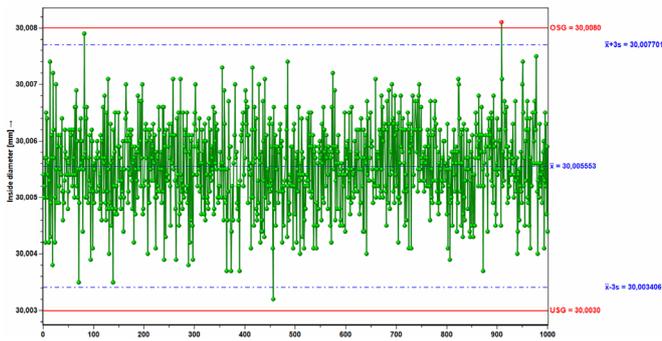


Fig. 2: Value chart of 1000 cylinder bores

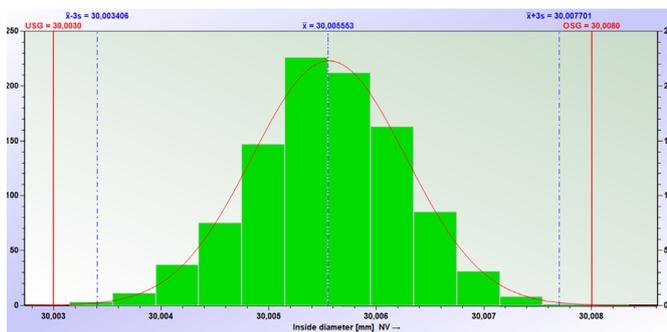


Fig. 3: Distribution of measured values in a histogram

This manufacturing process is not capable due to tight tolerances.

$C_p = 1.16$; $C_{pk} = 1.14$ this is why these parts have to be subject to a 100% inspection; only parts not exceeding the acceptance zone may be supplied to customers.

The measurement uncertainty study was based on the specifications of the 2nd edition of VDA 5 and the uncertainty was calculated in solara.MP.

Measurement system			
Tolerance	TOL	=	0.0050
Resolution	%RE	=	2.00%
Combined standard uncertainty	u_{MS}	=	0.0000982
Expanded measurement uncertainty	U_{MS}	=	0.000196
Capability ratio limit	Q_{MS_max}	=	15.00%
Capability ratio	Q_{MS}	=	7.86%
Minimum tolerance	TOL MIN-UMS	=	0.00262
↑ Measurement system capable (RE,QMS,QMP) ↑			
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Measurement process			
Combined standard uncertainty	u_{MP}	=	0.000187
Expanded measurement uncertainty	U_{MP}	=	0.000374
Capability ratio limit	Q_{MP_max}	=	30.00%
Capability ratio	Q_{MP}	=	14.98%
Minimum tolerance	TOL MIN-UMP	=	0.00250
↑ Measurement process capable (RE,QMS,QMP) ↑			
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Fig. 4: Results of the measurement uncertainty study

The results are as follows:

$U_{MP} = 0.000374\text{mm}$

$T' = T - 2 * U_{MP} = 0.005\text{mm} - 2 * 0.000374\text{mm} = 0.004252\text{mm}$

Part no.	F1	Part descr.	Piston
Char.No.	1	Char.Descr.	Inside diameter
Drawing Values		Collected Values	
T_m	30.0055	\bar{x}	30.005560
LSL	30.0030	x_{min}	30.0032
USL	30.0080	x_{max}	30.0081
T	0.0050	R	0.0049
Characteristics : significant		n_{eff}	1000
		n_{tot}	1000
		$n_{<T}$	999 / 99.900000%
		$n_{>USL}$	1 / 0.100000%
		$n_{<LSL}$	0 / 0.000000%
Model distribution		Normal Distribution	
Distr.regress.coeff.		f_{tot}	0.99883215
Distr.regress.coeff.		$f_{25\%}$	0.98779338
Calculation method		M4; Percentile (0,135% - \bar{x} - 99,865%)	
Potential Capability index	C_p	1.11 ≤ 1.16 ≤ 1.22	
Critical capability index	C_{pk}	1.09 ≤ 1.14 ≤ 1.19	
↓ The requirements were not met (C_p, C_{pk}) ↓			
Demand Potential Capability index	C_{p_target}	1.67	
Demand Critical capability index	C_{pk_target}	1.33	
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Fig. 5: Calculation of expected fractions nonconforming exceeding the specification

$USL(T) = 30.007626\text{mm}$, $LSL(T) = 30.003374\text{mm}$ where $UL(T)$ and $LL(T)$ are the limits of the acceptance zone.

When $T = 0.005\text{ mm}$, the estimated share of rejects amounts to 500 ppm.

Subtracting the expanded measurement uncertainty $U_{MP} = 0.000374\text{mm}$ from both tolerance limits, the acceptance zone is only $T = 0.004252\text{mm}$ and the proportion of parts that need to be sorted out raises to more than 3,000 ppm.

The following screenshot illustrates the measurement uncertainty range at the specification limits.

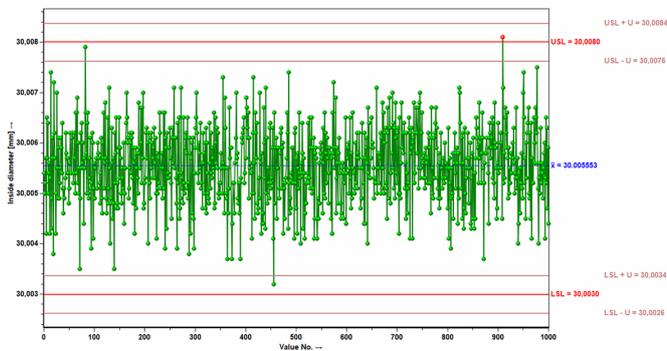


Fig. 6: Display of the uncertainty ranges at the specification limits

Conclusion

A process capability analysis at the level the customer demands and the continuous control of process stability protect you from high inspection efforts and an unnecessarily high amount of parts that must not be delivered to customers. The consideration of measurement uncertainty thus helps you avoid high failure costs.

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