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VDA 5 vs. MSA 4

The question arising after the release of the 2nd edition of VDA 5 is: Which guideline is better to apply? VDA 5 or MSA 4? This article tries to provide an answer.

Guidelines and standards for measurement process capability analysis

So far, the MSA (Measurement System Analysis) [1, 2, 3 and 4] for establishing measurement process capability is the most frequently used document in audits according to ISO/TS 16949. When the AIAG (Automotive International Action Group) announced the 4th edition, they explicitly stated that even other methods (not mentioned in MSA 4) are permissible as long as they are suitable or in case of an agreement between customer and supplier. Today, there really is an alternative to MSA 4.

The new VDA volume 5 “Capability of Measurement Processes” [13] published in November 2010 is available as a guideline meeting all these requirements. Additionally, it is much more practice-oriented than MSA 4. Furthermore, the approach of VDA 5 is based on the ISO standard 22514-7 Capability of Measurement Processes [8]. GUM (Guide to the Expression of Uncertainty in Measurement) is also worth mentioning. However, this guide lacks practical relevance for capability analyses in industrial production. And let’s not forget about numerous company guidelines (see [7], [9] and [12]).

Preliminary note

The author was a member of the VDA 5 “Capability of Measurement Processes” work group. You might thus allege that he is partial to this guideline. However, we still want you to judge the following aspects and evaluate the information based on your personal experience.

What is characteristic of VDA volume 5?

For a better understanding, we recommend you to read the PIQ-online article “Notes on the 4th edition of the MSA Manual” [11] first. This article takes a look at MSA from a critical perspective.

Terminology

VDA volume 5 only refers to the terminology defined in VIM (International Vocabulary of Metrology) [5]. Moreover, the calculation of expanded measurement uncertainty is based on GUM (Guide to the Expression of Uncertainty in Measurement).

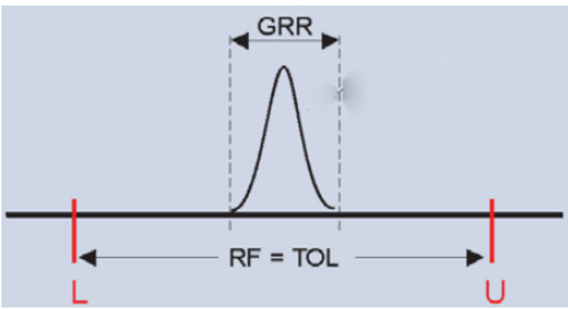
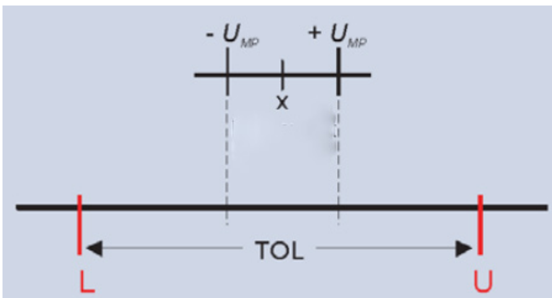
Uncertainty components

One of the main advantages of VDA volume 5 and the ISO standard is that the influence quantities affecting the measurement process and the corresponding uncertainty components are considered separately. You can immediately rank the influence quantities in order to find out how much these quantities contribute to measurement uncertainty. Additionally, there is a well-structured approach to the calculation of the expanded measurement uncertainty (it is like a recipe) allowing for few alternative methods. This fact leads to uniform and reproducible results that do not depend on the place/site where the results are produced – at the customer's or supplier's premises, in a plant or globally in several plants of a company.

Measuring system as a part of the measurement process

The measuring system is clearly defined to be a sub-element of the measurement process. Uncertainty components are resolution, calibration uncertainty on the standard, variation of the measuring system based on repeated measurements on a standard with known actual value, measurement bias and sometimes linearity. You can include available type-1 studies to calculate the expanded measurement uncertainty of the measuring system. If required, you just need to add some information, such as resolution or calibration uncertainty on the reference standard. You can thus transfer these completed studies easily without having to make new analyses. You may even calculate a capability index that you compare to a limit recommended by VDA 5. This is how you establish capability and calculate the minimum tolerance.

Manufacturers of measuring instruments are now able to specify the expanded measurement uncertainty of the measuring system independent of its future application. This is a kind of verification of the measuring system. Moreover, the entire approach provides operators of measuring systems in industrial production with a basis of decision-making defining whether a measuring system is generally suitable for a certain measurement task or specifying the minimum tolerance required to establish the capability of the measuring system. This evaluation is possible now since VDA volume 5 generally applies the tolerance as a reference figure.

	MSA 4 / company guidelines	VDA 5 or ISO/CD 22514-7
Capability index	$\%GRR = \frac{\sqrt{EV^2+AV^2}}{RF} \cdot 100\%$ where RF = total variation TV, process variation σ, P_p, P_{pk} or tolerance TOL, the latter is often applied in company guidelines	$\%Q_{MS} = \frac{2 \cdot U_{MS}}{TOL} \cdot 100\%$ $\%Q_{MP} = \frac{2 \cdot U_{MP}}{TOL} \cdot 100\%$ where TOL = tolerance U_{MS} or $U_{MP} = 2 \cdot \sqrt{\sum_{i=1}^{n} u_i^2}$ i = 1, 2, 3, ... u_i standard uncertainty of the i-th influence component of measuring system or measurement process
Limits	%GRR ≤ 10% acceptable 10 < %GRR < 30% acceptable for some applications 30 ≤ %GRR unacceptable	Measurement result y = x ± U_{MP} $\%Q_{MS} \leq 15\%$ capable $\%Q_{MP} \leq 30\%$ capable
Evaluation in graphics	 Measured values close to specification limits (U or L) might lead to wrong decisions.	 Measurement result y has to be within the tolerance TOL (see ISO 14253).

Evaluation based on ANOVA

You analyse any other influence components of the measurement process separately. i.e. repeatability on test parts, operator influence, test part influences, temperature or stability. In order to evaluate repeatability on test parts or operator influence, you apply the same method of ANOVA as in the MSA manual. However, the statistics EV and AV are not calculated by including a factor of “6” which leads to results that are not reproducible. Still, the specified variance components are identical. The advantage is that you can use available GRR studies as a basis for calculating the influence components mentioned before – similar to the measuring system approach.

The GRR study only allows for the analysis of two influence components whereas the method of ANOVA is able to analyse more than two influence components. A typical example is that it is not enough to consider nothing but repeatability on test parts and operator influence, since the process also takes measurements by means of different instruments and at different places of measurement. The number of experiments thus increases by a factor of 2k. In order to still keep the economic efficiency, you use D-optimum designs reducing the number of experiments considerably. The evaluation based on ANOVA provides you with an estimate of the respective standard uncertainty for each considered influence quantity.

Uncertainty from test part inhomogeneity and temperature

VDA volume 5 describes different methods of how to calculate standard uncertainties from test part inhomogeneity and temperature. Manufacturers of measuring instruments are particularly interested in uncertainty from test part inhomogeneity. In many GRR studies, the uncertainty from test part inhomogeneity has led to bad results. As soon as this uncertainty is too high, the measuring points will always vary in repeated measurements and test part inhomogeneity thus leads to a higher variance component that is not caused by the measuring system.

The more complex the measurement process and the smaller the demanded tolerances, the more important it is to consider uncertainty from temperature. This rule applies to the measuring instrument and to the test part. This is the reason why VDA volume 5 provides you with several methods to consider this influence quantity and to calculate uncertainty from temperature. Since the whole issue is quite complex, there is more than a single approach to this problem; depending on the respective application, there are different methods available. We recommend you to select the most suitable approach and to implement it consistently in your company.

Influences are not considered more than once

VDA volume 5 ensures that an influence quantity is not considered more than once in the formulas calculating the expanded measurement uncertainty. As an example, the calculation of the expanded measurement uncertainty always considers the highest uncertainty from resolution, from repeatability variation on reference standards or from repeatability on test parts.

According to the approach described before, the calculation of the expanded measurement uncertainty of the measurement process is well-structured. Due to clear formulas and methods, you may determine the standard uncertainty from the single influence quantities. By ranking these uncertainties, you easily identify the influence quantity affecting the measurement process most. This knowledge provides the basis for measurement process improvement. The fact that you may apply available data from type-1, type-2 and type-3 studies is also an advantage. You might just have to add some influence components. VDA volume 5 makes it much easier to calculate the expanded measurement uncertainty for the measuring system and the entire measurement process.

Attribute measurement processes

VDA volume 5 provides you with two different methods for attribute measurement processes – one applies to cases where reference parts are available and the other one to cases without any available reference parts. When there are reference parts available, you use the signal detection approach analogously to the MSA manual. Otherwise, VDA volume 5 recommends you to apply the Bowker test. The MSA manual does not include the Bowker test as such. According to VDA 5, however, even other methods are permissible, e.g. Cohen's kappa as given in the MSA.

Basis for auditing

Especially the fact that VDA volume 5 complies with ISO 22514-7 is the reason why this guide provides an excellent basis that will establish itself internationally. It can be assumed that many auditors will rather demand measurement process capability analyses according to the ISO standard or VDA 5 than MSA. These new demands will particularly affect the German automotive industry since the OEMs involved in the creation of VDA 5 will implement the requirements of this guide in their companies and, at the same time, they will expect their suppliers to meet VDA 5 requirements, too.

In audits according to ISO 9001, there is a "real" standard available now in the form of ISO 22514-7, i.e. auditors do not have to switch to the MSA manual. Time will tell which guide is going to succeed – MSA or VDA 5.

The good news

The Q-DAS software solara.MP since version 10 meets all requirements of VDA 5 and MSA 4. Users are even able to use data of MSA studies evaluated in previous solara.MP versions.

Influence quantities		MSA 4	Company guidelines			VDA 5 or ISO/CD 22514-7	Source of information
Resolution / data category	Measuring system	ndc ≥ 5	%RE ≤ 5% TOL	Measurement process	Measuring system	%RE ≤ 5% and $u_{RE} = \frac{RE}{2\sqrt{3}}$	Indication of measuring instrument
Uncertainty on reference part		*)	U ≤ 5% TOL			$u_{CAL} = \frac{U_{CAL}}{2}$	Calibration certificate
Repeatability on reference part		small	Cg ≥ 1.33			$u_{EVR} = s$	Type-1 study
Bias		t-test	Cgk ≥ 1.33			$u_{BI} = \frac{\lvert \bar{x} - x_m \rvert}{\sqrt{3}}$	Type-1 study
Linearity		t-test	%LIN ≤ 5% TOL			$u_{LIN} = \max\{u_{Bi_i}\}$	Type-1 study on three standards
Repeatability on test part		EV (ANOVA)			Measurement process	u_{EVO} = EV (ANOVA)	Type-2 or type-3 study
Reproducibility on test part		AV (ANOVA)				u_{AV} = AV (ANOVA)	Type-2 or type-3 study
Uncertainty from test part		Repeated measurements at the same position				$u_{OBJ} = \frac{TOL}{\sqrt{3}}$ or $\frac{a}{\sqrt{3}}$	With a from: - drawings - empirical values - estimations - experiments - similar measurement processes - long-term analyses - etc.
Temperature		--------------*)				$u_T = \frac{a}{\sqrt{3}}$	
Stability		Quality control chart				$u_{STAB} = \frac{a}{\sqrt{3}}$	
Uncertainty from other influences		--------------*)				u_{REST}	

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