TEQ Training & Consulting GmbH | Morteza Farmani | August 2015

The "Golden Rule of Metrology" Is no Longer State of the Art

Many participants of our seminars on measurement system analysis and measurement uncertainty studies ask about the tolerance needed to apply specific measuring equipment.

Measuring equipment fulfilling various measuring tasks is referred to as standard measuring equipment. 30% to 90% of all measuring devices applied by automotive suppliers are considered to be standard measuring equipment. Typical examples are callipers, micrometers or dial gauges.

An important characteristic of standard measuring equipment is that it is produced and calibrated according to specified guidelines and standards. These documents specify the maximum permissible error at different measuring points; you must not exceed these limits in the production of standard measuring equipment.

In general, even measuring machines and other measurement systems (especially new ones) have a documented MPE which will be provided to you when you purchase the respective equipment.

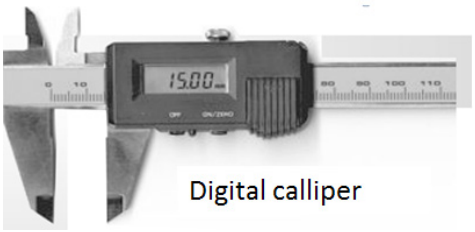
Some measurement engineers apply the following rule of thumb even in practice – they consider measuring equipment capable of performing a specific task if the tolerance of the characteristic is at least ten times the measurement uncertainty (error limit) of the measurement system for this characteristic.

The so-called "golden rule of metrology" for the selection of appropriate standard measuring equipment states that the maximum permissible error (MPE) must not exceed 10% of the tolerance to be inspected.

The following examples compare the result of this golden rule with the results calculated according to the industry standard VDA 5, 2nd edition 2010. Nowadays, VDA volume 5 is widely accepted, even outside the automotive industry.

Example 1 – digital calliper

Measuring interval: 150 mm
Resolution: 0.01 mm
Limit of error according to DIN 862 in a measuring interval of at most 100 mm: 20 µm → MPE = 20 µm



Digital calliper

The golden rule of metrology states that the minimum permissible tolerance of this digital calliper for a 100 mm measuring interval amounts to 200 µm, i.e. you may apply this calliper in a measuring interval of 100 mm for all tolerances of at least 200 µm.

After you made a preselection, you have to apply the classical procedures of measurement system analysis (type-1, type-2 or type-3 study) to establish capability under real conditions.

Calculating the minimum permissible tolerance T_{min-MS} according to VDA 5, 2nd edition 2010

You do not have to determine the uncertainty components of the measurement system in case the MPE is proved and documented. Since DIN 862 does not specify any distribution model for the limit of error, we will be on the safe side by using the rectangular distribution. The distribution factor of the rectangular distribution is b = 0.577. This leads to

$u_{MS} = u_{MPE}$!

MPE = 20 µm as given in DIN 862

You calculate the standard measurement uncertainty based on the formula given in VDA 5 (chapter 4.8).

$u_{MS} = u_{MPE} = MPE/\sqrt{3} = 0.577 * MPE = 0.577 * 20\ \mu m = 11.54\ \mu m$ ($1/\sqrt{3} = 0.577$)

Now you calculate the expanded measurement uncertainty by multiplying u_{MS} by factor K (= 2 when P = 95%).

$U_{MS} = 2*u_{MS} \rightarrow U_{MS} = 2 * 11.54\ \mu m = 23.08\ \mu m$

$$T_{min-MS} = \frac{2 \cdot U_{MS}}{15\%} \cdot 100\% \qquad T_{min-MS} = \frac{2 \cdot 23.08\,\mu m}{15\%} \cdot 100\% = 307.73\,\mu m$$

According to VDA 5, the minimum permissible tolerance for this calliper in a measuring interval of 100 mm amounts to about T_{min} = 308 µm.

By contrast, the golden rule of metrology says that this very calliper can already be applied to a tolerance of 200 µm in a measuring interval of 100 mm.

The following graphic shows how solara.MP determines the minimum permissible tolerance T_{min-MS} according to VDA 5. This result applies to a calliper measuring the “Thickness“ characteristic with a tolerance of 0.2 mm. The analysis is based on an evaluation strategy, e.g. the VW strategy.

Part number	1	Part		Stick	
Characteristic N	1	Characteristic		Thickness	
Nominal value		Unit	mm	U	17,700
		Calc.Tol.	0,200	L	17,500

Active	Uncertainty components	Symbol	Type	---	---	u	Rank	Help
☑	Resolution	u_{RE}	B			0.00289		
☑	MPE	u_{MPE}	B			0.0115	1	
	Measuring system	u_{MS}				0.0115		

Measuring system				
Tolerance	TOL	=	0.200	
Resolution	%RE	=	5.00%	0 5
Combined standard uncertainty	u_{MS}	=	0.0115	
Expanded measurement uncertainty	U_{MS}	=	0.0231	
Capability ratio limit	Q_{MS_max}	=	15.00%	
Capability ratio	Q_{MS}	=	23.09%	0 15
Minimum tolerance	$TOL_{MIN-UMS}$	=	0.308	
The requirements were not met (RE,U)				
VW-Konzern 10119 / VDA 5 (06/2012): VDA 5				

This evaluation shows that the calliper does not meet the requirements as given in VDA 5 – whereas it does meet the demands according to the golden rule of metrology.

Example 2 - micrometer

Measuring span: 0-25 mm
Scaling: 1 µm
Limit of error according to DIN 863-1 in a measuring interval of at most 25 mm: 4 µm ⟶ MPE = 4 µm

Micrometer

The golden rule of metrology states that the minimum permissible tolerance of this micrometer for a 25 mm measuring interval amounts to 40 µm, i.e. you may apply this micrometer in a measuring interval of 25 mm for all tolerances of at least 40 µm.

After you made a preselection, you have to apply the classical procedures of measurement system analysis (type-1, type-2 or type-3 study) to establish capability under real conditions.

For comparison, the calculation according to VDA 5

u_{MPE} = 0.577 * MPE = 0.577 * 4 µm = 2.308 µm

You do not have to determine the uncertainty components of the measurement system in case the MPE is proved and documented.

$u_{MS} = u_{MPE}$ = 0.577 * MPE

U_{MS} = 2 * u_{MS} ⟶ U_{MS} = 2 * 2.308 µm = 4.616 µm

$$TOL_{min-MS} = \frac{2 \cdot U_{MS}}{15\%} \cdot 100\% \qquad TOL_{min-MS} = \frac{2 \cdot 4.616\,\mu m}{15\%} \cdot 100\% = 61.55\,\mu m$$

The minimum permissible tolerance for this micrometer thus amounts to about T_{min} = 62 µm.

By contrast, the golden rule of metrology says that this very micrometer can already be applied to a tolerance of 40 µm in a measuring interval of 25 mm.

The following graphic shows how solara.MP determines the minimum permissible tolerance Tmin-MS according to VDA 5. This result applies to a micrometer measuring the “Thickness“ characteristic with a tolerance of 0.2 mm. The analysis is based on an evaluation strategy, e.g. the VW strategy.

Part number	1	Part				Stick		
Characteristic N	1	Characteristic				Thickness		
Nominal value		Unit	mm			U	17,700	
		Calc.Tol.	0,200			L	17,500	

Active	Uncertainty components	Symbol	Type	---	---	u	Rank	Help
☑	Resolution	u_{RE}	B			0.000289		
☑	MPE	u_{MPE}	B			0.00231	1	
	Measuring system	u_{MS}				0.00231		

Measuring system				
Tolerance	TOL	=	0.200	
Resolution	%RE	=	0.50%	0 5
Combined standard uncertainty	u_{MS}	=	0.00231	
Expanded measurement uncertainty	U_{MS}	=	0.00462	
Capability ratio limit	Q_{MS_max}	=	15.00%	
Capability ratio	Q_{MS}	=	4.62%	0 15
Minimum tolerance	$TOL_{MIN-UMS}$	=	0.0616	
Measurement system capable (RE,U)				
⊏ VW-Konzern 10119 / VDA 5 (06/2012): VDA 5				

Based on these results, we reached the following conclusion: The golden rule of metrology is no longer state of the art – at least in the automotive industry. Even in other industries, we recommend you to check whether you need a lower measurement uncertainty and whether it might be reasonable to calculate the minimum permissible tolerance according to VDA 5.
Another reason to follow our recommendation is the fact that VDA 5 methods as described in this article are meanwhile part of ISO 22514-7: 2012-09. This international standard is thus the current state of the art.

TEQ Training & Consulting GmbH
Eisleber Str. 2
69469 Weinheim / Germany
+ 49 6201 3941-15

Interested in this topic?
www.teq.de
Contact the author
morteza.farmani@teq.de