Performance verification of dimensional measuring instruments in automotive industry

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Abstract

The performance verification of a measuring instrument could be important for the user, which is made by accredited calibration laboratory or the manufacturer of the measuring device in automotive industry (related to ISO/TS 16949). There are controversies in decision making of the performance verification process in previously mentioned two cases. The main difference of the two approximations is that the accredited calibration laboratory has to operate in accordance with ISO 17025 and ILAC G8 guide, whilst the manufacturer of the measuring devices can use their own rules related to the performance verification. Unfortunately, if the measurement uncertainty calculations are the same in both cases, the decision for the performance verification of the measuring instrument could be different. The accredited calibration laboratory uses compliance, non-compliance of specification and a case when there is not possible to state compliance or non-compliance. But the manufacturers of the measuring devices use only compliance and non-compliance statements.

Keywords: accredited calibration laboratory, compliance of specification, decision making, conformity assessment

1 Introduction

To achieve the proper quality of an automotive part it is important to have an appropriate measuring process to control the required characteristics. A measurement process usually consists of the measuring device, the operators and other conditions. The calibration of the measuring device is needed but there are some situations when the performance verification is also required.

The scope of this paper is determining the process of the performance verification with decision making and showing examples from Hungarian automotive industry. Calculations related to callipers, micrometers and plug plain gauges are shown. A novel approximation of conformity assessment process is introduced to use the calibration results of the measurement device in performance verification. The calculation process is based on the GUM (Guide to the Expression of Uncertainty in Measurement) philosophy [1].

2 Conformity assessment of measurement devices

The process of the conformity assessment consists of the following steps. The first is the calibration of the measurement device and the determination of the measurement uncertainty values throughout the scale for defined scale values. The next part of the process is to determine the customer requirements, to define the base reference line of the conformance process. The third step is related to the decision making.

Calibration is

> *"an operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication."* [2]

Various laboratories can calibrate measurement devices related to the previous definition. The result of the calibration is usually a calibration diagram or curve where the visualized measurement error points have tails regarding the extended measurement uncertainty with a 95% coverage probability (see Fig.1). Therefore the obtained calibration results for each examined scale values are not single points, these are intervals.

In order to make conformity assessment of a measurement device it is needed to declare the tolerance, the specification. The tolerance or specification limits for the comparison could be either from the characteristic of the measurement device (the maximum permissible error (MPE) which is defined by standards, for example DIN 862 for Vernier calipers), or from the measuring characteristics (i.e. some part of the tolerance range related to the desired chararacteristic).

The specification which is the base reference of the comparison in performance verification should be defined by the users of the measurement device, by the customer. Practically, in most cases this reference limit used to be the MPE value of the measurement device.

ISO 17025 states (5.10.4.2):

> *"When statements of compliance are made, the uncertainty of measurement shall be taken into account."*[3]

There are several guidelines and standards [4-9] which describe the process of decision making in conformity assessment. Each of them makes comparisons where the measurement uncertainties are taken into account. Three types of decisions could be done:

- If the specification limit is not breached by the measurement result plus the expanded uncertainty, then *compliance* with the specification can be stated (see Case a) of Fig. 1).
- If the specification limit is exceeded by the measurement result minus the expanded uncertainty, then *non-compliance* with the specification can be stated (see Case e) of Fig. 1).
- If the measurement result plus/minus the expanded uncertainty overlaps the limit (see Case b), c) and d) of Fig.1), it is not possible to state compliance or non-compliance.

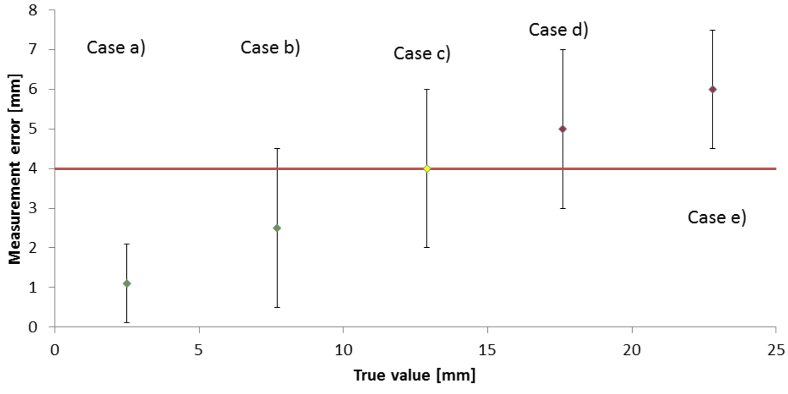

Figure 1. Calibration diagram for digital micrometer (0-25 mm) (The red horizontal line is the MPE value for this type micrometer.)

There is an example for calibration and performance verification of a micrometer in Table 1 and in Fig. 1. If the above mentioned statements are used the good qualifications can be found in the column of "Decision as per GUM". These are the right values if an accredited (ISO 17025 [3]) calibration laboratory makes this statements.

If the qualification of the measurement device is made by such a laboratory which is not accredited (e.g. the non-accredited lab of the manufacturer of the measurement device), then they do not usually take into account the measurement uncertainty. In this case the performance verification can be seen in the column "Decision as usual". Comparing the two types of decisions these differ from each other which is not so good from the customers point of view.

Table 1. Calibration results for digital micrometer (0-25 mm) (#: it is not possible to state compliance or non-compliance)

True value [mm]	*Measurement error [µm]*	*U [µm]*	*Base of reference (MPE) [µm]*	*Decision as per GUM-philosophy*	*Decision as usual (non-accredited labs)*
2,5	1,1	1	4	compliance	compliance
7,7	2,5	2	4	#	compliance
12,9	4	2	4	#	#
17,6	5	2	4	#	non-compliance
22,8	6	1,5	4	non-compliance	non-compliance

There are several guides which are declared that the ratio of the uncertainty of measurement to the specified interval should be reasonably small. The guidelines differ from each other. The APLAC Guide [8] proposes, that the uncertainty : tolerance (U:T) ratio should be 1:3. The ANSI/NCSL 540-1 [9] proposes that the U:T ratio should be 1:4. (Fig. 2).

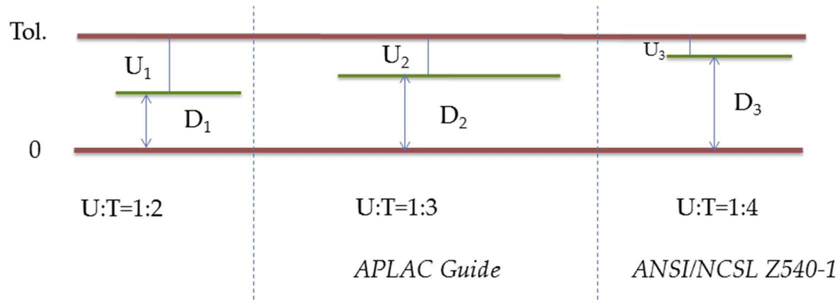

Figure 2. Ratio of the uncertainty of measurement to the specified interval

3 Selection of laboratories for industrial measurement purposes

The calibration of measurement devices used for the control of the production process in automotive industry is compulsory. The calibration could be made by his own, by an accredited calibration laboratory or by the manufacturer of the measuring device (ISO/TS 16949 [10]). There are occasions when the conformity assessment of the measurement device is also needed.

Table 2. Comparison of the accreditied calibration laboratories (in Hungary, NAT, in UK, UKAS) (CMC: Calibration and Measurement Capabilities, the vernier calipers are digital, 0-150 mm; the micrometers are digital, 0-25 mm)

Hungary			***UK***		
Labs	*Measurement devices*	*CMC [µm]*	*Labs*	*Measurement devices*	*CMC [µm]*
X	Vernier caliper	25+L/45	A	Vernier caliper	10 + (30 x length in m)
Y	Vernier caliper	20+1.8L/100	B	Vernier caliper	10 + (15 x length in m)
Z	Vernier caliper	10-15	C	Vernier caliper	10 + (30 x length in m)
X	Micrometers	2+L/25	A	Micrometers	1.0 + (8.0 x length in m)
Y	Micrometers	5+2L/100	B	Micrometers	1.5 + (5.0 x length in m)
Z	Micrometers	7+0.005L – 3+0.005L	C	Micrometers	1.0 + (8.0 x length in m)
X	Plain plug gauges	1.4+D/30	A	Plain plug gauges	1…50 – 0.80 50…100 – 1.0 100…150 – 1.5
Y	Plain plug gauges	2-4	B	Plain plug gauges	1 … 50 – 0.80 50 … 100 – 1.0 100 … 150 – 1.5
Z	Plain plug gauges	0.75+0.004L	C	Plain plug gauges	1…50 – 1.0 50…100 – 1.5

For choosing a laboratory for performance verification of a measurement device it is good to know what is the capability of that selected lab related to that concrete measurement device. In Table 2 calibration and measurement capabilities (CMC) of selected accredited calibration labs are shown from Hungary and UK for several dimensional measurement devices. The data are from the website of the accreditation bodies (NAT and UKAS). It is clearly seen that the CMC values can be more easily compared with each other if we choose the labs from UK than in case of Hungarian labs. The labs were chosen randomly from the database.

If I would like to order a conformity assessment for micrometer, which MPE value is 4 µm, the *Y* laboratory not good because its CMC value is greater than the required tolerance limit for micrometer. If my requirement is to have U:T=1:4, in this case *X*, *Y*, *Z*, *A*, *B*, *C* labs are not good for this purpose, because in this case the maximum permissible uncertainty is MPE/4=4/4=1 µm. The CMC values of these laboratories exceed this maximum permissible uncertainty value.

If the subject of the performance verification is plain plug gage there are more problems. The gages are produced very precisely; the manufacturing tolerances can be seen in Table 3. The size of the tolerance depends on the classification of the gage. For example if a plug plain gage with 10 mm diameter and Class X, have to be qualified, it is hard to find a laboratory which is CMC is below at least the half of the tolerance, i.e. below 0.5 µm. It can be seen that the chosen labs from Hungary and Uk does not able to qualify this type of gage. So in case of gages it is hard to daclare the compliance to specifications or there are only a few laboratories which meet this capability.

Table 3. Gagemakers tolerance chart [11]

Range	*Class*					
	XXX	*XX*	*X*	*Y*	*Z*	*ZZ*
0.254mm to 20.96mm	0.00025mm	0.0005mm	0.0010mm	0.0018mm	0.0025mm	0.0050mm
20.96mm to 38.35mm	0.00038mm	0.0008mm	0.0015mm	0.0023mm	0.0030mm	0.0060mm
38.35mm to 63.75mm	0.00051mm	0.0010mm	0.0020mm	0.0030mm	0.0040mm	0.0080mm

4 Proposal for conformity assessment for measurement devices

There are two approximations which can be used for conformity assessments. In the first case the upper specification limit which is the base of reference is a constant value (e.g. micrometers), in the second case the specification limit is proportional with the measured scale value (e.g. callipers).

If the base reference value for the decision of the conformity assessment is a constant value it has to be determine the largest measurement error plus related uncertainty value in the calibration diagram. This is the lower limit for using this device usually.

$$Conformance\ limit = Max\{Measurement\ error_i + Uncertainty_i\}$$

In case of the example was shown in Fig. 1 the limit is 6+1.5 µm=7.5 µm. This means that the micrometer can be used for that purposes where the permissible error is larger than 7.5 µm (Fig. 3, dashed green line). The calibration report should contain this value in order to make appropriate decisions. So, if in automotive industry this device is used for a characteristic which has tolerance range of larger than 75 µm the micrometer could be appropriate.

If the base of reference value for the conformity assessment is the function of the measurement scale the conformance limit can be calculated as follows:

- determine the linear function between the measurement error and the examined true values of the scale with least square method,
- add the largest measurement uncertainty value to the linear function as a constant.

In case of the example was shown in Fig. 1 the linear relationship is:

$$\text{Measurement error} = 0.2437 \cdot \text{True value} + 0.6244\ [\mu m]$$

The largest measurement uncertainty value was 2 µm, so the conformity limit can be calculated as follows:

$$Conformance\ limit = 0.2437 \cdot True\ value + 2.6244\ [\mu m]$$

The conformance limit can be seen in Fig. 3 (continuous green line) for the previous example.

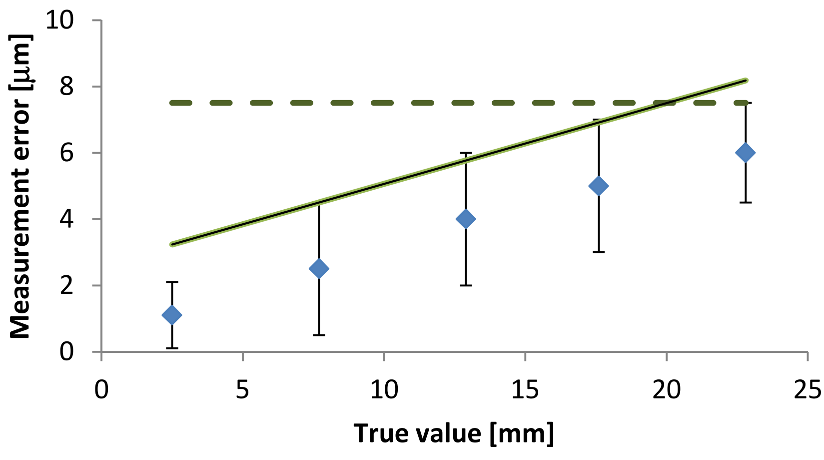

Figure 3. The conformance limits for the examined micrometer (dashed green line is related to the first case; continuous green line is related to the second case)

5 Conclusions

There are controversies in the field of conformity assessment after calibration. There are differences between the accredited calibration labs and labs of manufacturer of the measurement device in the process of the performance verification, and the differences were shown in this paper.

It could be better state a conformance limit which is calculated by the labs and take into account the measurement uncertainty. Proposals for the conformance limits were introduced during this work. This conformance limit show the behaviour of the examined measurement device, and knowing this limit it is easy to determine the compliance of the measurement device for the control of the selected manufacturing process.

6 References

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