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[1.] L'uboslav STRAKA

POSSIBILITIES TO THE DETERMINATION OF THE MEASUREMENT CAPABILITY OF DIGITAL CALLIPER

[1.] TECHNICAL UNIVERSITY OF KOŠICE, SLOVAKIA

ABSTRACT: *Before measuring and monitoring of processes or in determination of capability of manufacturing equipment, it is necessary to perform an evaluation of capability of measuring equipment of determination measurement equipment capability index. Determined index of capability of particular measuring equipment indicates its applicability for inspection of selected qualitative parameters in a given tolerance range. The paper is focused on evaluation of capability of digital calliper within its entire measuring range [0 to 150 mm] by the means of capability index C_{gm} and C_{gmk}. Evaluation of capability of the given measuring equipment was carried out by repeated measurements of standards with dimensions representing lower, middle and upper range of the measuring instrument at given accuracy [30 μm] of measuring equipment.*
KEYWORDS: *Measuring equipment, standard deviation, capability index, tolerance*

INTRODUCTION

Justification of measuring equipment capability is evoked by constantly growing need to prove suitability of chosen inspection method from a view of global approach to inspection process. Capability of measuring equipment can be understood as the ability of the measuring instrument to constantly achieve criteria [established in advance] that are derived from an observed sign of technological process.

MEASUREMENT EQUIPMENT CAPABILITY

The aim of evaluation of measuring equipment capability in general is to give an objective view of their functional capability and correctness of measured values readings. The assessment takes into account also an extent of influence of measuring instrument operator and location of its use, or in case of error analysis, it enables to recognise also their causes. [1]

Measuring instruments that are often used by several operators during a number of working shifts, after certain time manifest a decrease of reliability to a point when it can not be proved that shown values of measurements are correct. Just for these situations the simple methods are suitable – methods that detect i. e. confirm or disprove suspicion of measuring equipment capability loss. [2]

PROCESS TO EVALUATE THE CAPABILITIES OF MEASURING EQUIPMENT

Test of measuring instrument capability as one from statistical methods focused on measuring systems applied in industry [3], consists of repeated measurements with calibrated standard in measuring equipment application location. In evaluation of measuring equipment capability by determination of capability index, measuring equipment testing is necessary in the same conditions as conditions in which the equipment will be applied. Before the test, it is necessary to adjust the measuring equipment in such a way that no additional adjustments will be needed during the test.

For correct evaluation process is necessary:

- *to establish conditions and course of the test,*
- *to train personnel for testing in accordance with the norm,*
- *to specify the process that should be controlled and to determine observed parameter,*
- *to define measuring system and to provide for required technical equipment,*
- *to establish measurement range,*
- *to choose selection characteristics which will serve for the process observation.*

Nominal value of standard Xr should be chosen in a way that it falls into the used range of measuring equipment. Primarily this value is chosen in the middle of tolerance of relevant sign T.

Mean value $\bar{X}_a$ and standard deviation S_w are calculated from the formulas [2]:

$$\bar{X}_a = \frac{1}{n}\sum_{i=1}^{n} Xi\,, \qquad [1]$$

$$S_w = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(X_i - \bar{X}_a)^2}\,. \qquad [2]$$

where: n - is number of carried out measurements,
X_i - i-tuple measured value.

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The C_{gm} value [capability gauge measurement] represents the influence of the measurement arrangement on the measurement value distribution and the value C_{gmk} represents the influence of the measurement equipment on the distribution. Capability indexes C_{gm} and C_{gmk} are calculated from the formulas:

$$C_{gm} = \frac{0,2.T}{6.S_W}, \quad [3]$$

$$C_{gmkU} = \frac{(X_r + 0,1.T) - \bar{X}_a}{3.S_W}, \quad [4]$$

$$C_{gmkL} = \frac{\bar{X}_a - (X_r - 0,1.T)}{3.S_w}. \quad [5]$$

where: T - tolerance of sign, X_r - conventional true value [nominal size of standard].

In evaluation of capability indexes C_{gmkU} and C_{gmkL}, usually the lesser value is taken into consideration. Criterion for capability evaluation is fulfilling of condition C_{gmkU} and $C_{gmkL} \geq 1.33$. In the case that one of capability index values is lesser than 1.33, the measuring instrument is deemed incapable [unsuitable]. [4]

EVALUATION THE MEASUREMENT CAPABILITY INDEX OF DIGITAL CALIPER

For evaluation of entire range of measuring equipment [5], such combination of gauge blocks is recommended which enables checking in positions responding to integer multiple of nominal gradient [6], but also in between these positions. Capability evaluation of digital calliper DIGIMATIC was carried out in the same conditions in which the given device will be used, i. e. in laboratory conditions at ambient temperature of 20°C. Checking with Johansson gauge block was carried out in the same place and at the same position. Following table shows basic parameters of measuring equipments used in verification test of digital calliper capability.

Tab. 1 . Measuring range and accuracy of applied measuring equipments [8]

Measuring equipment	Range		Accuracy class	Accuracy		Manufacturer
Digital calliper DIGIMATIC	0 ÷ 150mm		1	0.03mm		MITUTOYO
Johansson gauge blocks	4.0 ÷ 131.4mm		1	±0.8μm		MITUTOYO

Fig. 1 The verification test of measurement equipment capability index a digital micrometer with using Johansson gauge blocks

For verification of capability of observed digital calliper the set of steel gauge blocks in accordance with standard DIN EN ISO 13 385-1, VDI, VDE and DGQ2618, of accuracy class 1 (dimension 30.0; 41.3; 131.4mm; diameter 4.0 and 25 mm) was applied. Nominal dimension for verification test with gauge blocks was value X_{r1}=4.0 mm; X_{r2}=25.0 mm and X_{r3}=30.0 mm for lower zone of calliper measuring range, X_{r4}=41.3mm for middle zone of calliper measuring range, and X_{r5}=131.4mm for upper zone of measuring range of digital calliper DIGIMATIC.

From recorded values the mean measured value $\overline{X_{ai}}$ and standard deviation S_{wi} were calculated with statistical software SPCwin32 according to formulas (1) and (2). Results are shown in following table 2.

Tab. 2 Mean measured value $\overline{X_{ai}}$ and standard deviation S_{wi} of digital calliper

Evaluated dimension (etalon) X_r [mm]	Mean measured value $\overline{X_{ai}}$ [mm]	Standard deviation S_{wi} [mm]
4.0	4.0013330	0.0062345
25.0	25.001167	0.0061317
30.0	30.001000	0.0051089
41.3	41.300500	0.0046668
131.4	131.400667	0.0048246

Norm STN ISO 8258 states that if value of capability index of measuring equipment [7] is $C_{gm} \geq 1.34$, measuring equipment is capable and if value of capability index of measuring equipment is from the interval <1; 1.33>, measuring equipment can be deemed partially capable. Criterion for evaluation of measuring instrument is set to values, C_{gmkU} and $C_{gmkL} \geq 1.33$. From capability indexes C_{gmkU} and C_{gmkL} smaller value of the calculated values is taken into consideration for evaluation of measuring instrument capability, this value in the same time becomes a minimal indicator of process capability C_{gmk}. In the case that values of indexes C_{gmk} and C_{gm} are very low, it is necessary to find the reasons. Following table shows results of calculations of measuring instrument capability indexes C_{gm}, C_{gmkU} and C_{gmkL} for particular evaluated dimensions of standards, calculated according to formulas (3), (4) and (5).

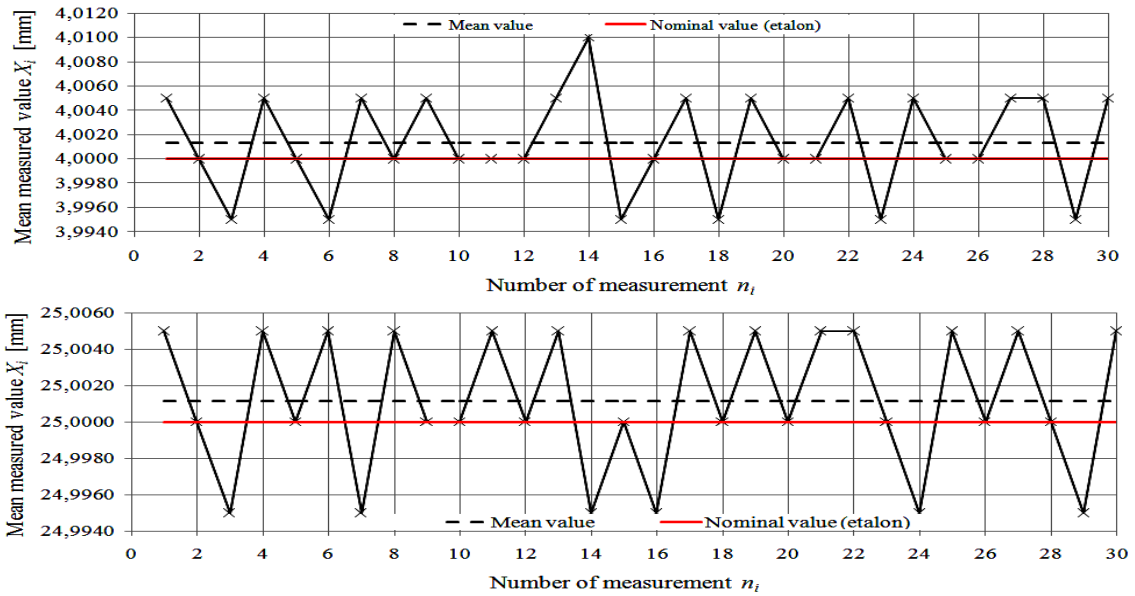

Fig. 2. Mean and nominal measured values of standards with diameters 4.0 and 25.0mm

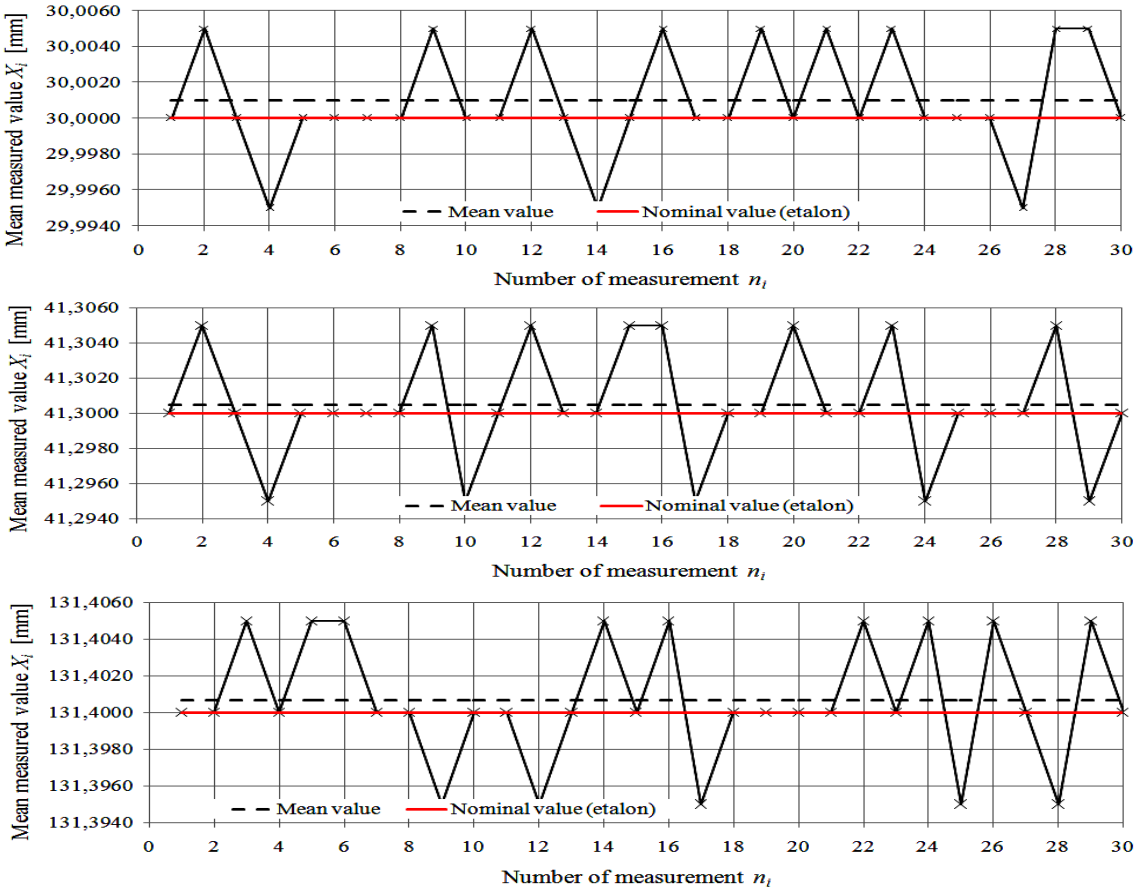

Fig. 3. Mean and nominal measured values of standards with dimensions 30; 41.3 and 131.4 mm

Tab. 3 .Measurement equipment capability indexes C_{gm}, C_{gmkU} and C_{gmkL} of digital calliper for tolerance T = 0.20mm

Evaluated dimension (etalon) [mm]	T = 0.20 mm			Fulfilling of the condition ≥1.33
	C_{gm}	C_{gmkU}	C_{gmkL}	
4.0	1.07	0.99	1.14	partially fulfilled
25.0	1.09	1.02	1.15	partially fulfilled
30.0	1.30	1.24	1.37	partially fulfilled
41.3	1.42	1.39	1.46	fulfilled
131.4	1.38	1.34	1.42	fulfilled

Results of experimental measurements show that tested digital calliper DIGIMATIC is for tolerance of sign T = 0.20 mm partially insufficient since in lower zone of measuring range (4 to 30.0 mm) are values C_{gm} and C_{gmkU} from interval <1; 1.33>. In the middle zone (30.0 to 41.3 mm) and upper zone (41.3

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to 131.4 mm) of measuring range the values of C_{gm} and C_{gmkU} are >1.33, so it can be concluded that measuring equipment fulfils capability condition in a given measuring range. Following diagram describes dependence of digital calliper capability index C_{gm} on tolerance of sign T.

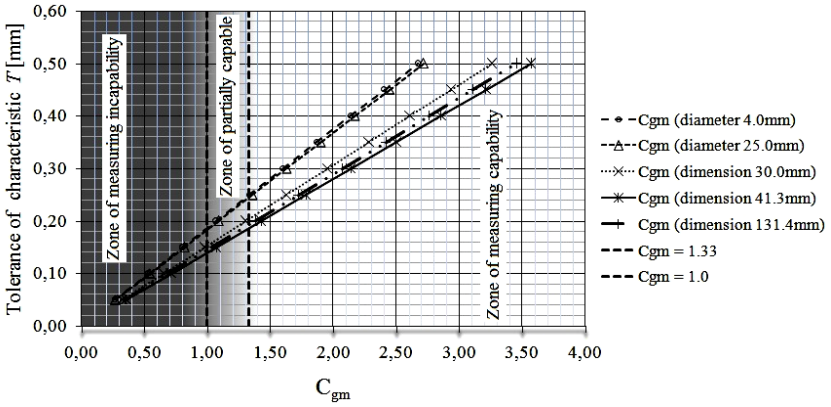

Fig. 4. Dependence of measurement equipment capability index C_{gm} on tolerance T for entire range of digital calliper

On the basis of the diagram, it can be concluded that evaluated digital calliper DIGIMATIC is in its lower measuring range (4 to 25 mm) capable for tolerance of sign T > 0.24 mm, in its middle measuring range (25 to 41.3 mm) it is capable for tolerance of sign T > 0.20 mm and in its upper measuring range (41.3 to 131.4 mm) it is capable for tolerance of sign T > 0.18 mm. This means that evaluated digital calliper DIGIMATIC achieves higher capability C_{gm} in upper half of measuring range, i. e. achieves higher capability of measuring in narrower tolerance zone than in lower measuring range.

CONCLUSIONS

Method of determination of capability of measuring equipment through capability index C_{gm} is relatively demanding because it requires rather extensive set of experimental measurements. The results of the method are useful information which can be used to reveal deficiencies resulting from unsuitable metrological properties of some measuring instruments for given applications, and also from insufficient qualification of some users. This method of testing of measuring equipment is proper mainly for regular evaluation of capability of measuring systems as a part of metrological management. The aim of the paper was to describe methodical procedure of evaluation of capability of digital calliper DIGIMATIC by the means of measuring instrument capability indexes C_{gm} and C_{gmk}. Principle of capability examination of evaluated digital calliper DIGIMATIC consisted of repeated measurements of standard (etalon) value throughout its entire measuring range. Detailed examination of measuring equipment capability leads to a finding that upper measuring range renders better properties than lower measuring range. This means that tested calliper can be used in its upper measuring range for measuring of dimensions with narrower tolerance zone than in its lower measuring range. As was shown by the results of experimental testing, the capability index determination has rather high informative value. Too low values of C_{gm} and C_{gmk} show that measuring instrument capability was not met, on the other hand, high values indicate that for given application and given technological requirement the meter has excessively high (and unnecessary) accuracy. Considering tolerance zone on the zone value under 0.20 mm, tested digital calliper renders capability index value C_{gm} less than 1.0. In this case, to ensure capability of measuring process in tolerance zone T < 0.20 mm it would be necessary to choose measuring equipment with higher accuracy e.g. digital micrometer.

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