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CAPABILITY ASSESSMENT OF MEASURING EQUIPMENT USING STATISTIC METHOD

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Abstract:
Capability assessment of the measurement device is one of the methods of process quality control. Only in case the measurement device is capable, the capability of the measurement and consequently production process can be assessed. This paper deals with assessment of the capability of the measuring device using indices C_g and C_{gk}.

Key words: *measuring device, index C_g and C_{gk}.*

INTRODUCTION

Demands on measurement accuracy are increasing constantly together with demands on evaluation of quantifiable characteristics of measurement systems. The highest requirements are put on measuring systems in automotive industry in engineering area. In practice life, frequent use of devices decreases of measurement accuracy, which can lead to results distortion. Extensive expenditures in new measuring devices or even longer time devoted to measurement procedure do not necessarily guarantee the best outputs. That is why there are methods for confirming or rejecting suspicions of measurement devices capability loss.

MATERIAL AND METHODS

Measuring devices (means) are in general understood as technical means needed for measurement realization. Any gauge, data converter, reference material and auxiliary equipment necessary for measuring process realization can be regarded as measuring device [5]. Capability of measuring device tells about it functional capability and measured data correctness. This characterizes it convenience for attribute measurement in selected range (interval).

One of the methods of capability evaluation is measurement device capability assessment using capability indices C_g and C_{gk}. These indices asset the measuring devices for skewness and repeatability. Skewness expresses the difference between agreed reference value and average value of the test results (Fig. 1). The measurement repeatability expresses the conformity tightness between subsequent measurement results achieved at the same measuring conditions [6].

This procedure of capability assessment is used in case of measuring devices where the device operator cannot affect the results. It is based on repeated product, measurement standard measurement, with reference value being in the middle of measured dimension allowance. The measurement is done by one person (operator) with one measuring device using the same procedure in relatively short time frame; 50 repeated measurement (minimum 25) is recommended. Stable conditions have to be kept.

It is assumed measurement results have the normal distribution [4, 9, 12].

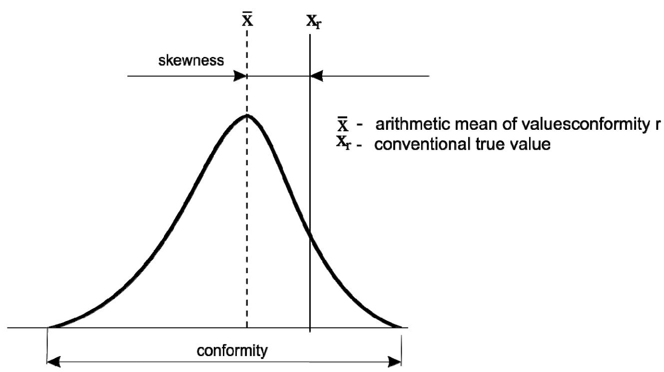

Fig. 1 Skewness and conformity of measurement

Electronically controlled throttle body is the central control element in the electronic control of engine air flow. It consists of throttle with electric drive and position sensor of the throttle. This observed product is a part of the production process of international (global) organisation, oriented to design and manufacturing of high-tech systems and components for automotive industry.

Following specifications where followed in application of the method:

- 30 measurements of the measurement standard,
- measurement realised by one person,
- one measuring device used,
- the same measuring procedure used,
- the same conditions kept when measuring,
- measurements realised in the short time frame.

Repeatability index c_g of the observed measuring device is calculated using formula

$$C_g = \frac{0.2 \times T}{6 \times s_g} \tag{1}$$

where:

$$s_g = \sqrt{\frac{1}{n-1}\sum_{i-1}^{n}(x_i - \overline{x_g})^2} \qquad \overline{x_g} = \frac{1}{n}\sum_{i=0}^{n} x_i \tag{2}$$

where:
x_i measured value i,
n number of measurements,
$\overline{x}_g$ mean of measured values,
s_g corrected sample standard deviation,
T measured dimension allowance [1, 4, 7, 10].

$$T = HMR - DMR \quad (3)$$

where:
HMR – upper dimension limit (USL),
DMR – lower dimension limit (LSL).

Skewness and repeatability index C_{gk} of the measuring device is calculated using formula:

$$C_{gk} = \frac{0.1 \times T - \left|\overline{x}_g - x_r\right|}{3 \times s_g} \quad (4)$$

x_r being the reference value chosen in the middle of measured dimension range [1, 4, 7, 10].

These indices indicate whether the result of measurement of the measurement standard falls with probability 99.73% into selected tolerance range of the device set as 20% of tolerance width of measured dimension. The C_g index value takes into account the measurement conformity, c_{gk} value the conformity as well as systematic error of the measuring process from the reference value set by the standard. It results from the definition that $C_g \geq C_{gk}$.

When $C_g \geq 1.33$ and at the same time $C_{gk} \geq 1.33$ is valid (for T ≥ 50 μm), the measuring device is suitable and can be used in manufacturing process. Satisfying conditions $Cg \geq 1$ and at the same time $C_{gk} \geq 1$ is sufficient in case of T < 50 μm.

If the conditions are not fulfilled measuring device cannot be used in manufacturing process and corrective actions are necessary (device repair, design change of the measuring device, training of the operators and other).

The indices C_g and C_{gk} can be calculated using formulas (1, 2, 3, 4, 5):

$$C_g = \frac{\frac{K}{100} \times T}{6 \times s_g} \qquad C_{gk} = \frac{\frac{K}{200} \times T - \left|\overline{x_g} - x_r\right|}{3 \times s_g} \quad (5)$$

K is chosen tolerance percentage (for instance according to BOSCH methodology the K = 20, according to FORD methodology K = 15).

RESULTS

The measurement was realised in production facility of the manufacturer at the ambient temperature 22°C. The aim of the measurement was to verify the measuring device capability. The 30 repetitions of the chosen dimension were realised. Measured values and basic numerical characteristic x_g and s_g are presented in table 1. The tolerance value is set in organisation as 0.05 mm (USL = 40.025 mm, LSL = 39.975 mm).

Repeatability index C_g of the measuring device can be computed as:

$$C_g = \frac{0.2 \times T}{6 \times s_g} = \frac{0.2 \times 0.05}{6 \times 0.00066} = 2.53$$

The accuracy and repeatability index of the measuring device is expressed according to formula:

$$C_{gk} = \frac{0.1 \times T - \left|\overline{x}_g - x_r\right|}{3 \times s_g} = \frac{0.1 \times 0.05 - \left|40.003 - 40.000\right|}{3 \times 0.00066} = 2.37$$

Repeatability %R and accuracy and repeatability %A&R indices are used in internal documents of the organisation [11], according to following formulas and conditions:

$\%R = \frac{20}{C_g}$ requiring the fulfilment of the condition $\%R \leq 15$, (6)

$\%A\,\&\,R = \frac{20}{C_{gk}}$ requiring the fulfilment of the condition $0 \leq \%A\&R \leq 15$ (7)

Relation between repeatability %R and accuracy and repeatability %A&R calculation is %R ≤ %A&R (Fig. 2).
In our case:

$$\%R = \frac{20}{C_g} = 7.905 < 15 \qquad \%A\,\&\,R = \frac{20}{C_{gk}} = 8.439 < 15$$

Table 1
Measured values

Measur nr.	Measured values (mm); reference value 40000 mm							
1 – 8	40.0005	40.0004	40.0001	40.0011	39.9999	40.0003	39.9998	40.0009
9 – 16	39.9988	40.0009	39.9999	40.0001	40.0002	39.9999	40.0013	40.0011
17 – 24	39.9996	40.0012	40.0001	40.0004	40.0006	40.0012	39.9988	40.0009
25 – 30	40.0001	39.9998	40.0011	39.9999	40.0009	39.9999		
	n = 30		T = 0.05		$\overline{x}_g$ = 40.0003		S_g = 0.00066	

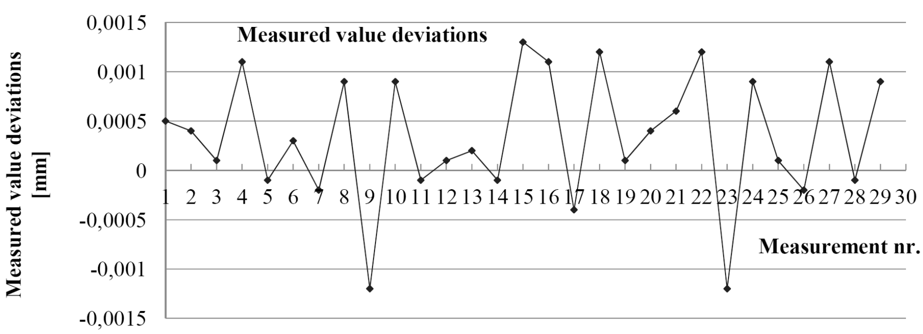

Fig. 2 Behaviour of the measured values deviation

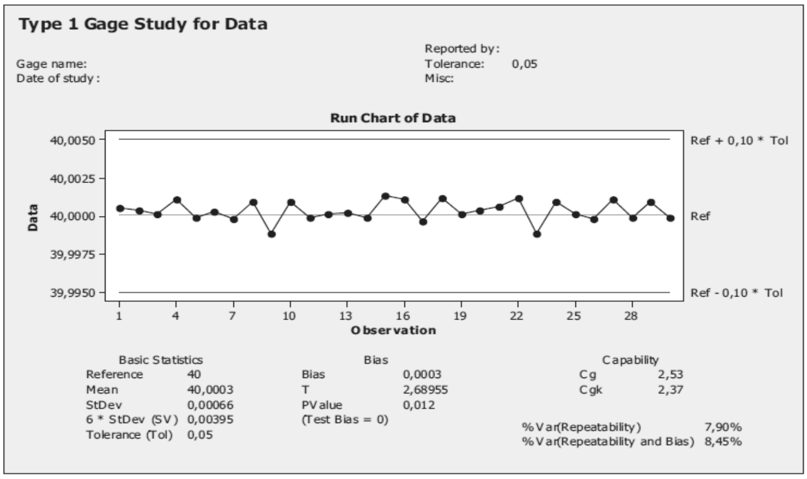

Fig. 3 Behaviour of the measured values deviation

Bacause both conditions are fulfilled (Cg ≥ 1.33 and at the same time Cgk ≥ 1.33, as well as equivalent conditions %R ≤ 15, 0 ≤ %A&R ≤ 15 and %R ≤ %A&R), the measuring device can be qualified as capable and it can be used in manufacturing process.

Software product MINITAB was used for check of the calculated results and the capability assessment output is depicted in the Figure 3.

CONCLUSION

Demands on measurement accuracy are still growing, increasing demands and requirements on measuring devices. Capablity assesment of the measuring device is process, presenting important element of continual quality improvement, because of the decision in quality control are based usually on checking and measurement. The goal of the assesment wa to prove the device is capable and suitable for measurement of the observed quality sign. It provides the chance to indentify problems in the initial phase of the manufacturing process and helps to assure meet the quality requirements. The method of the measuring device assesmsent described here is used in complex monitoring of capability of manufacuring processes and in periodical assesment of capability of the measuring systems as the part of metrological management and control.

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