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INDICES Cg AND Cgk IN THE ASSESSMENT OF THE MEASURING DEVICE CAPABILITY

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Abstract: The requirements for the measuring accuracy are increasing and at the same increasing also the requirements for the assessing of the quantifiable characteristics of the measuring devices, respectively measurement systems. The reviewing of the capability of the measuring device is one of the important methods of the quality management process. Only in the case when the measuring device is capable we can proceed to the assessment of the capability of the measuring and consequently also the production process. The article deals with the assessment of the capability of the measuring device by means of C_g and C_{gk} indices witch can determine the capability of the measuring device for the purpose. The conclusion of the article deals with the calculation of the indices by software R.
Keywords: capability of measuring device, C_g and C_{gk} indices, qualityTools package

1. INTRODUCTION

Measurement is defined as "the assignment of numbers [or values] to material things to represent the relations among them with respect to particular properties." The process of assigning the numbers is defined as the measurement process, and the value assigned is defined as the measurement value. *Measuring devices* in general mean technical devices needed for the execution of measuring. Any measuring instrument or gage, reference material and auxiliary equipment inevitable for the execution of measuring process can be considered as a measuring device. *Measurement system* is the collection of instruments or gages, standards, operations, methods, fixtures, software, personnel, environment and assumptions used to quantify a unit of measure or fix assessment to the feature characteristic being measured; the complete process used to obtain measurements.

At the time when measuring is an inseparable part of many areas of human activity, it is a very important goal to reach correct and fair results with the corresponding accuracy. All measuring devices fall under regular calibration in terms of the Metrology manual. In practice it happens that the daily use of these measuring devices decreases the reliability of the measuring, which in the end can lead to incorrect results. Neither huge investment into new measuring devices, nor longer time spent by the measuring process may not be a guarantee of the high quality output. Just for these situations there are methods, which can confirm or deny the suspicion of the loss of the capability of the measuring device.

2. METHODS

Measurement System Analysis (MSA) focuses on understanding the measurement process, which considers the defect size and suitability of the measuring device, resp. measuring system.

The capability of the measuring device predicates of its functional capability and of the correctness of the measured data. It characterizes its appropriateness for the measuring of a particular attribute in the given scale. One of the methods of the assessing of capability is the determination of the capability of the measuring device by means of *capability indices* C_g and C_{gk}**.** These indices assess

the measuring device from the point of view of and repeatability. *Bias* represents the difference between the accepted reference value and mean value of the results of the experiments. Measuring *repeatability* represents the closeness of the compliance between the results of the consecutive measurements realised at the same conditions of the measuring [2, 4].

This procedure of the determination of the capability is used at the measuring devices, at which no influence of the results by the measuring attendance occurs. It is based on the repeated measuring of the selected size of product, the control standard, whose nominal value lies in the middle of the tolerance of the measured parameter. The measuring is performed by one person with one measure and the same procedure in a relatively short time interval, whereby it is recommended to perform 50 (at least 25) repeated measurements. Within the measuring it is necessary to ensure the same conditions. It is assumed that the results of the measuring are governed by normal distribution [3, 8]. The calculation of the C_g index (*index of repeatability*) of the monitored measuring device is set by the relation

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

$$\bar{x}_g = \frac{1}{n}\sum_{i=1}^{n} x_i \,,\; s_g = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}_g\right)^2} \,, \tag{2}$$

where x_i is *i*-th measured value, n number of measurements, $\bar{x}_g$ average value of measurements, s_g selective standard deviation of measuring and T represents tolerance of the measured dimension [1, 3, 6, 9]. For the index C_{gk} (*index of bias and repeatability*) of the measuring device reads relation

$$C_{gk} = \frac{0.1 \cdot T - \left|\bar{x}_g - x_r\right|}{3 \cdot s_g}, \tag{3}$$

where x_r is a reference value, which is preferably selected in the way that is selected in preference so that it lies in the middle of the tolerance of the measured dimension [1, 3, 6, 9].

The indices determine if the result of the measuring of the control standard lies with the probability of 99.73% in the selected tolerance zone of the scale of measuring device, which is set to 20% of the width of the tolerance of the measured dimension. The value of the index C_g makes only provision for the consistency of the measuring, the value C_{gk} consistency and also systematic deviation of the measuring process from the reference value given by the standard (partiality). It follows from the definition of the indices that $C_g \geq C_{gk}$.

If it reads that $C_g \geq 1.33$ and at the same time $C_{gk} \geq 1.33$ (for $T \geq 50$ μm), then the measuring device is proper and can be used in the production process. In case $T > 50$ μm the fulfilment of the conditions $C_g \geq 1$ and concurrently $C_{gk} \geq 1$ is sufficient. If the conditions are not fulfilled, then it is not possible to include the measuring device into the production process and it is necessary to make corrective measures (repair or adjustment of the measuring device, training of operators and others.) In general we can calculate indices C_g and C_{gk} by relation [2, 6]

$$C_g = \frac{\frac{K}{100} \cdot T}{6 \cdot s_g}, \quad C_{gk} = \frac{\frac{K}{200} \cdot T - \left|\bar{x}_g - x_r\right|}{3 \cdot s_g}, \tag{4}$$

where k is a selected percentage of tolerance (e. g. in methodology by BOSCH k = 20 is chosen, by methodology FORD k = 15).

In [10] besides indices also repeatability %R and accuracy and repeatability %A&R are introduced, for which the following relations [10]

- ✓ $\%R = \frac{20}{C_g}$, where the condition $\%R \leq 15$ must be fulfilled, (5)
- ✓ $\%A\&R = \frac{20}{C_{gk}}$, where the condition $0 \leq \%A\&R \leq 15$ must be fulfilled. (6)

Between value of repeatability %R and calculation of accuracy and repeatability %A&R is valid $\%R \leq \%A\&R$.

3. IMPLEMENTATION OF THE ASSESSMENT OF CAPABILITY OF MEASURING DEVICE IN PRACTICE

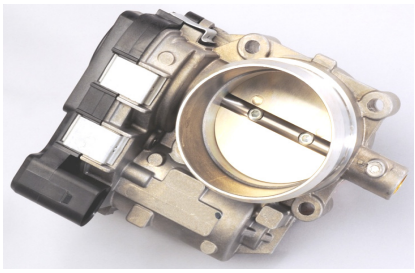

Figure 1. Throttling flap

In electronic management/control of engine charging for spark engines an electronically operated unit of flap is a central regulating member. It consists of a throttling flap with an electric drive and an angular sensor of the throttling flap (Figure 1). The monitored product is a part of the production process of an international organisation, which focuses on the design and production of highly – technological systems and components for car industry. The measuring took place in the production area of the enterprise at the temperature 22°C and humidity 50%. The goal of measuring is to check the capability of line measuring device (Figure 2).

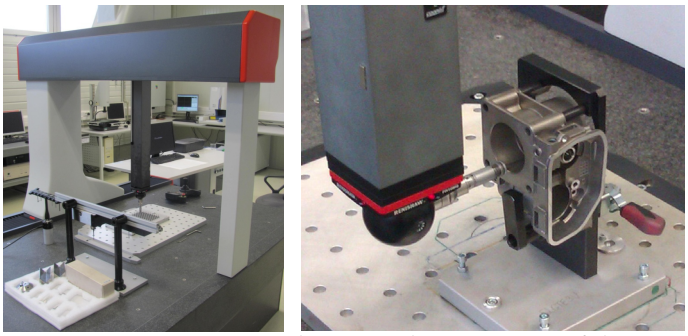

Figure 2. Measuring device and measuring of the parameters of the throttling flap

In the measurement of the chosen size (in mm) was made 30 repeated measurements. The measured values and basic numeric characteristics $\overline{x_g}$ and s_g are given in the table. The value of the tolerance is determined by the organisation to 0,05 mm (USL=40.024 mm, LSL=39.975 mm).

In the measurement of the selected size (in mm) were performed 30 repeated measurements.

Table 1. Measured values

Measured values (mm), Nominal value 40.000 mm							
No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
40.0005	40.0004	40.0001	40.0011	39.9999	40.0003	39.9998	40.0009
No.9	No.10	No.11	No.12	No.13	No.14	No.15	No.16
39.9988	40.0009	39.9999	40.0001	40.0002	39.9999	40.0013	40.0011
No.17	No.18	No.19	No.20	No.21	No.22	No.23	No.24
39.9996	40.0012	40.0001	40.0004	40.0006	40.0012	39.9988	40.0009
No.25	No.26	No.27	No.28	No.29	No.30		
40.0001	39.9998	40.0011	39.9999	40.0009	39.9999		
n=30		T=0.05		$\overline{x_g}$ = 40.00032		s_g = 0.00061	

The index of repeatability C_g of the measuring device is calculated by the relation:

$$C_g = \frac{0.2 \cdot T}{6 \cdot s_g} = \frac{0.2 \cdot 0.05}{6 \cdot 0.00061} = 2.73 \cdot$$

The index of the bias and repeatability C_{gk} of the measuring device is expressed by the relation:

$$C_{gk} = \frac{0.1 \cdot T - |\bar{x}_g - x_r|}{3 \cdot s_g} = \frac{0.1 \cdot 0.05 - |40.00032 - 40.000|}{3 \cdot 0.00061} = 2.55 \cdot$$

For the repeatability %R and accuracy and repeatability %A&R it reads

$$\%R = \frac{20}{C_g} = 7.33 \le 15 \cdot, \%A\,\&\,R = \frac{20}{C_{gk}} = 7.84 \le 15 \cdot$$

Because both conditions are met ($C_g \ge 1.33$ and at the same time $C_{gk} \ge 1.33$, equally also $\%R \le 15$, $0 \le \%A\&R \le 15$ and $\%R \le \%A\&R$) measuring device is suitable and can be used in the production process.

4. PACKAGE QUALITYTOOL

For the assessment of capability we can also use the free software R. R is a language and an integrated environment for data analysis, statistical and mathematical computing, and graphical data processing and representation. This free software is very similar to the S language and runs on most UNIX/Linux platforms, Macintosh and Windows. R belongs to open source software and its latest version can be downloaded directly from its home page at http://www.r-project.org/.

R is a tool for accomplishing many conventional as well as modern statistical computing and analytical tasks. The basic environment contains several standard, recommended packages, and many more are available through the CRAN archive on the home page, including updates.

There are many packages for process quality assessment through statistical methods. For example, with the use of package qualityTools we can simply calculate indices C_g and C_{gk} [5]. Graphic output of the R package is in Figure 3. The assessment of capability can be analyzed by using the cg() function.

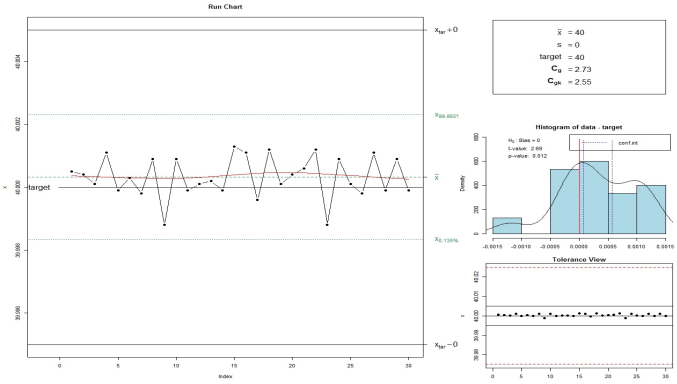

Figure 3. Assessment of capability (output R package)

>library(qualityTools)
>data=c(40.0005,40.0004,40.0001,40.0011,39.9999,40.0003,39.9998,40.0009,39.9988,40.0009,39.9999,40.0001,40.0002,39.9999,40.0013,40.0011,39.9996,40.0012,40.0001,40.0004,40.0006,40.0012,39.9988,40.0009,40.0001,39.9998,40.0011,39.9999,40.0009,39.9999)
>cg(data,target=40.0000,tolerance=c(40.025,39.975))

Conclusion

It is important to realize that for the ensuring of very exact parameters, attributes of various products it is not enough to deal with technological aspects of production process only but it is also important to ensure with the same concern the reliable measuring of the monitored parameters. The assessment of the capability of the measuring device is a process, which represents an important element of the consistent quality improvement of the production process, because the decisions on the quality are usually based on the control and measuring of various parameters of the products. The goal of such assessment is to prove that the measuring device is capable and suitable for measuring of the monitored attribute of quality. It provides for a possibility to identify the inadequacies as early as the initial phase of the production process and it helps to ensure the fulfilment of the quality requirements.

The given method of the assessment of the capability of the measuring device by means of indices C_g and C_{gk} is used at the complex monitoring of the capability of the production processes and at regular assessment of the capability of the measuring systems as a part of metrology management.

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