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RESULTS OF ASSESSES OF THE CAPABILITY OF PRECISE INDICATOR

Nermina Zaimović – Uzunović
Univerzitet u Zenici
Mašinski fakultet
Fakultetska 1., Zenica
Bosnia and Herzegovina

Esad Pobrić
J.P. Komunalno d.o.o
Mostar
Bosnia and Herzegovina

Daut Denjo, Senada Pobrić
Univerzitet "Džemal Bijedić"
Mašinski fakultet
USRC Mithad Hujdur- Hujka, Mostar
Bosnia and Herzegovina

Lejla Denjo
Institut za mjeriteljstvo BiH
Augusta Brauna 1. Sarajevo
Bosnia and Herzegovina

ABSTRACT
This paper presents the results of the capability assessement of precise indicator, measurement range ± 50 μm and graduation 1 μm. The capability assessement of precise indicator was made in a factory "RFK valjčići" in Konjic. The experiment was caught testing and capability assessment indexes C_g and C_{gk}, repeatability, reproducibility, linearity, overall repeatability and reproducibility of the precise indicator.
Keywords: measurement system, capability assessement

1. INTRODUCTION
In order to get better quality control, but also reach improvements of production processes, quality of measurement systemhave to satisfy high quality of measured characteristics of process. One problem to provide assessment the quality of products is dependence on the capability of the applied measurement system. Measurement system is assumed as; instrument, software, auxiliary equipment, measurement methods and controllers. All mentioned elements can be a cause of variation of quality of products and significant facts for costs to business results.
Assessment of quality of measurement system is a prerequisite for determining the stability and capability of the manufacturing process. In the assessment procedure, variations of measurement systems, may be identified and quantified.Variations are result of random and systematic effects.
In practice to assesses the capability of the measurement systems MSA document is mainly used. It is created by the Automative Industry Action Group (AIAG) in 1990. On the basis of that document, the working groups of automobile companies (BMW AG, Audi AG, Robert Bosch GmgH,

DaimlerChRYler AG, Fiat Auto SpA, Ford Werke AG, Adam Opel AG, Q-DAS GmgH, Volkswagen AG) prepared guide: „Measurement System Capability“ Reference Manual (Leitfaden zum "Fähigkeitsnachweis von Messsystemen"). Second fully revised edition of VDA 5, based on ISO 22514 -7 since 2010, describes the requirements regarding the suitability of the test process, the suitability of measurement systems and measurement process, expanded measurement uncertainty and conformity assessment.

2. CAPABILITY ASSESSMENT OF MEASUREMENT SYSTEMS BY GUIDE

According to the guide, there are three studies for assessment of the capability of the measurement system. Study 1 is usually done by suppliers in assessing new measurement systems and measurement systems that have made some modifications, but before using it in the process of quality control. It consists of testing and assessing capability indexes C_{gk} = (0,1T- B_i)/2s_g and C_g = 0,2T/4s_g, and checking functionality. For this purpose, the real product is used as a working standard measured in laboratory conditions and which has traceability to national and international standard. A prerequisite for the implementation of the procedure is to determine the accuracy of the measurement system Bi. Capability index C_g reflects random errors, while C_{gk} reflects random and systematic errors. If these coefficients are greater or equal to 1.33 measuring system is capable.

In study 2, is determined impact of the operator. The aim of this procedure is based on access of characteristic value % R&R of the measuring device, taking into account all influences suitable for the planned measurement tasks. Influences and disturbances are; dust, vibration, temporal and spatial temperature gradients, operator, measurement method, measurement procedure, structure (quality) measured object, etc . Study 2 can be performed only after the successful certification of the suitability of the study 1. In this procedure the repeatability (EV) and reproducibility (AV) of the measurement system are determined and the total repeatability and reproducibility R&R as the square root of the sum of squares of repeatability and reproducibility.

Study 3 is a special case of study 2, used for measurement systems in which the operator has no effect, (eg. mechanized measuring device, automatic control, automatic handling, etc.) or operator influence is negligible.

For the analysis and assessment of the capability of the measurement system there are three basic methods:

- Average Range Method
- Method ANOVA (Analysis of Variance)

According to the guide, measuring systems which meet the share of variability in the field of tolerance R&R ≤ 20% (new measurement systems), and R&R ≤ 30% (systems which are in exploitation) are capable or suitable measurement systems.

3. EXPERIMENTAL WORK

The experiment has been performed by testing and assessing capability indexes C_g and C_{gk}, linearity, repeatability, reproducibility and total repeatability and reproducibility of the precise indicator.

3.1. Testing and assessing capability indexes C_g and C_{gk}

Before the experiment condition, that resolution of the precise indicator must be % RE ≤ 5%, in our case %RE = 2.56% is tested, so this requirement is met.

In this study used working standard has been traceabile to the international standard of length. Nominal diameter of standard for tested repeatability is 15,060 mm. Test included 30 repeated measurements and than calculated average value of nominal diamenter.

Average value and standard deviation of repeated measurements: $\bar{x}_g = 15,06$ mm; $s_g = 0,262 \cdot 10^{-3}$ mm

The difference between average value and the real value of standard: $B_i = 0$

Capability of indexes C_g and C_{gk} according to the guide: $C_g = 7,443 \geq 1,33$; C_{gk}=7,443≥1,33

The minimum value of tolerance determined through formula for C_{gk} and C_g: $T_{\min} \geq 0,0105$ mm

The precise indicator is provided for control of the rollers with tolerance T = 0,039 mm

3.2. Testing of linearity with three working standards

Testing of linearity is done with working standards, nominal values of 15,440 mm, 15,460 mm and 15,480 mm with ten repeated measurements, than it was calculated.
Average values at the lower limit, the middle and the upper limit:

$\bar{x}_{gu} = 15,440$ mm; $\bar{x}_{g} = 15,4599$ mm; $\bar{x}_{go} = 15,4799$ mm

Lower and upper deviation of linearity: $Li_u = 0,5025\%$; $Li_o = 0,5025\%$

Both values must satisfy the requirement: $\%Li_u, Li_o \le [3\% + (\%U)]$, $\%U = 1,282\%$

U_1 – measurement uncertainty of working standard is U_1 = 0,5 μm.

For our case $\%Li, Li = 0,5025 \le 4,28\%$

3.3. Average Range Method

Average Range Method provides an assessment of repeatability and reproducibility of the measurement system. This approach provides separation on the two different components, the repeatability and reproducibility, but not their interaction.
For realization this method, 10 numbered rollers by random selection is taken from production. Checked diameter of rollers is 15,440 mm, tolerance (-0.039, +0.009).Three controllers performed measurements, measuring two sets of rollers, than it was calculated.

Average values of measurands by controllers: $\bar{x}_1 = 15,43775$ mm ; $\bar{x}_2 = 15,43805$ mm ; $\bar{x}_3 = 15,4383$ mm

Average values of ranges: $\bar{R}_1 = 0,5 \cdot 10^{-3}$ mm; $\bar{R}_2 = 0,7 \cdot 10^{-3}$ mm; $\bar{R}_3 = 0,4 \cdot 10^{-3}$ mm; $\bar{\bar{R}} = 0,5333 \cdot 10^{-3}$ mm

Variation of equipement - repeatability: $EV = 2,435 \cdot 10^{-3}$ mm ; $\%EV = 6,245\%$

The maximum difference between average values: $\bar{\bar{X}}_{diff} = \bar{X}_{max} - \bar{X}_{min} = 0,55 \cdot 10^{-3}$ mm

Variation of appraiser - reproducibility : $AV = 1,484 \cdot 10^{-3}$ $\%AV = 3,805\%$

The repeatability and reproducibility: $R\&R = 2,851 \cdot 10^{-3}$; $\%R\&R = 7,31\%$ mm;

3.4. Method ANOVA

Analysis of variance (ANOVA) is a standard statistical technique. It may be used for the analysis of measurement errors and other sources of variability of the data of measurement system. In the analysis of variance, the variance can be broken down into four categories: parts, measurers, the interaction between parts and measurers, and repetition error.
The results obtained after applying this method are:

- Variance operator influence: $S_P^2 = 1,51667 \cdot 10^{-6}$ mm^2
- Variance part influence: $S_T^2 = 0,000385$ mm^2
- Variance interaction: $S_{PT}^2 = 6,648 \cdot 10^{-7}$ mm^2
- Variance gage influence: $S_E^2 = 1,666 \cdot 10^{-6}$ mm^2

Check the F test:

$\frac{S_{PT}^2}{S_E^2} = 0,3988 < 2,25 = F_{60,6_{1-95\%}}$, therefore interaction is not significant, so $S_{add}^2 = 5,618 \cdot 10^{-7}$ mm^{-2}

Characteristic values obtained by ANOVA method are:

- For the measuring device: $VE = 5,618 \cdot 10^{-7}$ mm^2
- For operator: $VP = 4,774 \cdot 10^{-8}$ mm^2
- For parts: $VT = 6,4127 \cdot 10^{-5}$ mm^2
- Equipment Variation: $EV = 3,86 \cdot 10^{-3}$ mm; $\%EV = 9,897\%$
- Appraiser Variation: $AV = 0,001125$ mm ; $\%AV = 2,885\%$
- Part Variation: $PV = 0,0412$ mm

  The total repeatability and reproducibility: $R\&R = 0,00402$ mm; $\%R\&R = 10,309\%$
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4. ANALYSIS OF RESULTS ASSESSMENT OF THE PRECISE INDICATOR

Capability assessment of the precise indicator in real working conditions in factory "RFK valjčići" in Konjic is shown the following:

- Systematic error of the precise indicator, actually difference between the average value of repeated measurements and the real value of standard, is equal to zero.
- Capability index C_{gk} takes into account the systematic and random components and capability index C_g takes into account only the random components (repeatability). According to guide for assesses of the capability of the measurement systems, values of the capabilities indexes are 7,443 and satisfying the condition $C_g \geq 1,33$ i $C_{gk} \geq 1,33$.
- Linearity of the precise indicator satisfies the condition %Li , Li ≤[3% + (%U=1.282)], for the precise indicator is %Li ,Li = 0,5025 ≤ 4,28%
- The maximum difference in the measuring of samples between three controllers is $4 \cdot 10^{-3}$ mm.
- Repeatability of the precise indicator using Average Range Method is EV = $2,435 \cdot 10^{-3}$ or percentage % EV = 6.245%, while using the method ANOVA is EV = 3.86 · 10-3, the percentage for tolerance % EV = 9.897 %.
- Reproducibility using Average Range Method is AV = $2,419 \cdot 10^{-3}$, or percentage %AV=3.805%, while using the method ANOVA is AV = $1,125 \cdot 10^{-3}$, or percentage %AV=2.885% .
- Repeatability and reproducibility using Average Range Method is R&R = $2,851 \cdot 10^{-3}$, or percentage %R&R = 7,31%, while using the method ANOVA is R&R = $4,02 \cdot 10^{-3}$, or the percentage %R&R = 10,309%.
- According to the guide, criteria for capability assesement of measurement system is R&R≤20% for a new measurement system, and R&R≤30% for measurement systems which are in use. On this basis the precise indicator is capable.

5. CONCLUSION

In order to get better control, but also improvement of the production process, a quality of measurement system for detecting the characteristics of the process is required. One of the common problems in product quality assessement is capability of used measurement system. The selection, design or improvement of appropriate measurement system is an important step in development and improvement of process.

In the past, the measurement method and the measuring device which is calibrated using standard were the basic measures of validity of the measurements. Calibration is performed with standardized equipment, under controlled environmental conditions, and device operated by qualified personnel.

Real conditions of usage are far from those in which the measuring device is calibrated, and the accuracy of measurement becomes questionable. The effects of influencing factors are variation results of measurement, which can endanger the whole procedure and lead to uselessness results. To avoid problems of this kind, except calibration, is necessary to assess the device in working conditions by measuring a given characteristic with all influences. Expected that the measurements in real conditions have accuracy and the least variation measures. Due to the above there is a difference in the analysis measurement systems, depending on whether the measurement system used in the laboratory or in industrial conditions.

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