COMPARATIVE ANALYSIS OF THE ANALYTICAL METHODS FOR ASSESSING THE PRECISION OF THE MEASURING SYSTEM

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Abstract
The results of performed analysis and the study of analytical methods for assessing the precision of the measuring system are presented in this paper. Studies are related to the methods for assessing the precision based on the range calculation and the method of variances analysis (ANOVA).The importance of each factor in variation inducation in the measurement process is estimated by applying both methods in the analysis of the same measured sample. In order to assess the accuracy and efficiency of the applied methods, the obtained results are compared, which is the basis for obtaining specific conclusions.Reliability of the obtained results from the investigations are verified by applying the tools of programming package MINITAB.

KEYWORDS: PRECISION, ANALYTHICAL METHODS, MEASURING SYSTEM, VARIATIONS

1. Introduction

Modern measurement techniques has developed various measuring devices. Certain types of measuring devices have different specific properties, but also some common general characteristics that allow comparation. One of the basic metrological characteristics of the measuring device is its precision.

Measuring equipment precision - is the ability of the measuring device to show the similar measured values (Figure 1).

1) accurate and precise 2) inaccurate and precise

3) accurate and impreccise 4) inaccurate and imprecise

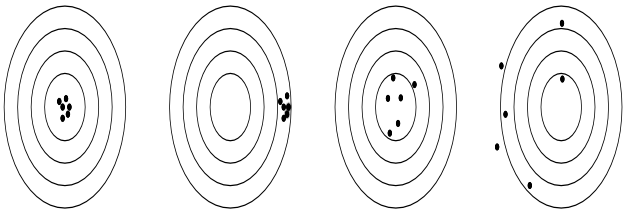

Figure 1: *Possibilities of accuracy and precision or inaccuracy and imprecision of a measurement [G1]*

The metrological charastheristics – measurement precission contains two typical aspects [G1] :

- repeatability of the measurement results, the degree of mutual overlapping of each measurement results obtained in mutually multiple repetition of the measuring operation over a measured value, which value is time-independent (constant), using the same measurement equipment, the same operator and the same ambient conditions.
- reproducibility of the measurement results, the variations that occur when multiple realization of the measurement process, using the same measurement equipment and different operators.

In practice, analytical and graphical procedures are used for assess the measurement systems accuracy. Analytical procedures for the determination of repeatability and reproducibility of the measuring system are aimed to determine (quantify) which part of the calculated variations of the observed measurement process are due to the variations of the measuring system, while graphical procedures allow analysis of the measurement process.

Analytical methods for repeatability and reproducibility calculation of the measuring system, which are subject of this paper can be:

• Method based on range, which assess the measurement variations by comparing the standard deviations of the factors in the measurement process. This "traditional" method divides the total variation in three categories: variations from product to product (variations induced in the manufacturing process), measurement repeatability and reproducibility (variations caused by the measuring system).

• ANOVA (Analysis of Variance) method - investigates the effects of one or more qualitative inputs (factors) on the quantitative outputs, that helps assessing which of the factors have the most significant impact on the output (answer). ANOVA Gauge R & R is a method which uses ANOVA random effects model for measurement systems analysis. This method calculates the level of variations induced in the measuring process of the measurement system and compares it with the total variation in order to determine the "quality" of the measuring system, i.e. its participation in the total variation. This method goes a step forward in terms of the first method and the component reproducibility is separated in two subcomponents: operator and operator - measured sample component in interaction.

Which analytical method will be applied depends on the measurement nature. If it is a non-destructive test (test sample after measuring retains all its properties), there is possibility to use both analytical methods.

In the case of a destructive test (test sample after measuring loses its characteristics, and repeated measurement is not possible) can be applied only ANOVA - method. The of homogeneity of the tested samples serie should be assumed, i.e. all samples in the tested

serie sufficiently identical to be able to consider operation with the same samples. Otherwise the variations of the process will "mask" the variations of the measuring system.

2. Preparation, planning and realization of then engineering experiment

In order to realize the analysis of the measuring system accuracy as a function of the measuring equipment and operator, it is necessary more operators to measure more samples on the same measurement equipment several times in reference conditions. Experiment is prepared from the measured samples. The aim is as much as possible sources of variation to be covered in the measurement process in order to be properly understood and assessed.

The aspect of measurement reproducibility to be covered, it is necessary the participation of more operators. Some standards [A1] require the participation of at least ten operators, but others require participation of only two or three operators for the same sample measuring.

To cover aspects of the measurement repeatability, the same samples are measured several times by the same operators. Each measurement cycle of each sample must include the whole set of required operations, including the complete handling, sampling and disposal of the measuring sample from the measuring system.

To include the interaction between the operator and the sample (eg some sample could be more difficult for measuring than the other samples), usually five till ten samples are measured.

Of course, this is not a universal criteria for the minimum samples recommended for R & R matrix. This is the question for the person which manage the experiment to establish a balance between the risks, measurements and laboratory ability. Model 10x2x2 (10 samples, two operators and two repetitions of measurements) is acceptable sample for certain studies, although there are little degrees of freedom for the component of the operator.

In order the measuring sample to be considered as relevant for further processing and carry out more valid conclusions it is necessary to check the existence of harsh errors and their elimination and verification of the fulfillment of the conditions of normality and homogenity of the measuring sample:

1) As a first step in the process of determining of the participation of measuring equipment and operator in the total level of variations from the set of measured values by applying the Grabs criteria [G2], harsh errors are identified and eliminated for measured values of each operator separately.
2) In the next step of the analysis, it is necessary to test the fulfillment of the conditions for normality of measured results and homogeneity of the variations. This is done through testing the hypothesis by applying more tests:

- for testing of normality: λ - test, λ- test, Anderson – Darling, Ryan – Joiner, Kolmogorov – Smirnov test, by using of probability diagram or by p - value analyze e.t.c.

- for testing of homogeneity: z – test, Student t – test, Fisher F – test e.t.c.

3. Results

Example number 1. *R&R Analisis of the mearuring system precision*

Table 1: *Measured values in the analysis of the components to the measuring system precision.*

Number	FIRST OPERATOR		SECOND OPERATOR	
Product	First measurement	Second measurement	First measurement	Second measurement
1	50,08	50,08	50,06	50,06
2	50,04	50,05	50,04	50,04
3	50,03	50,02	50,04	50,02
4	49,99	49,96	49,98	49,98
5	50,10	50,08	50,08	50,06
6	49,98	50,00	49,99	50,00
7	50,08	50,06	50,10	50,09
8	49,99	50,00	50,01	50,01
9	50,02	50,02	50,00	50,01
10	49,96	49,94	49,98	49,99

By the implementation of Grabs test for the series of measurements on the first and the second operator high values of p – indicator can be seen, significantly bigger than the level of trust α = 0.05 (p = 1.000 for the first operator, and p = 0.923 for the second operator) and can be concluded that in both series of measurements do not exist unusually measurements – harsh errors.

Although it is about series with a relatively small number of measurements (twenty measurements in serie), the two series of measurements (from the first and the second operator), show a high degree of compliance to normal distribution (p = 0.199 for the first operator, and p = 0.168 for the second operator),

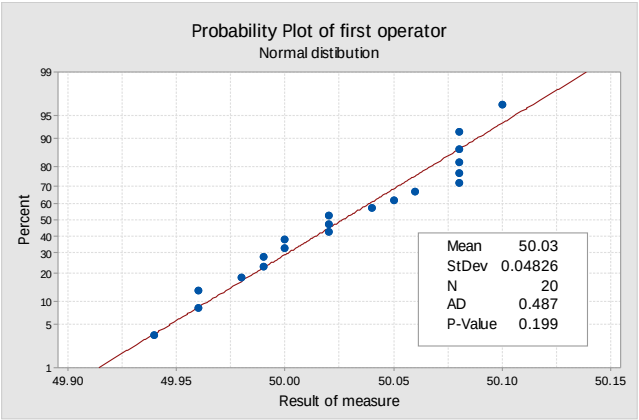

Figure. 2 *Analysisof the measurind results normality by using of probability diagram*

The existence of consistency of the variations and their uniformity can be determined by using of t – test for analysis of the homogeneity of the variations of whole measured sample.

Table 2: *Calculated values in the analysis of the components to the measuring system precision using a balanced ANOVA - method.*

Sources	Var. comp.	% Participation	Standard deviation	% Participation
Measuring system	0,0002381	12,58%	0,0154290	35,47%
Repeatibility	0,0001025	5,42%	0,0101242	23,27%
Reproducibility	0,0001356	7,16%	0,0116428	26,76%
Operator	0,0000000	0,00%	0,0000000	0,00%
Product*Operator	0,0001356	7,16%	0,0698570	26,76%
Product	0,0016544	87,42%	0,2440490	93,50%
Total variations	0,0018925	100,00%	0,2610170	100,00%

Table 3: *Calculated values in the analysis of the components to the measuring system precision using a method based on range*

Source	Var. Comp.	% Participation	Standard deviation.	% Participation
Measuring system	0,0001039	7,36%	0,0101950	27,13%
Repeatibility	0,0001039	7,36%	0,0101950	27,13%
Reproducibility	0,0000000	0,00%	0,0000000	0,00%
Product	0,0013078	92,64%	0,0361635	96,25%
Total variations	0,0014117	100,00%	0,0375731	100,00%

4. Conclusion

Both methods for assess the accuracy of the measuring system show that the manufacturing process is the most important factor that induces variations. Variations of the measuring system according to ANOVA – almost equally is due to the repeatability (variation of the measuring instrument) and reproducibility (variations induced by the interaction of the operator and the measuring sample). Because the method based on range did not detect variations from the interaction of the operator and the measuring sample, the whole measuring system variations are shown for repeatability.

• Procedure for analysis of the components on variation and procedure for standard deviation factors analysis are used in the analysis of the measuring system. The obtained results with both procedures are equally indicative. Which metrics will be used depends on the purpose of the research. If the measuring system is used in process for improvement, (reduction of variations in the manufacturing process), analysis of the components of variations is used, and if assessed the quality of the product in terms of meeting the specified values, then analysis of the standard deviations is used.

• Ability of ANOVA - Method to assess the variations caused by interaction of the operator and measuring sample makes this method more effective in detecting the sources of variation. Furthermore, only ANOVA – Method is applied in the realization of the analysis of the measuring system in the case of destructive test. The application of ANOVA method can significantly improve the view for measuring system precission by fulfillment of assumptions for realization of engineering experiment, by possession of mathematical, technical and practical experience of the operator and computer supported analytical process.

5. Literature

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