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THE SOURCES OF UNCERTAINTY OF THE MEASUREMENT RESULT AS ELEMENTS OF THE MEASUREMENT PROCESS

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Abstract

Research objective – to facilitate the detection and determination of the contributing components associated with the sources of uncertainty in measurements across the full range of aspects of calibration, testing and inspection and process control. In the paper, based on the concept of the duality of measurement process – measurement result, the five elements of the measurement process ware divided and classified as base sources of uncertainty. Some relations with other references with more or less structured classifications of the sources of measurement uncertainty are exampled. The scientific contribution is the application of a universal approach to determine the sources of uncertainty before empirical or experimental assessment of their contribution. As a result of the study the initial analysis of the sources of uncertainty is unified and simplified by asking the question of the contribution to the measurement uncertainty of each of the well-defined and universal five element of the measurement process.

Keywords: measurement, process, result, uncertainty, sources of uncertainty in measurements

1. Introduction

A fundamental issue in measurement, and especially in calibration, is the correct estimation of uncertainty, which is possible by accounting for the contributions of all its significant components. While uncertainty evaluation methods are well analyzed, developed and described [1-9], the detection and determination of the contributing components associated with the sources of uncertainty remains within the realm of the metrologist's empirical expertise.

In the paper "A Concept of Measurement Process-Result Duality in the Context of Measurement Uncertainty" [10] was explained the duality of the measurement process – measurements results. The main presented idea there is that the result is not an element of the measurement process because it is a product the process. This concept opposes some other classifications where the result is considered as a component of the process [11]. Based on this concept, we can classify and separate the elements of the measurement process and the elements of the measurement results.

In the paper [10], after analysis of well-known sources [2-7, 12-17], the five elements of the measurement process are specified as follow:

- measurement object;
- measurement method;
- measuring instrument;
- measurement subject;
- influence factors.

According VIM [12] §2.9 NOTE 2 "*A measurement result is generally expressed as a single **measured quantity value** and a **measurement uncertainty***".

Therefore, the elements of the measurement results are:

- measured quantity value;
- measurement uncertainty.

From its own side VIM [12] §1.19 the quantity value consists "*value number and reference*". For completeness, we note that uncertainty is also expressed by value number and dimension.

As emphasized in [1] "*The errors characterize the measurement process*". The analysis [10] of the elements of the measurement process define the respective errors. Consequently, the sources of uncertainty can be specified by considering un-excluded errors in the measurement process as the cause of measurement uncertainty.

The primary sources of the components of uncertainty are related with the elements of the measurement process [10].

The purpose of this report is to specify and detail essential components of the uncertainty inherent in the individual elements of the measurement process.

2. Object and subject of the measurement process

Talking about the measurement process, adhering to VIM [12], instead of quantity is preferably usage of the term "*measurand*" where in § 2.3 it is defined as a "*quantity intended to be measured*". Considering the most abstract definition according NOTE 3 to the same paragraph (2.3) of VIM [12] here the measurand is named OBJECT of the measurement.

Considering the measurement process as an abstract process it is an interaction between the OBJECT and the SUBJECT of the process (Fig. 1). In the measurement case, the SUBJECT of the measurement process could be an operator, device, controller, algorithm or any subject who is using the measurement result.

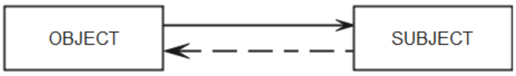

Fig. 1. Interaction between the object and the subject the measurement proces

The interaction in the process is always both ways, even often in the measurements the influence of the SUBJECT over the OBJECT is negligible.

The measurement is a quantitative process. Before obtaining the digital values of the quantities (of the OBJECT), the SUBJECT shall pass the qualification of the OBJECT. That means the SUBJECT has an a priori imagination about the OBJECT before measurements. This a priori imagination is related with the identification of the OBJECT and its classification to a group of OBJECTS.

The a priori imagination for the object is named a “*Model*” of the OBJECT [18, 19]. The model, more or less adequate to the OBJECT qualifies it to a group of objects having the same quantity or set of quantities (in the most sophisticated cases), possible to be measured.

3. Measurement method and measuring instrument

The interaction between the OBJECT and the SUBJECT always happens according to any METHOD, named measurement METHOD (Fig. 2). VIM [12] § 2.5 says “*measurement method*” or “*method of measurement*” is a “*generic description of a logical organization of operations used in a measurement*”.

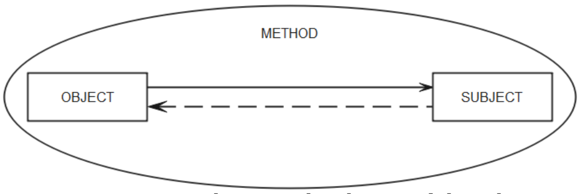

Fig. 2. Interaction between the object and the subject according a method of measurement

The METHOD is based on the key principles [2, 7, 12] of interaction between the OBJECT and the SUBJECT of the measurement process. All qualifications of the OBJECT shall be considered in the METHOD of measurement. So, some authors unreasonably refer the model of the OBJECT to the description of the METHOD [11]. In this case VIM [12] with the NOTE to § 2.5 is definitely clear.

The interaction between the OBJECT and the SUBJECT according to the chosen METHOD is realized with measurement tool/s named MEASURING INSTRUMENT/s (Fig. 3).

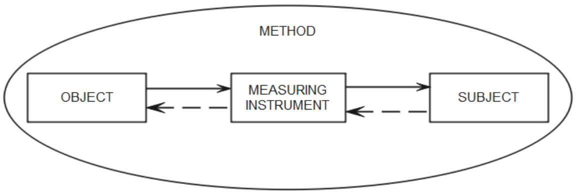

Fig. 3. Measuring instrument in the process of interaction between the object and the subject according to the measurement method

The definition for MEASURING INSTRUMENT in VIM [12] § 3.1 is a “*device used for making measurements, alone or in conjunction with one or more supplementary devices*”. As much complex is the device (instrument), as more the measurement METHOD is built into its action. In some cases, the realization of the measurement method needs several simple devices. In other cases, the METHOD requires just one complex device. Than METHOD is implemented in the device (Fig. 4).

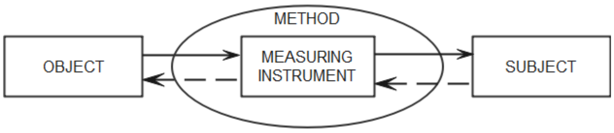

Fig. 4. Realization of the measurement method in the process with a complex measuring instrument (measuring system according VIM)

Such complex devices, often used in on-site measurements, in VIM [12] are named “*measuring systems*” with a respective definition in § 3.2. To simplify the exposition here is used the name MEASURING INSTRUMENT only.

4. Influence factors

The INFLUENCE FACTORS are circumstances and respective quantities, which deviation affects the measurement result. VIM [12] § 2.52 is talking about “*influence quantities*” with a definition: “*quantity that, in a direct measurement, does not affect the quantity that is actually measured, but affects the relation between the indication and the measurement result*”. The exposition here prefers the GUM’s definition for “*influence quantity*” as a “*quantity that is not the measurand but that affects the result of the measurement*” [2]. In this way the INFLUENCE FACTORS impact over the MEASURING INSTRUMENT, over the OBJECT of measurement, and could influent over the SUBJECT (Fig. 5).

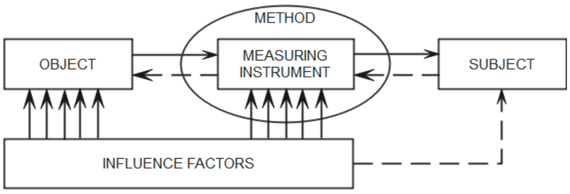

Fig 5. Impact of the influence factors over the object, measuring instrument and subject of the measurement process

5. The elements of the measurement process

The specified five elements of the measurement process: OBJECT, SUBJECT, METHOD, MEASURING INSTRUMENT and INFLUENCE FACTORS exist and can be analyzed in all cases of measurement processes.

For example, in calibration (Fig. 6), the OBJECT is the device being tested (most popular as device under test – DUT or unit under test UUT), the MEASURING INSTRUMENT is the reference tool (calibrator, reference measure etc.) and the SUBJECT is an operator.

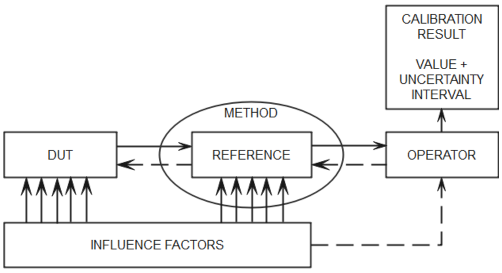

Fig. 6. Measurment process and its elements in calibration

The result in calibration is a value and inherent uncertainty for each calibration point.

In testing and inspections we add a NORM to compare with the indication of the MEASURING INSTRUMENT. The elements of the measurement process are the same.

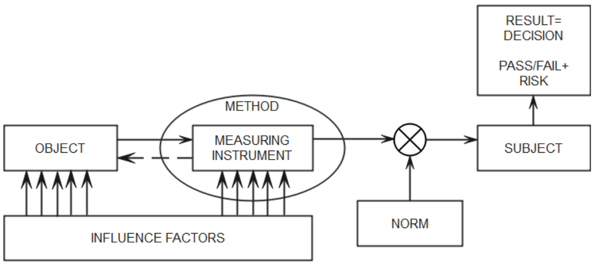

Fig. 7. Measurment process and its elements in testing and inspection

In this case, the result is a decision from the type PASS/FAIL and the measurement uncertainty reflects on the risk type α or β.

In case of control of a process, the result from the measurement process is used to form an IMPACT over the OBJECT.

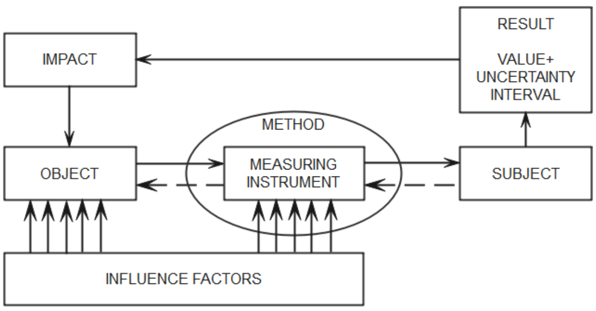

Fig.8. Measurment process and it's elements in control of a process

The uncertainty of the result here reflects on stability of the control and often leads to inaccurate process stabilization.

6. How the GUM sources correspond to the elements of the measurement process?

Let briefly make a correspondence between mentioned above GUM's [2] sources and the elements of the measurement process:

a) incomplete definition of the measurand – **Inadequacy of the model**;

b) imperfect realisation of the definition of the measurand – **Inadequacy of the model**;

c) non representative sampling — the sample measured may not represent the defined measurand – **Subject**;

d) inadequate knowledge of the effects of environmental conditions on the measurement or imperfect measurement of environmental conditions – **Influence Factors**;

e) personal bias in reading analogue instruments – **Instrument**;

f) finite instrument resolution or discrimination threshold – **Method**;

g) inexact values of measurement standards and reference materials – **Instrument**;

h) inexact values of constants and other parameters obtained from external sources and used in the data-reduction algorithm – **Inadequacy of the model**;

i) approximations and assumptions incorporated in the measurement method and procedure – **Method**;

j) variations in repeated observations of the measurand under apparently identical conditions – **Influence Factors**.

7. Conclusion

The sources of uncertainty are defined in the measurement process. These fractions of uncertainty form the combined uncertainty and finally expressed in measurement result via expanded uncertainty.

Each specific source of uncertainty refers to the respective element of the measurement process. It is much easy for the metrologists, to start analysis of the sources of uncertainty with the well specified and universal five element of the measurement process: **Object, Method, Measuring instrument, Subject** and **Influence factors**.

Then the analysis could be deeper with the specific appearance of the factors of each element.

The approach of this concept is universal for all types of measurements on the stage of determining the uncertainties.

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Джерела невизначеності результату вимірювання як елементи вимірювального процесу

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Abstract

Мета дослідження – полегшити виявлення та визначення складових компонентів, пов’язаних із джерелами невизначеності у вимірюваннях по всьому діапазону аспектів калібрування, тестування та контролю, а також управління технологічним процесом. У статті на основі концепції подвійності: процес вимірювань – результат вимірювань, як основні джерела невизначеності розділені та класифіковані п’ять елементів процесу вимірювання (об’єкт вимірювання; метод вимірювання; вимірювальний прилад; предмет вимірювання; впливаючи фактори). Розглядаються особливості процесу вимірювання та його елементів при калібруванні, випробуванні, верифікації та керуванні процесом. Як приклади наведені деякі зв'язки з іншими посиланнями з більш менш структурованими класифікаціями джерел невизначеності вимірювань. Наводяться відповідність джерел невизначеності, які перелічені в Настанові з оцінювання невизначеності вимірювань, елементам вимірювального процесу. Науковий внесок – це застосування універсального підходу до визначення джерел невизначеності перед емпіричною чи експериментальною оцінкою їхнього вкладу. В результаті дослідження початковий аналіз джерел невизначеності уніфікований та спрощений за рахунок постановки питання про внесок у невизначеність вимірювань кожного з чітко визначених та універсальних п'яти елементів процесу вимірювань.

Ключові слова: вимірювання, процес, результат, невизначеність, джерела невизначеності вимірювань