SELECTING OF MEASURING INSTRUMENTS

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ABSTRACT: One of the tasks at planning of quality inspection is selection of measuring instruments. The measuring instruments are the most important part of the measuring process, so that their selection has to be done carefully. The selection of measuring instruments is a complex task, which depends on the size, the character and the value of measured magnitude. The purpose of this paper is to analyze the existing methods for selection of measuring equipment. In the paper, there are presented the advantages and disadvantages of existing methods and recommendation for their implementation, according to the metrological tasks given. There are results obtained, using the Measurement System Analysis (MSA), for selection of the correct measuring instrument and method; assessment the capabilities of measuring instruments.

KEY WORDS: measuring instruments, accuracy, capabilities.

1. INTRODUCTION

The selection of measuring instruments for linear measurements takes the following main factors into account: manufacturing program, the construction features of the details and manufacturing accuracy – the tolerance zone (IT), measuring instrument error and the measuring costs.

In the single production companies, the special measurement instruments are inapplicable, so it is recommended the dimensions control of manufacturing products to be made using universal measuring equipment (i.e. calipers, micrometers, indicating internal gages). In the serial production, the main measurement testing and control instruments are limit gauges, measurement templates and semiautomatic measurement instruments.

For the selection of measurement instruments, the set of metrological, exploitation and economical

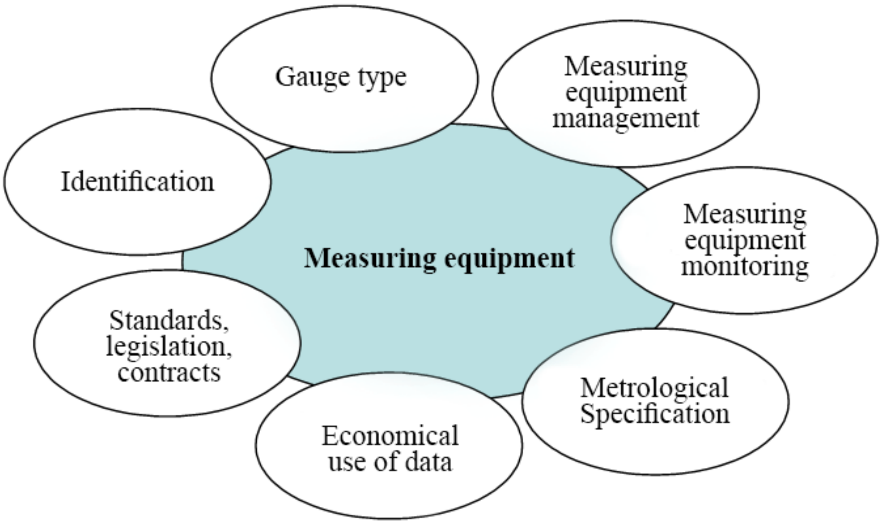

Figure 1. Information about the measuring equipment

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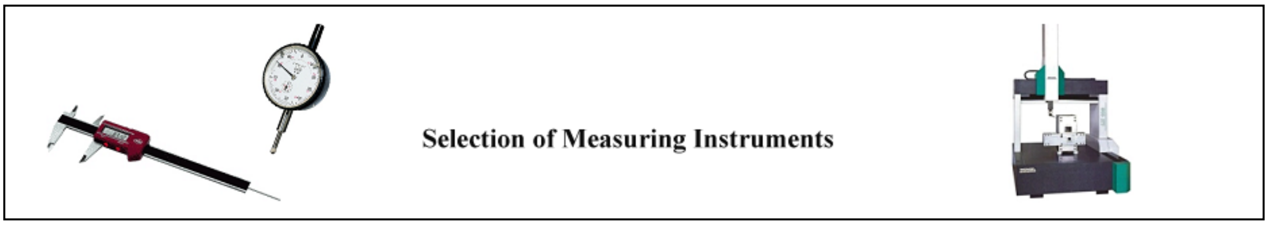

Main criteria

- given measurement task
- measured quantity
- measured range of the parts
- the dimensions and tolerances
- available time for tests

Minor criteria

- in what form the measured values have to be
- how the values have to be processed
- how the measuring equipment have to be used
- who should operate the measuring equipment

Advanced Minor Criteria

- type / construction
- environmental conditions
- sensors
- control
- software
- consulting and services

Figure 2. Criteria for selection of measuring equipment

indices are reviewed. The metrological indices are:

- scale interval;
- measurement method;
- accuracy;
- measurement range (interval).

The exploitation and the economic indices are:

- the cost and the reliability of measurement instruments;
- running time before repair is needed;
- inspection intervals;
- easy to use;
- inspection and repair costs including the measurement instrument delivery costs to the place for inspection and back (Fig. 1) (Zinner, 2006).

Figure 2 shows the required information for the preliminary selection of measurement instruments.

The purpose of preliminary selection of measurement instruments is to reduce the possible

Metrological task

- Measurement object
- Inspection characteristic
- Inspection scope
- Results dokumentation

Additional condotions

- Measurement place
- Enviromental influences
- Measuring time (cycle times)
- Level of automation

Output data

- Standards
- Legislation
- Regulations
- Guidelines
- Safety requirement
- Customers requirement
- Internal instructions

Organisation

- Existing measurement instruments
- Staff
- Metrological infrastructure

Costs

- Labor costs
- Staff costs
- Training costs
- Operational preparation
- Costs for monitoring of inspection equipment

Figure 3. Factors for selection of measurement instruments (Zinner, 2006)

solutions when selecting the proper measuring equipment. For the preliminary selection of measurement instruments, the main criteria are taken into account, which include organization and technical criteria.

This criteria may be arranged by priority (Fig. 2) (Zinner, 2006). Figure 3 shows the factors which are taken into account in the selection of measuring instruments.

2. METHODS FOR SELECTING OF MEASUREMENT INSTRUMENTS

2.1 Selection of measurement instruments depending on the production accuracy of details

In this method for selection of measurement instruments depending on the manufacturing tolerance, the acceptable measurement error Δ_A is determined, using specially designed tables and the total error of measurement method for specific measurement instruments Δ_Σ (Sergeev, 2008; RD50-98-86, 1987).

The criterion for selection of certain measurement instrument is:

$$\Delta_\Sigma \leq \Delta_A \quad (1)$$

The advantages of this method are that it is easy to use, fast and convenient for application and does not require high qualification of operators (it needs not to make calculations and studies). As disadvantage, one may indicate that guidelines and standards, which help to be performed, have not been updated and processed many years and they may only be used for measuring linear dimensions.

2.2 Uncertainty measurement analysis

The uncertainty of measurement is absolute parameter, connected with the result of measurement which characterized the results dispersion.

They may be assigned to the measurement value based on the available information.

The uncertainty of measurement contains many components visible by the mathematical measurement model. The methods of determining the uncertainty are given in Guide to the Expression of Uncertainty in Measurement - GUM and ISO 14253-2:2013 (Guide, 1993; ISO 14253,2013). Determining the uncertainty according to GUM is theoretically and practically inapplicable in production. In fact, the Procedure for Uncertainty Management (PUMA) takes generic usage in ISO/TS 14253-2:2013, which is one very practical iterative method for assessment and presentation of measurement uncertainty, according to the conception and the methods shown in GUM.

This method is specific to the geometrical measurements, but it may be used in other spheres of the applied metrology, especially in metrological assurance in the quality systems using ISO 9000, ISO 17025:2000, where assessment of uncertainty of measurement is required.

Figure 4 (Guide, 1993) presents sequence of determining the uncertainty and the acceptance criteria of certain measurement instrument for solving certain metrological task.

The requirement for selection of measurement instrument is: $U_{EN} \leq U_T$, where:

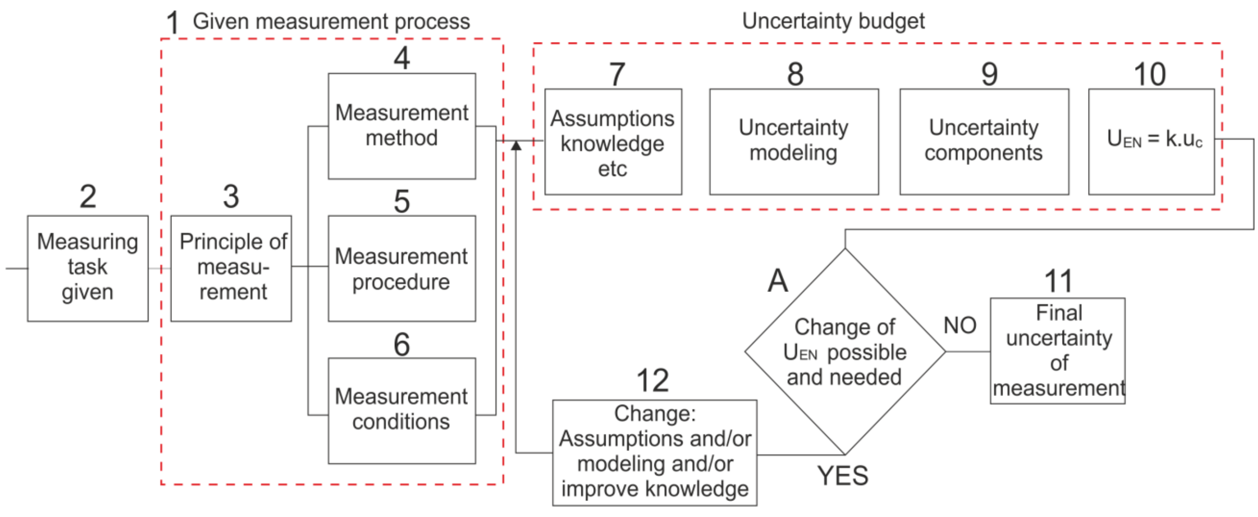

Figure 4. Uncertainty management for a result of measurement from a given measurement process

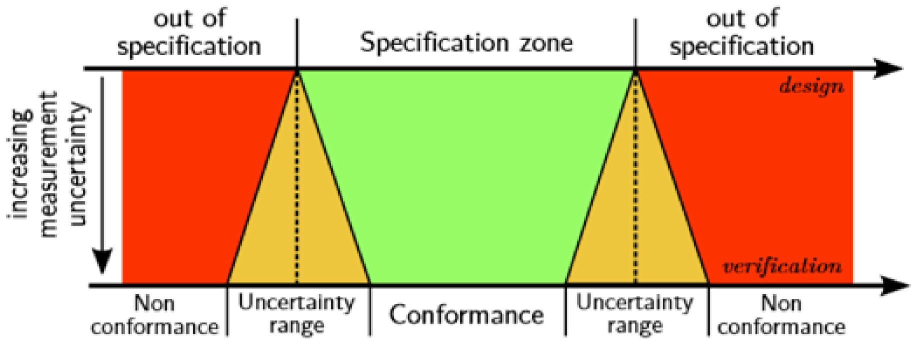

Figure 5. Influence of increasing measurement uncertainty on (non-) conformance zone, ISO 14253-1 (ISO 14253-1, 2013)

U_{EN} – approximated uncertainty of measurement;

U_T – target uncertainty.

The target uncertainty is determined by the following equation:

$$U_T = \frac{T}{C_m} \tag{2}$$

For the different industry sectors, the C_m values are accepted from 3 to 10. As a result, the target uncertainty may be set within wide limits.

The advantages of this method are that it may be applied in measuring of all physical quantities and it may include all known components of uncertainty. The disadvantages are related to necessity of highly skilled operators, labor intensity and absence of specific instructions to determine the target uncertainty.

2.3 Measurement process analysis

The analysis of measurement process capabilities includes special tests in real manufacturing conditions. At this analysis, large part of the actually changing conditions are reported. In the literature, several methods are given for assessing the capabilities of measuring instruments at a predetermined tolerance for manufacturing (Measurement, 1995; General Motors, 1998; Dietrich, 2002).

The main application of these methods is at the Automotive Industry, but they may be used in each other branch, which have to improve the measurement process. For assess the capabilities of measurement instruments, several methods are used:

2.3.1 Assessment of the measurement instruments capability index C_g and C_{gk}

2.3.2 Determining the common precision R&R, which includes the Repeatability (Reliability/ Equipment Variation - EV) and the Reproducibility (Appraiser Variation - AV) of measurement instruments;

2.3.3 Determining the common precision R&R by dispersion analysis (ANOVA method).

Among all the methods mentioned in this paper, common precision method (R&R) and ANOVA method are the most widespread and significant.

Although any of the methods includes information about the reasons for the variation, the ANOVA method has wider application.

The advantage of the method is the possibility of application for universal measuring instruments and for complex measuring systems – for measuring various physical quantities. Disadvantages of this method are the labor intensity, the need of highly skilled operators and software for assessment the capabilities of measurement instruments.

2.4 Method of economic efficiency

In selecting the measuring instruments, the technical and economic indices of measurement process should be accounted. This requires the establishment of dependences between measurement accuracy and manufacturing accuracy, which aims minimum labor costs and measuring instruments. For this purpose, it is necessary to assess the impact of the measurement uncertainty onto errors of assessing product suitability.

These errors are respectively the number of correctly received unsuitable products and incorrect rejected edible products, whose characteristics fall within the zone of uncertainty (Fig. 5).

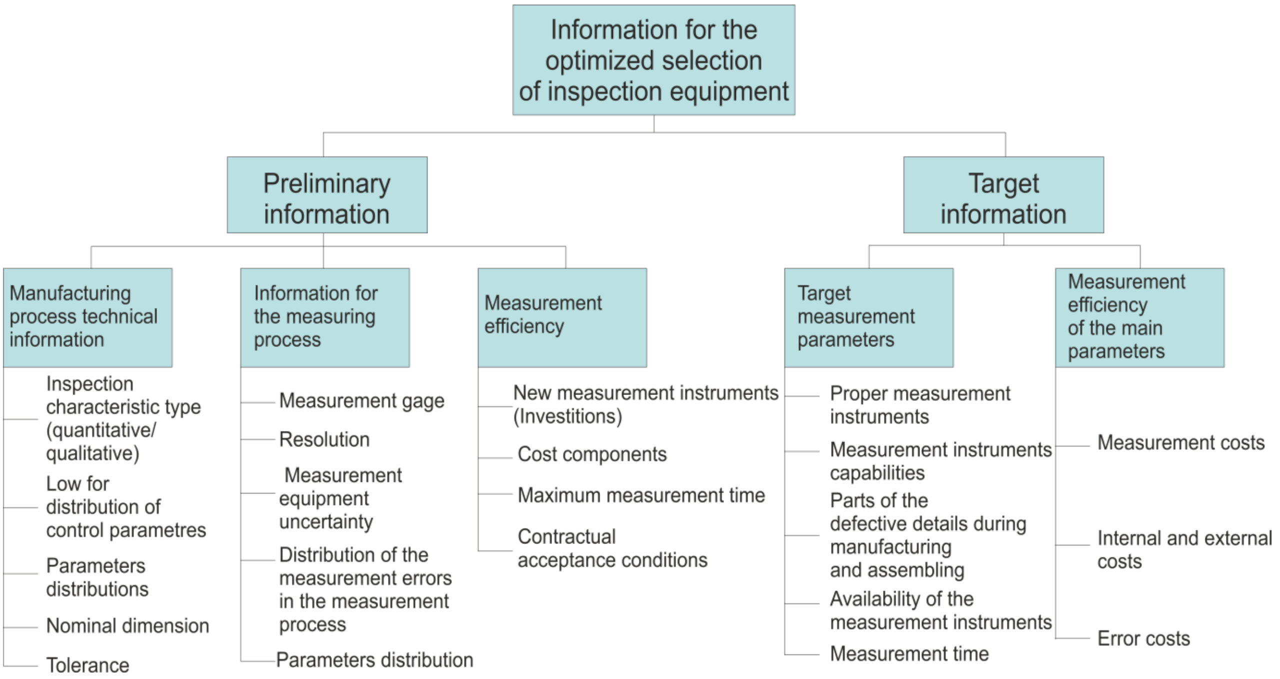

Figure 6. Optimization of selection the measurement instruments

The advantage of this method is that it reports for the effectiveness and efficiency of the measuring process. The disadvantage is the need of information about distribution lows of inspection characteristics, measuring errors and preliminary assessment of the probability of correctly received and incorrect rejected products.

After selecting the measuring instruments by the methods above described, an optimization of the selection by the criteria shown in Figure 6 should be made (Zinner, 2006).

Table 1. Advantages and disadvantages of methods for selection of measurement instruments

Method	Advantages	Disadvantages
Selection of Measurement Instruments Depending on the Production Accuracy of Details	• easy to use; • fast and convenient for application; • does not required high qualification of operators (it is not need to make calculations and studies).	• guidelines and standards, which helps to performed, have not been updated and processed many years and they can only be used for measuring linear dimensions.
Uncertainty Measurement Analysis	• may be applied in measuring of all phisical quantities; • may be included all known components of uncertainty.	• a labor intensity; • need for highly skilled operators; • absence of specific instructions to determine the target uncertainty.
Measurement Process Analysis	• may be applied for universal measuring instruments and for complex measuring systems – for measuring various physical quantities.	• labor intensity; • need for highly skilled operators and software for assessment the capabilities of measurement instruments.
Method of Economic Efficiency	• reported on the effectiveness and efficiency of the measuring process.	• an information is required about distribution lows of inspection characteristics, measuring errors and preliminary assessment of the probability of correctly received and incorrect rejected products.

This requires developing a methodology for optimizing the selection of measurement instruments.

In Table 1, advantages and disadvantages of reviewed methods are given.

3. CONCLUDING REMARKS

In this paper an overview of the existing methods for selecting a measurement instrument is made and the advantages and disadvantages are shown. The comparison of the selection methods shows that the greatest requirements linked to the accuracy of the measurement instruments are visible in the application of the methods for analysis of measurement process capabilities and lower requirements – by using the acceptable measuring error depending on the tolerance.

It is necessary to create a complex methodology for selection of measurement instruments which account the type of the inspection, the accuracy requirements and efficiency of measurement process.

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6. NOTATION

The following symbols are used in this paper:

MSA – Measurement System Analysis;

IT - Tolerance zone;

Δ_A - Acceptable measurement error;

Δ_Σ - Total error of measurement method;

U_{EN} – Approximated uncertainty of measurement;

U_T – Target uncertainty;

T – Tolerance;

GUM - Guide to the Expression of Uncertainty in Measurement;

ANOVA – Analysis of Variance;

C_g - Gage potential index;

C_{gk} - Gage capability index;

EV – Equipment variation;

AV – Appraiser variation;

R&R – Repeatability and reproducibility.