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Guidelines for implementation of statistical process control (SPC) —

Part 4: Reference data sets for measurement process analysis software validation

Lignes directrices pour la mise en œuvre de la maîtrise statistique des processus (MSP) —

Partie 4: Jeu de données pour la validation des logiciels d'analyse de processus de mesure

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Foreword

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This document was prepared by Technical Committee ISO/TC 69, *Applications of statistical methods*, Subcommittee SC 4, *Applications of statistical methods in product and process management*.

A list of all parts in the ISO 11462 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The test examples were developed for the assessment of systems performing a measurement system analysis (MSA). They allow MSA software developers to evaluate their systems. Thus, the end user of those systems can be sure that the data sets are evaluated correctly with a high level of reliability. In order to cover as wide a spectrum as possible, suitable data sets were prepared individually for various constellations. The evaluation results of those data sets are documented and commented on the following pages.

The results were verified multiple times using different computer programs. This turns the data sets and the results into references for validation of the software. The data sets are listed in the related clauses of this document or can be accessed via https://standards.iso.org/iso/tr/11462/-4/ed-1/en.

Guidelines for implementation of statistical process control (SPC) —

Part 4: Reference data sets for measurement process analysis software validation

1 Scope

This document describes examples for software validation for software implementing the standards of ISO 22514-7 on the capability of measurement processes. In detail, the following standards are covered:

— ISO 22514-7.

It provides data sets and test results for testing the implementation of the evaluation methods described in these standards. This includes:

a) the calculation of standard uncertainties from other sources (other than experiments – type B – ISO/IEC Guide 98-3);

b) the estimation of uncertainty components using repeated measurements on reference parts;

c) the estimation of uncertainty components using repeated measurements on multiple parts with different operators and their evaluation using the ANOVA method;

d) the combination of uncertainty components using the Gaussian law of uncertainty propagation;

e) the calculation of measurement process capability indices;

f) the influence of operators on attributive measurements;

g) the uncertainty range and capability indices for attributive measurements.

The test examples are intended to cover the calculation of the measuring system capability and measurement process capability according to ISO 22514-7.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 22514-2, *Statistical methods in process management — Capability and performance — Part 2: Process capability and performance of time-dependent process models*

3 Terms and definitions, and symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 22514-2 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.2 Symbols and abbreviated terms

Symbols used in this standard are identical to symbols used in ISO 22514-7.

a	half width of a distribution of possible values of input quantity
a_{OBJ}	maximal form deviation
α	significance level
B_i	bias
C_{attr}	capability index for attributive measurement
C_{MP}	measurement process capability index
C_{MS}	measuring system capability index
d	average interval
d_{LR}	interval from the last reference value, for which all operators have assessed the result as unsatisfied to the first reference value, for which all operators have the result as approved
d_{UR}	interval from the last reference value, for which all operators have assessed the result as approved to the first reference value, for which all operators have the result as unsatisfied
e_{nj}	residuals
K	number of repeatability measurements
k	coverage factor
k_{CAL}	coverage factor from the calibration certificate
L	lower specification limit
l	measured length
M	the number of subgroups
M_{PE}	maximum permissible error (of the measuring system) (MPE-value)
m_{ij}	frequencies in Bowker-test
N	number of standards
n	sample size of each subgroup
Q_{attr}	attributive measurement process capability ratio
Q_{MP}	measurement process capability ratio
Q_{MS}	measuring system capability ratio
Q_{MS_max}	capability ratio limit for measuring system

Q_{MP_max}	capability ratio limit for measurement process
R_E	resolution of measuring system
$\hat{\sigma}$	sample standard deviation
T	temperature
U	upper specification limit
U_{CAL}	uncertainty on the calibration of standards
u_{α}	standard uncertainty on the coefficient of expansion
u_{AV}	standard uncertainty from the operator´s repeatability
u_{BI}	standard uncertainty from the measurement bias
u_{CAL}	calibration standard uncertainty on a standard
u_{EV}	standard uncertainty from maximum value of repeatability or resolution
u_{EVR}	standard uncertainty from repeatability on standards
u_{EVO}	standard uncertainty from repeatability on test parts
u_{GV}	standard uncertainty from reproducibility of the measuring system
u_{IAi}	standard uncertainty from interactions
u_{LIN}	standard uncertainty from linearity of the measuring system
u_{MPE}	standard uncertainty calculated based on maximum permissible error
$u_{MS\text{-}REST}$	combined standard uncertainty from other influence components not included in the analysis of the measuring system
u_{OBJ}	standard uncertainty from test part inhomogeneity
u_{RE}	standard uncertainty from resolution of measuring system
u_{REST}	standard uncertainty from other influence components not included in the analysis of the measurement process
u_{STAB}	standard uncertainty from the stability of measuring system
u_T	standard uncertainty from temperature
u_{TA}	standard uncertainty from temperature expansion coefficients
u_{TD}	standard uncertainty from temperature difference between workpiece and measuring system
U_{attr}	expanded measurement uncertainty on an attributive measurement
u_{attr}	combined standard uncertainty of attributive measuring
U_{MS}	expanded measurement uncertainty of the measuring system
u_{MS}	combined standard uncertainty on measuring system
U_{MP}	expanded measurement uncertainty of the measurement process

u_{MP} combined standard uncertainty on measurement process

u_{MX} standard uncertainty from effect of spindle clamping

u_{RA} standard uncertainty from resolution

u_{RE} standard uncertainty from repeatability

x_i i^{th} reference quantity value

x_{mU} reference quantity value of the standard (master) at the upper specification limit

x_{mm} reference quantity value of the standard (master) in the centre of the specification

x_{mL} reference quantity value of the standard (master) at the lower specification limit

$\bar{x}$ arithmetic mean of the conventional true values

y_j j^{th} measurement value

$\bar{y}$ arithmetic mean of the measured values

3.3 Abbreviated terms

ANOVA analysis of variance

MSA measurement systems analysis

MPE maximum permissible error

4 Overview of the test examples

4.1 Overview

For an overview of the test examples see Table 1.

Table 1 — List of the test data sets

Test data set number	Sub-clause	Characteristics type	Decimal points	Description of data set	Source/ Reference
1	5.1	Variable	2	All uncertainty components mentioned in the 22514-7 are covered. Combination of type A and type B evaluation, including Linearity and GRR studies	ISO 22514-7 + additions
2	5.2	Attributive	---	Test on influence of operators based on experimental data	ISO 22514-7
3	5.3	Attributive	--- (6)	Calculation of uncertainty range and capability of the attributive measurement process based on experimental data	ISO 22514-7
4	5.4	Variable	4	Measurement process capability with three reference standards Linearity study, GRR with ANOVA Multiple uncertainty components: resolution, calibration, repeatability, linearity, bias, operators, part-interaction	VDA 5

Table 1 *(continued)*

Test data set number	Sub-clause	Character-istics type	Decimal points	Description of data set	Source/ Refer-ence
5	5.5	Variable	4	Measurement process capability of a CMM Repeatability and bias with one standard Multiple uncertainty components: resolu-tion, calibration, repeatability, linearity, bias, temperature	VDA 5 and ISO 15530-3
6	5.6	Variable	4	Measurement process capability of automat-ed test device Multiple measurements on one standards and 10 parts Multiple uncertainty components: resolu-tion, calibration, repeatability, linearity, bias, MPE(gauge)	VDA 5
7	5.7	Variable	4	Measurement process capability of a multi-ple-point measuring instrument GRR with ANOVA Multiple uncertainty components: resolution, calibration, repeatability, linearity, bias, MPE (sensor), reproducibility, part-interaction, temperature, error of temperature compen-sation	VDA 5

4.2 Notes

4.2.1 Notes on the accuracy of the test examples and results

Capability indices are always given with two digits (rounded).

4.2.2 Note on outlier detection

Each test data set was tested for outliers using Grubbs' test for outliers (according to ISO 5725-2) with a level of significance of 1 % and no outliers were detected.

4.2.3 Note on capability indices

There are various different capability indices given in the relevant different standards and guidelines. All are based on the ratio of the specification interval and the measurement uncertainty. Only the expansion factors and limit values vary. In this standard only the capability indices according to ISO 22514-7 are used.

4.2.4 Note on the model of the measurement and correlations

Although ISO/IEC Guide 98-3 provides the possibility of including non-linear models and correlations between input quantities, correlations and non-linearities are not covered by the ISO 22514-7. Therefore, only a linear model with sensitivity coefficients of one for every input quantity as well as no correlations are considered in this standard and its examples.

4.2.5 Note on other reference data sets

ISO/TR 12888 provides multiple examples especially for the case of GRR studies[1].

4.2.6 Note on systematic errors

According to ISO/IEC Guide 98-3 any systematic error is compensated and the uncertainty of the systematic error is included into the measurement budget and is part of the combined uncertainty.

5 Reference data sets description and evaluation

5.1 Test data set 1 – example of linearity study with at least three standards

5.1.1 Test data set 1 – information

Test data set for ISO 22514-7 capability of measurement processes with a linearity and ANOVA study.

This example has been taken from ISO 22514-7:2021, Annex A (the data originally come from ISO 11095). The uncertainties arising from the object and the temperature were added.

5.1.2 Test data set 1 – data, calculations and results

5.1.2.1 Calculation of the measuring system capability

5.1.2.1.1 Components of type B which are not taken into account by experiments

Resolution

The uncertainty component caused by resolution is $u_{RE} = 0{,}001\,44\,\mu m$.

The uncertainty component u_{RE} is much smaller than u_{EVR}, see behind Table 4. Therefore, the component u_{RE} is not used.

Object

The maximum expected error due to the clamping of the part during the measurement is $a_{OBJ} = 0{,}001\,5\ \mu m$.

The uncertainty component is therefore:

$$u_{OBJ} = \frac{a_{OBJ}}{\sqrt{3}} = 0{,}000\,866\,\mu m$$

Calibration

It is assumed according to the calibration certificate that the calibration uncertainty u_{CAL} is 0,005 µm.

5.1.2.1.2 Components of Type A which are derived from a linearity study with at least 3 standards

An experiment is carried out on an imaging system (an optical microscope with a measuring device). The data listed in Table 2 are measured values and true values of intervals in the range of 0,5 µm to 12 µm.

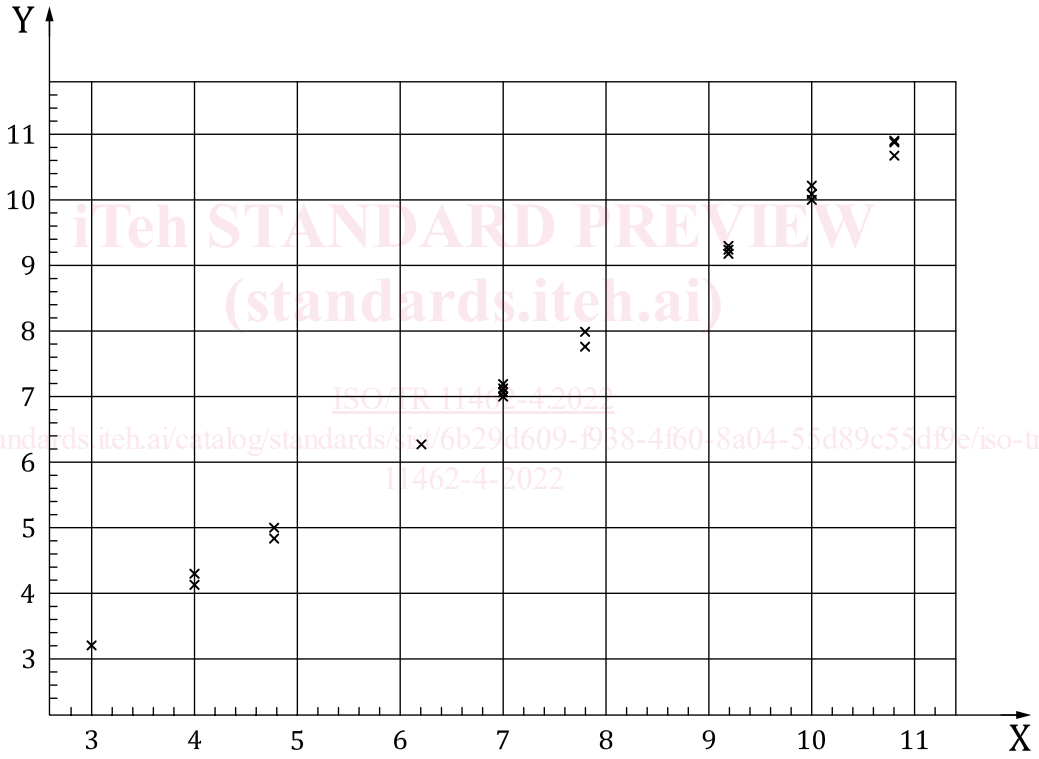
Table 2 — Values from repeated measurements on reference materials

Conventional true values x_n of the 10 reference materials	Values y_{nj} from $K = 4$ repeatability measurements on $N = 10$ reference materials			
	y_{n1}	y_{n2}	y_{n3}	y_{n4}
6,19	6,31	6,27	6,31	6,28
9,17	9,27	9,21	9,34	9,23

Table 2 *(continued)*

Conventional true values x_n of the 10 reference materials	Values y_{nj} from $K = 4$ repeatability measurements on $N = 10$ reference materials			
	y_{n1}	y_{n2}	y_{n3}	y_{n4}
1,99	2,21	2,19	2,22	2,20
7,77	8,00	7,81	7,95	7,84
4,00	4,27	4,15	4,15	4,15
10,77	10,93	10,73	10,92	10,89
4,78	4,95	4,87	5,00	5,00
2,99	3,24	3,17	3,21	3,21
6,98	7,14	7,07	7,18	7,20
9,98	10,23	10,02	10,07	10,17

Data in Table 2 are plotted in Figure 1.



Key

X reference value (µm)

Y measured value (µm)

Figure 1 — Plot of measured and true values

5.1.2.1.3 *Calculation of means and residuals*

For each reference material the mean value $\bar{y}_n$, the bias $B_{i,n}$ and the residuals e_{n1} to e_{n4} are calculated.

See Table 3 for the calculated values.