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Statistične metode za obvladovanje procesov - Sposobnost in delovanje - 6. del: Statistike procesne sposobnosti karakteristik, porazdeljenih po multivariatni normalni porazdelitvi

Statistical methods in process management - Capability and performance - Part 6: Process capability statistics for characteristics following a multivariate normal distribution

Méthodes statistiques dans la gestion de processus - Aptitude et performance - Partie 6: Statistiques de capacité opérationnelle d'un processus pour les caractéristiques qui suivent une distribution normale à plusieurs variables

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Statistical methods in process management — Capability and performance —

Part 6:

Process capability statistics for characteristics following a multivariate normal distribution

Méthodes statistiques dans la gestion de processus — Aptitude et performance —

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Foreword

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ISO 22514-6 was prepared by Technical Committee ISO/TC 69, *Applications of statistical methods*, SC 4, *Applications of statistical methods in process management.*

Introduction

Due to the increased complexity of the production methods and the increasing quality requirements for products and processes, a process analysis based on univariate characteristics is in many cases not sufficient.

Instead it may be necessary to analyse the process on the basis of multivariate product characteristics. This can for instance be in cases where geometric tolerances, dynamic magnitudes as unbalance, correlated characteristics of materials or other procedural products are observed.

By analogy with ISO 22514-2, this standard provides calculation formulae for process performance and process capability indices, which take into consideration process dispersion as well as process location as extension to the corresponding indices for univariate characteristics. The indices proposed are indeed based on the classical C_p and C_{pk} indices for the one-dimensional case. The motivation for the extension to the multivariate case is explained in Annex A.

Examples of possible applications are two-dimensional or three-dimensional positions, unbalance or several correlated characteristics of chemical products.

The dispersion of the measuring results is composed by the dispersion of the product realization process and the precision of the measuring process. It is assumed that the capability of the used measuring system was demonstrated prior to the determination of the capability of the product realization process.

This standard is applicable if the distribution of the values for the observed product characteristics by means of the parameters of their distribution model are analysed and evaluated in relation to specified values.

The calculation method described here should be used to support an unambiguous decision, especially if

- limiting values for process capability indices for multivariate, continuous product characteristics are specified as part of a contract between customers and suppliers, or
- the capabilities of different constructions, production methods or suppliers are to be compared, or
- production processes are to be approved, or
- problems are to be analysed and decisions are made in cases of complaints or damage events.

NOTE: Product realization processes include e.g. manufacturing processes, service processes, product assembly processes.

Statistical methods in process management — Capability and performance —

Part 6:

Process capability statistics for characteristics following a multivariate normal distribution

1 Scope

This International Standard provides methods for calculating performance and capability statistics for process or product characteristics that follow a multivariate normal distribution.

NOTE In principle this International Standard can be used for bivariate up to d variate cases.

2 Normative Reference

The following referenced documents are indispensable for the application 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 1101, *Geometrical Product Specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*

3 Terms and Definitions

For the purpose of this document, the terms and definitions given in ISO 9000 and ISO 22514-1 and the following apply.

3.1
process capability estimate
statistical estimate of the outcome of a characteristic from a process which has been demonstrated to be in a state of statistical control and which describes that ability of the process to realise a characteristic that will fulfil the requirements for that characteristic

[ISO 22514-1 3.3.3]

3.2
characteristic
distinguishing feature

[ISO 9000:2005, definition 3.5.1]

NOTE 1 A characteristic can be inherent or assigned.

NOTE 2 A characteristic can be nominal, ordinal, differential or rational.

NOTE 3 There are various classes of characteristic, such as the following:

— physical (e. g. mechanical, electrical, chemical or biological characteristics);

— sensory (e. g. related to smell, touch, taste, sight, hearing);

— behavioral (e. g. courtesy, honesty, veracity);

— temporal (e. g. punctuality, reliability, availability);

— ergonomic (e.g. physiological characteristic, or related to human safety);

— functional (e. g. maximum speed of an aircraft).

EXAMPLE In the multivariate case of dimension *k* characteristics are given by a k-tuple, i.e. an ordered set consisting of *k* elements. For *k* = 3 an example is (colour, mass, number of defects).

3.3
tolerance zone
space limited by one or several geometrically perfect lines or surfaces, and characterized by a linear dimension, called a tolerance

[ISO 1101 2004]

NOTE 1 In the univariate case the tolerance zone is an interval.

NOTE 2 In the bi-variate case, the tolerance zone is a tolerance ellipse or alternatively a tolerance circle (when the tolerance zone for the both univariate characteristics has the same size.).

NOTE 3 In the tri-variate case, the tolerance zone corresponds to a tolerance ellipsoid or alternatively a tolerance sphere (when the tolerance zone for the three components have the same size).

3.4
process capability
statistical estimate of the outcome of a characteristic from a process which has been demonstrated to be in a state of statistical control and which describes that process's ability to realize a characteristic that will fulfill the requirements for that characteristic

[ISO 3534-2: 2006 2.7.1]

3.5
process performance
statistical measure of the outcome of a characteristic from a process, which may not have been demonstrated to be in a state of statistical control.

[ISO 3534-2: 2006 2.6.1]

4 Process analysis

The purpose of process analysis is to obtain sound knowledge of a process. This knowledge is necessary for controlling the process efficiently so that the products realized by the process fulfil the quality requirement.

A process analysis is always an analysis of one or more characteristics that are considered to be important to the process.

Product characteristics can often be analysed instead of process characteristics because product characteristics not only characterise the products, but due to their correlation with process characteristics they also characterise the process creating these products.

The values of the characteristics under consideration are typically determined on the basis of samples taken from the process flow. The sample size and frequency should be chosen depending on the type of process and the type of product so that all important changes are detected in time. The samples should be representative for the multivariate characteristic under consideration, whereas univariate characteristic values are considered in ISO 22514-2. This standard describes multivariate capability statistics.

5 Calculation of process capability and performance

The term “multivariate” may refer to dimensions in space, for example the coordinate measuring technique, as well as measuring technique for multivariate variables (e.g. unbalance of a wheel).

For practical reasons, the model for multivariate normal distribution has been chosen for the calculation of the statistics which are described in this clause. However, the choice of normal distribution does not exclude that in special cases other model distributions will describe the reality better. Also, for practical reasons, in this standard the process variation intervals have been chosen as ellipsoids.

The most important properties of the multivariate normal distribution are explained in annex A.

The term capability can only be used for processes that have been demonstrated to be in control using control charts. In the multivariate case the distinction between special and common causes is usually more difficult than in the univariate case. If the process has not been demonstrated to be in control we use the term performance in this standard.

5.1 Process capability index

Consider a d-dimensional normal distribution with covariance matrix $\boldsymbol{\Sigma}$. In order to calculate the multivariate C_p index the normal distribution must be centred to have mean at the centre of the tolerance zone. For that normal distribution determine the largest contour ellipsoid that is completely contained in the tolerance zone and calculate the probability of the volume bounded by that contour ellipse under the d-dimensional normal distribution with covariance matrix $\boldsymbol{\Sigma}$ and mean at the centre of the tolerance zone. Denote that probability by P. Then the multivariate C_p index is

$$C_{\mathrm{p}} = \frac{1}{3}\Phi^{-1}\left(\frac{P+1}{2}\right)$$

In order to estimate a C_p index from d-dimensional data start by estimating the covariance matrix of the multivariate normal distribution from the data. Denote the estimate by $\hat{\boldsymbol{\Sigma}}$ and use that covariance matrix to determine the contour ellipsoid and its probability $\hat{P}$. Finally the estimated multivariate C_p index is

$$\hat{C}_{\mathrm{p}} = \frac{1}{3}\Phi^{-1}\left(\frac{\hat{P}+1}{2}\right)$$