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Measurement system analysis using designed experiments with minimum α–β Risks and n

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Abstract

Quality and productivity improvement are most effective when they are an integral part of the product and process development cycle. The main object of this study is re-identifying the variability sources that lead to errors in the measurements made for the correct evaluation of whether the targeted quality standards are reached in quality assurance systems, as well as at re-establishing a model with designed experiments, by virtue of including laboratory factor as a measurement variability factor into the Measurement System Analysis (MSA) studies, whereby it is currently ignored. The measurement systems that need to be examined and kept under control, in order to set the extent to which the products meet the customers requirements and expectations, have been analyzed statistically.

Besides, new producer (α)–consumer (β) risks and the required minimum sample size (n) for its design will also be identified. As for the business organization chosen for the application of the model, a new determined sample size with α, β error probabilities has been identified as a result of the applications with the new model.

Keywords: MSA; Repeatability; Reproducibility; Measurement errors; Stability; Bias; Linearity; Residual; Random factor; Experimental design; Variance components; Analysis of variance (ANOVA); Producer–consumer risks and sample size

1. Introduction

As today's favorite approach, "Zero-error" in quality, can be achieved only through efforts towards identifying the reasons of errors and preventing their occurrence by applying quality control and quality assurance systems.

QS-9000 quality standard, whose primary aims are continual improvement, error prevention, minimization of extravagance and variabilities, and improvement of quality systems, is, in addition to ISO-9000 quality assurance conditions, a new quality assurance system that aims at perfection and zero-error. MSA, one of the reference fields of QS-9000, is a statistical approach used in the accuracy and sensitivity estimations made for a measurement device [1]. In establishing a quality system, MSA vested with the necessary assumptions should be applied perfectly since it is essential to be accurate in each measurement and evaluation [2].

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2. Measurement system analysis (MSA)

In quality assurance systems, design and appropriateness qualities gain their significance only after measurement activities. The quality of measurement data depends on the statistical properties of multiple measurements that are obtained through a measurement system operating under fixed conditions. However, it is possible to directly determine the variability of the measured quality characteristic against the real value only if measuring devices as well as real persons to operate them have no errors [3].

MSA is divided into two types of analyses: those made for quantitative and qualitative measurement data and those made with test materials. Moreover, the same characteristic of the product should be measured repeatedly in order to determine the sensitivity of the measurement process [4].

It is quite obvious that the main aim of a measurement system would be to minimize measurement errors. Therefore, it is crucial to identify the deviation sources that could affect the results produced by the system as well as to ensure that the number of the measurements is adequate enough both for deviation and for sensitivity [5].

Some of the most essential basic concepts used in the identification of the variance of the measurement system are stability, bias, linearity, repeatability and reproducibility. It is an important problem to identify the main factors that could affect the stability of the measurement system, yet it can be resolved by designed experiments [6].

2.1. Measures of variability

A designed experiment is test or series of tests in which purposeful changes are made to the input variables so that we may observe and identify corresponding chances in the output response. In a characterization experiment, we usually interested in determining which process factors affect the response. Generally, there are two basic factors, both independent from each other, which effect the variability of measurements method [7]. These factors are:

(a) Failure of the device in repeating itself.
(b) Failure of a measurer in reproducing his/her measurement method In such case, the variance of the measurement value would be

$$\sigma^2_{\text{measured value}} = \sigma^2_{\text{real value}} + \sigma^2_{\text{measurement error}}$$

Here

$$\sigma^2_{\text{measurement error}} = \sigma^2_{\text{repeatability}} + \sigma^2_{\text{reproducibility}} \quad (1)$$

Grubbs [8], in the methods that he suggested in order to distinguish product variance from device variance, carried out his studies with two or more measurement devices. He suggested a method for estimating the sensitivity of the measurement device, whereby two or more measurement devices are used for measuring the same pieces [9]. This method is a model where two or more measurement devices are used for measuring each piece, and thereby generalizing under the same conditions and assumptions [10]. This model of Grubbs [11] allows us to compare data obtained through two or more measurement devices [12].

Thus, repeatability is the variance of the measurements obtained while measuring the characteristic of a measurement device, while reproducibility is the variance of the medium of the measurements obtained by different measurers in measuring the same characteristic of the same piece with the same measuring device. In other words, it is the consistency of the measurement method in the variability structure. Thus, the sensitivity of the measurement method would also be the reproducibility thereof [3].

3. Experimental design for process and analysis

Designed experiments are a powerful approach to improving a process. In order to use this approach, it is necessary that everyone involved in the experiment have a clear idea in advance of the objective of the experiment, exactly what factors are to be studied, how the experiment is to be conducted, and at least a qualitative understanding of how the data will be analyzed [13]. Designed experiments can often be applied in the product design process. In measurement systems, the designed experiments is used in order to determine