TAGUCHI´S APPROACH TO QUALITY ENGINEERING

TAGUCHIHO PRÍSTUP K INZINIERSTVU KVALITY

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1 INTRODUCTION

Genichi Taguchi is Japanese engineer and a statistician, whose approaches to statistical quality control started to spread intensively in Europe of the 80´s. The basic idea of his work is that the reduction of variation is the main means of quality improvement.

According to G. Taguchi, the programme of continuous quality improvement consists in the reduction of variation of performance characteristics of a product (performance characteristics of a product are quality measures which determine the performance of a product from viewpoint of the rate of satisfaction of the user's requests).

In the reduction of variation of performance characteristics and quality measures is a very useful tool the design of experiments. Let us look at the possibilities of using Taguchi's signal-to-noise ratio.

2 THE EXPERIMENTS TO MEASURE LOCATION AND DISPERSION EFFECTS

When one experimental run (in one run there is the same combination of the levels of a factor) is repeated more than once, we can calculate a value of the chosen measure of location of output (quality measure) y and chosen measure of dispersion.

We can describe typical experiment for the measurement of effects of the factors on the location of the output and on its variation like this. Let us consider m various runs (combinations of the levels of the factors). Let repeat every run n times (e.g. n units are produced). Let us consider as the measure of location an arithmetic average $\bar{y}$ and as the measure of dispersion the standard deviation s. We calculate the standard deviation on the basis of the obtained outputs. We usually can identify factors, which have a very important influence on the location and (or) on the variation of output.

We can use these factors for the reduction of variation of output and for such process adjustment so that the distribution of output is centred in the best possible way.

3 THE OUTPUT TRANSFORMATION AND SIGNAL-TO-NOISE RATIO

The output transformation is understood as the change of the originally used scale of measurement of the value of output or a change of the originally metric. One of the very often used transformations is the logarithmic transformation. It is a non-linear transformation, in which their logarithms are concerned instead of the original information. We consider e.g. a transformation by decadic logarithms. Instead of the original variable y we get a new variable $z = \log y$.

This transformation can help us distinguish the effects of a factor on the location of the output from their effects on the variation of the output. Sometimes these effects on variation in the original scale of measurement can be masked because of the link between the location and dispersion on the original scale. So the transformation can help to find them.

A logaritmic transformation can be an effective tool for increasing the ability to distinguish the effects in the case, when increases in the mean produce proportionale increases in dispersion. For finding a possible link it is very useful to use a diagram, in which on the axis x there are values of $\log \bar{y}$, and on the axis y values of $\log s$. When a diagram indicates a direct linear relation we cannot discount its real existence and a logarithmic transformation is useful.

Inverse relationships between location and dispersion are rare in a practice. In general, two points are worth bearing in mind:

1. A transformation may be useful despite the lack of an apparent pattern in a log-log plot.
2. We must be very careful by deciding about transformation. Sometimes, a non–transformed information can obtain for us a very good ability to distinguish the effects and a transformation could make it worse.

It seems that G. Taguchi must have met with the problem of a lack of separability in his practice so he offered a method of analysis based on the signal-to-noise ratio, which is calculated for every run. Each signal-to-noise ratio is a function of the n response values derived from one run of the experiment. Such a run (or runs) is searched which maximises the signal-to-noise ratio.

G. Taguchi considers different types of signal-to-noise ratio, in dependence of the character of the quality measure. Here are the basic types:

1. The quality measure such that we wish to minimise it (smaller-the-better)

2. The quality measure such that we wish to maximise it (larger-the-better)

3. The target value T of the quality measure is a finite number different from zero (nominal is best)

In the process of search for an optimal run or runs it is possible to apply a two-stage algorithm of optimisation, which was suggested by G. Taguchi:

1. From all runs, which are considered in a experiment, we can choose those, which contain such a combination of the levels of the factors influencing only variation, which maximises the signal-to-noise ratio.
2. From all runs, which we obtained like results of optimisation in the first stage, we can choose those, which contain such a combination of the levels of the adjustment factors (factors influencing only location), which minimise the deviation of the estimate of the expected value of quality measure from the target value. The chosen runs are optimal.

4 PARAMETER DESIGN

Generally, in the stage of the reduction of variation of the performance characteristic it is possible to search for controllable variables and try to find such a combination of their levels that the variability of performance characteristic is small, despite of the variability of the explaining variables e.g. input materials etc., despite of the variability proper to the production process itself.

G. Taguchi enlarges this approach by incorporation of the surroundings variability in which the product is going to be used, into the formal analysis.

The term noise according to G. Taguchi expresses every cause of variability of performance characteristic in a user’s hands regardless to whether its origin is in the production process, in the way of using the product by the users, or in the influence of the environment.

As robust we understand every product or process, which works well (the variability of its performance characteristics is small) in conditions of present noise.

A suitable tool for obtaining a robust product or process project is the design of experiments. According (1) we will consider 2 types of factors in the design of experiments:

1. Control factors - which the engineer has under his control in the real world of production and use, not only by experimenting.
2. Noise factors - their levels can be chosen at least approximately in an experiment but not in the real world.

G. Taguchi projected a way of the experimentation simultaneously with control and noise factors by help of the formulation of the so called inner and outer arrays.

Obviously $\bar{y}$ measures the location, s measures the effect of the noise or robustness. The higher the effect of the noise is, the smaller is robustness. The next process is similar to previous one:

1. From all runs which are considered in the experiment, we choose those, which contain such a combination of the levels of the factors which influences only robustness, which minimises *s.*
2. From all runs obtained as a result of optimisation in the first stage, we choose those, which contain such an adjustment factor level combination, which minimises the deviation of the estimate of the expected value of the quality measure from the target value. The chosen runs are optimal.

5 ENGINEERING STRATEGY

In general G. Taguchi divides engineering into 3 constituent parts:

System design: It is about the selection of technology, which is suitable to achieve desirable product functions. This stage can be financially very demanding, because it can require research to obtain a new or improved technology.

Parameter design: It is about the selection of parameters for the technology, which we found in the first stage. In this stage we usually experiment with the less expensive components. It does not depend on, if the variability of their characteristics is high. Also in this case we can find such a combination of the levels of the factors which secures the robustness of the studied performance characteristics. In this stage the tolerances can be as wide as possible.

Tolerance design: It is about a possible narrowing of the tolerances caused by a contingent selection of components and materials of greater quality so that we can obtain a high – quality robust system as a whole. In this stage information from the previous stage is used for the selection of suitable materials and components as well. The elements with the biggest influence on robustness are " the hottest candidates ". The corresponding costs of their using are studied as well.

From these three stages only the parameter design is relatively cheap. It is a pity that this stage is not often used in the engineering practise. When the parameter design did not precede the tolerance design, it is usually hard to consider, which components of the system we should study in case when we would like to decrease the variation of performance characteristics. Often we consider all components of the system to have the same importance from the point of view of their possibilities to decrease the total variation, what usually noticeably simplifies the real situation.

An engineer usually subjectively determines tolerance limits also for performance characteristics.

But the user usually does not consider in terms of tolerance limits, he is interested in a nominal values. So, G. Taguchi recommends to use a quadratic loss function for measuring the effect of variation on performance characteristics. This leads from understanding of quality as a function of state "good" (in the frame of tolerance limits) - "bad" (out of tolerance limits), to understanding of improving quality by the reduction of variation.

For more information about Taguchi´s approach to statistical quality control we can recommend you e.g.: (1), (6). Some interesting facts you can find e.g. in (2), (3), (4), (5), (7), (8), (9) and some alternative approaches and generalised ideas e.g. in (10), (11), (12).

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