Taguchi's Approach to Quality – An Overview

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Abstract: Taguchi defines quality in a negative way as 'loss imparted to society from the time the product is shipped'. According to Taguchi, a product does not cause a loss only when it is outside specification limit but whenever it deviates from its target value. Any quality improvement programme should have its main objective, the minimisation of the variation of product performance about its target value. Taguchi's recommended technique is a straightforward, well integrated system for implementing statistical experimental designs. It encourages proper experimentation and closer association between statisticians and engineers and increases statistical awareness in industry.

Key-words: Taguchi loss function, target control factors (TCF), variability control factors (VCF), total quality loop

1. Introduction

Professor, Genichi Taguchi, director of the Japanese Academy of Quality and four times recipient of the Deming Prize, devised a quality improvement technique that uses experimental design methods for efficient characterisation of a product or process, combined with a statistical analysis of its variability. This approach allows quality considerations to be included at the early stage of any new venture: in the design and prototype phase for a product; during routine maintenance; or during installation and commissioning of a manufacturing process.

Taguchi's main objective lies in his definition of quality (or non-quality): 'Quality is the amount of damage incurred to society from the moment the product has left the factory.' Taguchi defines quality in a negative way as 'loss imparted to society from the time the product is shipped'. By, 'society' he means the customer as well as the employees of the company; because, if the customer suffers, the whole company will eventually suffer through rework, guarantee cost, loss of reputation, loss of market share, and eventually loss of jobs. Therefore, serving society is also Taguchi's aim. (Logothetis, 2001)

Taguchi uses his loss function approach to establish a value base for the development of products. The function recognises the need for average performance to match customer requirements and the fact that variability in this performance should be as small as possible. According to Taguchi, a product does not cause a loss only when it is outside specification limit but whenever it deviates from its target value. Any quality improvement programme should have its main objective the minimisation of the variation of product performance about its target value. Smaller the performance variations better the quality. Larger the deviation from the target; larger the society's (producer's and consumer's) loss. This loss can be approximately evaluated by Taguchi's loss function, which unites with the function specification through a quadratic relationship.

2. Objectives of the study

The paper tries to understand the approach towards improvement of product quality as proposed by Taguchi, one of the doyens of quality management. It tries to relate the difference between the traditional /conventional loss function and Taguchi's loss function. The paper addresses the issue of variability in product performance which is the cause of quality loss and tries to measure the loss through Taguchi's loss function.

3. Research Methodology

The study is essentially theoretical in nature. The materials for this study has been obtained from relevant books, journals, magazines and published work of various research scholars in the field of quality management.

4. Conventional Loss function and Taguchi's Loss Function

The traditional quality metric suggests

- All products within specifications are equally good
- All products outside specifications equally bad.

Unfortunately, this definition has led to the mindset which becomes a barrier towards improvement in products.

Figure 1: Traditional Loss Metric

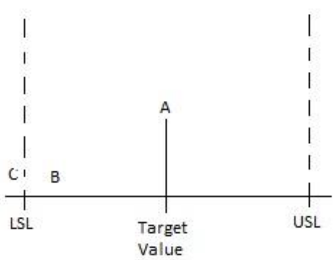


Figure 1 shows the target value, lower specification limit (LSL) and upper specification limit (USL).Both the products A and B are considered equally good although product A meets the specifications as per the target and product B is within the specification limit but far away from the target. Product C is considered to be non acceptable or equally unacceptable as it is beyond the lower specification limit.

It was Taguchi who defined and quantified quality loss via his ‘Loss Function’ which is quite different from the traditional concept. He unites the financial loss with the functional specification through a quadratic relationship that comes from a Taylor Series Expansion (which is an approximation method).

Taguchi’s loss function is as under:

$L(Y) = M/D^2 (Y-t)^2$

Where L(Y) = the quality loss function

t = target value/most desirable value of a product

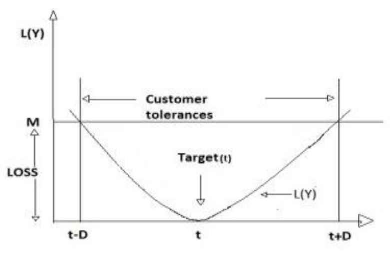
Y = performance of a product/the response found in test or analysis

M = producer’s loss (in monetary terms)

D = customer’s tolerance

The figure 2 shows the Taguchi’s loss function

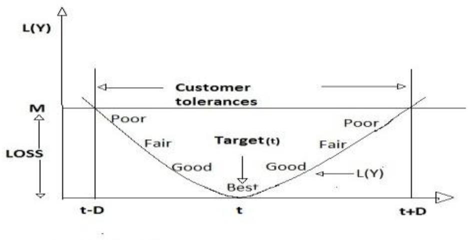
Figure 2: **Graphical representation of Taguchi’s Loss Function**



Source: Ross (1988)

As per figure 2 the loss to the society increases as the performance characteristic deviates from the target value (t). In general this loss is square of the deviation from the target. In the figure t +D and t-D are the functional limits beyond which 50% of system product needs customer maintenance.

Figure 3: **Relationship between quality loss and deviation from the target value (t)**



In figure 3 the relationship between quality loss and deviation from the target value (t) as per Taguchi is shown. It is observed that as the measured value of the product characteristics/ customer tolerances increases the product moves away from the target (best) to poor, unlike the traditional approach. The loss to the society is measured by the function L(Y) which is continuous.

5. Taguchi Loss Function- A Case

The cost of repairing a failed processor in the factory is ₹1000 per unit and the tolerance interval ranges from 0.325+0.025 (GHz) to 0.325-0.025 (GHz).

a. The Taguchi Loss Function is given as follows

$L(Y) = M/D^2 (Y\text{-}t)^2$ equation (1)

where,

L(Y) = the quality loss function

t = target value/most desirable value of a product

Y = performance of a product/the response found in test or analysis

M = producer's loss (in monetary terms)

D = customer's tolerance

Substituting the values in equation (1) we get

$1000 = M/D^2 (0.025)^2$

or, $M/D^2 = 1000/(0.025)^2$

or, $M/D^2 = 1600000$

Therefore, Taguchi's Loss Function is given by

$L(Y) = 1600000 (Y-t)^2$

b. Supposing a team of experts after carefully studying the root cause of scrap found out that the cost of scrap can be reduced to ₹500. If the process deviation from the target can be held at 0.015 GHz, then the Taguchi's loss will be as follows:

$L(Y) = M/D^2 (Y-t)^2$ equation (2)

or, $500 = M/D^2 (0.025)^2$

or, $M/D^2 = 8,00,000$

substituting the value of $M/D^2 = 800000$ in equation (2) we get

$L(Y) = 800000 (Y-T)^2$

or, $L(Y) = 800000 (0.015)^2$

or, L(Y) = ₹180

Therefore one can conclude that the losses can be reduced from ₹500 to ₹180 by reducing external failures/reducing process deviations.

6. Taguchi Technique and division of factors

There are two main aspects to the Taguchi technique.

First, the behaviour of a product or process is characterised in terms of factors (parameters) that are separated into two types:

- Controllable (or design) factors – those whose values may be set or easily adjusted by the designer or process engineer.
- Uncontrollable (or noise) factors- the sources of variation often associated with the production or operational environment; overall performance should, ideally, be insensitive to their variation.

Second are the controllable factors, which are divided into

- Those which affect the average levels of the response of interest, referred to as *target control factors* (TCF), sometimes called *signal factors*.
- Those which affect the variability in the response, the *variability control factors* (VCF); and
- Those which affect neither the mean response nor the variability, and can thus be adjusted to fit economic requirements, called the cost factors.

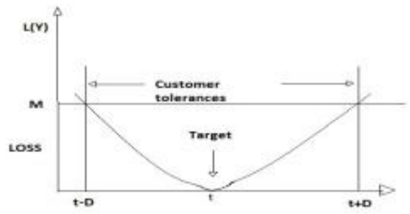
It is this concentration on variability which distinguishes the Taguchi approach from traditional tolerance methods or inspection-based quality control. The idea is to reduce variability by changing the variability control factors, while maintaining the required average performance through adjustments to the target control factors.

7. Taguchi's Loss function and its characteristics

The three characteristics that shape the definition of Taguchi loss function are as follows:

i) Nominal – The Best

Figure 4: **Nominal- The Best**



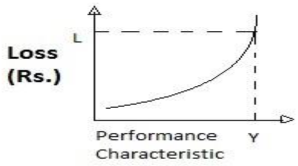
Source: Uthayakumar, 2014

Taguchi observed that many situations are approximated by the quadratic function [$L(Y) = M/D^2 (Y-t)^2$] which is called the Nominal- the best type. As shown in figure 4 nominal- the best, where the best characteristic or target value (t) is the median of the specified upper and lower acceptable limits and the losses owing to the deviance from the target value rise proportionately to the extent of deviance on either side of the mean. The frequency settings in radio and wireless equipments can be a good example of such characteristic. When the equipment does not conform exactly to the set frequency it is considered defective, thereby increasing the social costs for repair or replacement.

ii) Smaller – The Better

Smaller – The Better, where the ideal target value or best quality standard is zero, and the higher the actual value, the higher the private and social costs. Examples of such cases include heat loss in heat exchanger, or carbon-dioxide emissions. For instance, the more heat lost by the heat exchanger, the less efficiently it functions, and higher the social costs.

Figure 5: **Smaller-The Better**



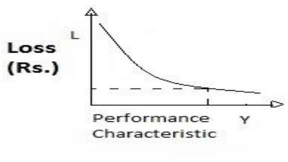
Source: Uthayakumar, 2014

The figure 5 shows the smaller –the better concept. The target value for smaller- the better is 0. There are no negative values for the performance characteristic (Y). The dotted lines represent a particular point of performance characteristic(Y) which corresponds to loss (L). It shows that the loss increases as Y increases. Example of such cases include the radiation leakage from a microwave appliance, the response time for a computer, pollution from an automobile, out of round for a hole, etc. where these are the performance characteristics for this concept.

iii) Larger – The Better

Larger – The Better, where the ideal characteristic or best quality standard is infinity and the higher the actual value, the better, and the lower the actual value, the more the private and social costs. Examples of such cases include maximising product yield from a process, agricultural output, and the like. For instance, the higher yields indicate better quality seeds, and lower yields increase the social costs.

Figure 6: **Larger- The Better**



Source: Uthayakumar, 2014

In figure 6 larger – the better, the target value is ∞ (infinity), which gives a zero loss. There are no negative values and the worst case is at Y = 0. The dotted lines represent a particular point of performance characteristic(Y) which corresponds to loss (L). It shows that the loss decreases as Y increases. Actually, larger – the better is the reciprocal of smaller – the better. Examples of such cases include bond strength of adhesives, welding strength, etc.

8. Taguchi Philosophy – The main points

Taguchi's philosophy focuses on the need to change

- the timing of the application of quality control from on line to off line, so that one can cease to rely on inspection, can build quality into the product and the process and thus 'do it right the first time'.
- the experimental procedures from varying one factor at a time to varying many factors at a time, through statistical experimental design techniques.
- the objectives of the experiments and the definition of quality from 'achieving conformance to specification' to 'achieving the target and minimising the variability'.
- the attitude for dealing with uncontrollable factors: remove the effect not the cause, by appropriately tuning the controllable factors.

9. Conclusion

Taguchi prefers to measure quality by *statistical reliability* such as standard deviation or mean square error (such as the loss function) rather than percentage defects or other more traditional tolerance- based criteria. The main criterion is keeping the performance at the target value while minimising variability so that the output is optimised in every aspect. In fact, this criterion is not new, already being the basis for on-line control engineering (such as *quadratic control*). But the use for *static control* of engineering seems to be very new. The principal idea in the Taguchi's philosophy is that statistical testing of a product should be carried out at the design stage in order to make the product and the process robust to variations in the manufacturing and environment.

Taguchi's recommended technique is a straightforward, well integrated system for implementing statistical experimental designs. It encourages proper experimentation and closer association between statisticians and engineers and increases statistical awareness in industry. More importantly, it completes the *total quality loop*.

Every organisation demands a real understanding of variation and an adequate appreciation of the damage which variation causes. Taguchi's loss function can satisfy both the demands.

Statistically speaking, the problem of establishing constancy and maintaining consistency of purpose can be related to Taguchi's problem of achieving the mean (target) and minimising dispersion (variability) around the mean. One can only say that with regards to the problem of variability, the cause of non- quality is usually the more difficult to resolve. But one must keep trying as the search for excellence is a never ending journey.

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