Optimization of Process using Robust Design (Taguchi Method): An Review

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Abstract: *This paper is an attempt to review the literature available on optimization of process variables for obtaining optimized economics of the process using Robust Design technique (Taguchi Method). A number of techniques have been used for optimization of variables including geometric programming, geometric plus linear programming, goal programming, dynamic programming, fuzzy logic, scatter search technique, genetic algorithm and response surface methodology for analyzing a machining process, but Taguchi Method has been found more effective and accurate for optimization of process variables.*

Keywords: *Optimization, Taguchi Method, Loss Function, Noise, Orthogonal Array*

1. INTRODUCTION

Taylor (1907) first time showed that at some optimum speed, maximum metal removal rate exists, which is generally an area of concern for any manufacturing organization. Before his experiments, there was no scientific base existing for optimization of machining operations (turning, milling, grinding, drilling etc.). The economics of the process was dependent upon the workers for selection of appropriate cutting speed and tool for machining. Traditionally, the selection of machining conditions (like feed, depth of cut, cutting speed etc.) was left to the machine operator. Machining parameters for example in Electrochemical Machining are feed rate, depth of cut, type of electrolyte, electrolyte concentration etc. The setting of these parameters determines the quality characteristics of machined part. For obtaining optimized machining economics, the variables need to be optimized. With span of time a number of optimization techniques were developed. Every process was involving a number of iterations using various combinations of process variables for optimized output. [5]

2. TAGUCHI ON QUALITY

It is a statistical experimentation and analysis method or selecting the best setting for 4 to 5 process/product design parameters.

The foundation of Taguchi method is based on two premises:

- Society incurs a loss any time the performance of a product is not on target. Taguchi has argued that any deviation from target performance result in a loss to society. He has redefined the term “quality” to be the losses a product imparts to society from the time it is shipped.[1]

- Product and process design requires a systematic development, progressing stepwise through system design, parametric design and finally tolerance design. Taguchi method provides an efficient, experiments based framework to achieve this.

The first premise suggests that whenever the performance of the product deviates from the target performance, society suffer loss.

The second premise forms the foundation of quality engineering, a discipline that aims at not only the function but also the quality performance into product and processes.

2.1 Achieving Quality—Taguchi's Seven Points

The following seven points highlight the distinguish features of taguchi approach, which is aimed at assuring quality:

- Taguchi characterized the term 'quality' as the deviation from on target execution, which shows up from the outset to be a Catch. As indicated by him, the quality of a made product is the all out misfortune created by that product to society from the time it is sent.
- In a competitive economy, ceaseless quality improvement and cost decrease are essential for remaining in business.
- A Continuous Quality Improvement program remembers consistent decrease for the variety trademark in their objective qualities.
- Customer's misfortune owing to product execution variety is regularly relative to the square of the deviation of the exhibition attributes from its objective qualities.
- The last quality and cost of a fabricated product and its assembling procedure.
- Variation in product execution can be diminished by misusing the non-direct impacts of the product parameters on the presentation attributes.
- Statically arranged tests can proficiently and dependably distinguish the setting of product and procedure parameters that lessen execution variety.

Taguchi proposes an all-encompassing perspective on a quality, which relates quality to cost, not simply to maker at the hour of creation, however to the customers and society overall. Taguchi characterizes quality, as "the nature of an item is the misfortune bestowed by the product to society from the product is sent". This monetary misfortune is related with misfortunes due to improve, misuse of assets during fabricate, guarantee costs, customers grumblings and disappointment, time and cash spent by customers on bombing items and possible loss of piece of the overall industry.[3]

Taguchi quadratic loss function is the principal operational joining of cost of value and changeability of product that permit configuration specialists to really ascertain the ideal plan dependent on cost examination and experimentation with the design.

2.2 Loss- function

Taguchi has characterized quality as a misfortune granted to society from the time a product is sent. Societal misfortunes incorporate inability to met customer prerequisite, inability to meet perfect execution and hurtful symptoms. Numerous practitioners have incorporated the misfortunes because of creation, for example, crude material vitality and work expended on usable products or potentially harmful side effect.

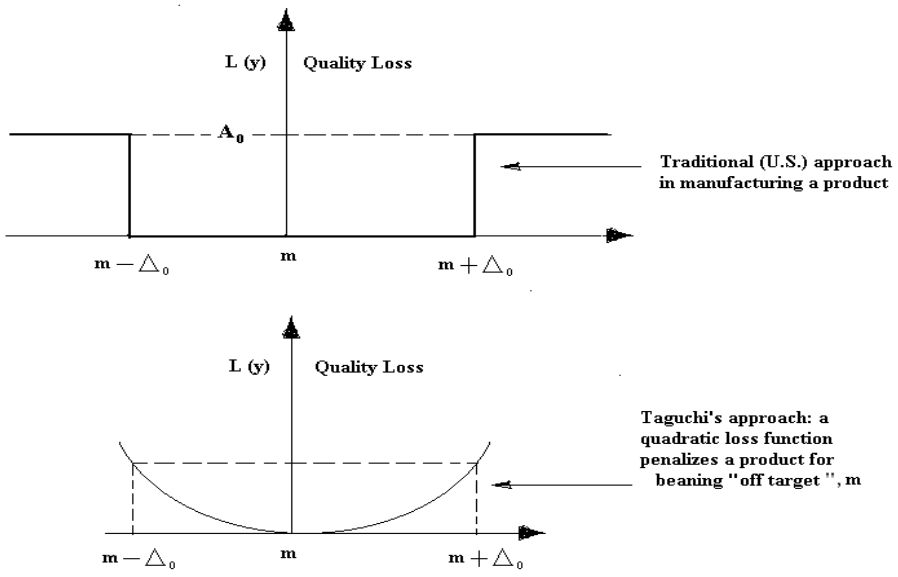


Figure 1: Loss Function

Expecting the target is right misfortunes of concern are those brought about by an product's basic performance attributes digressing from target. The loss function remedies for insufficiency depicted above by the combining cost, target, and variety into one metric.

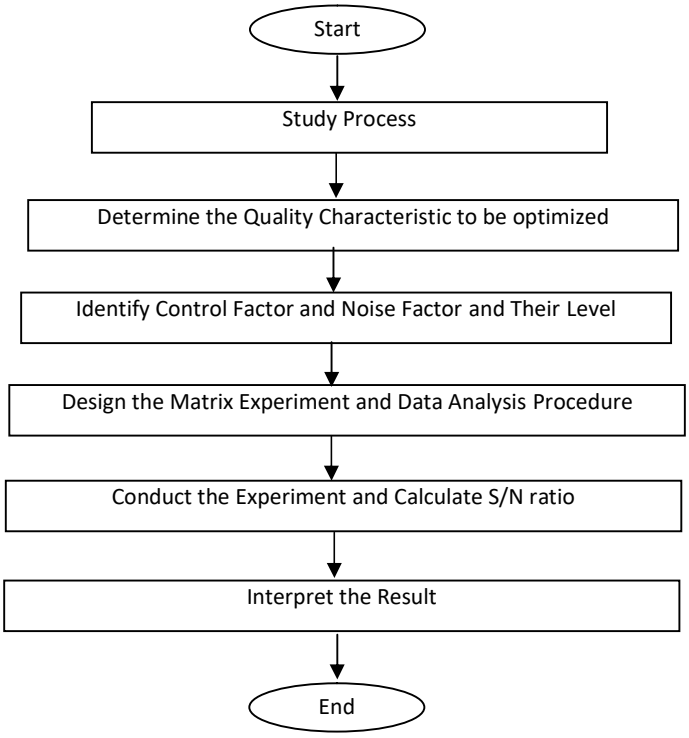
$$L(y) = k[\sigma 2 + (y - \tau) 2] \quad \ldots (1)$$

Where L = the average or expected loss

Basically, there are three Loss Functions

Normal-the-best	L = k (y-τ) 2 where k = A/ Δ2 L = k (MSD) where MSD = [Σ (y-τ) 2]/ n L = k [σ2 + (y-τ) 2]
Smaller-the-best	L = ky2, where k = A/ y2 L = k (MSD), where MSD = [Σ y2]/ n L = k [--y2 + τ 2]
Larger-the-better	L = k (1/y2), where k = Ay2 L = k (MSD) where MSD = [Σ (1/y2)]/ n L = k [Σ (1/y2)]/ n

3. METHODOLOGY



3.1 Optimize the Quality Characteristic (Response Factor)

The very first step is to determine which quality characteristic or variable under observation that contributes to the optimization of process output e.g. metal removal rate in any machining operation. [1]

3.2 Identify Control Factor and Noise Factor and Their Level

Next step is to identify the control factor and noise factors and designate their levels.

3.3 Matrix Experiment Design and Data Analysis Procedure

The next step is to design the matrix experiment, characterize the data information and their analysis. To begin with, select the suitable appropriate orthogonal arrays for the noise and control factors to fit a particular study that are chosen. Taguchi characterized various standard orthogonal arrays and their respective linear graph for this purpose. The variation of noise factors factors is concentrated by intersection the orthogonal array of control factor by a orthogonal array of noise factor. [1]

3.3.1 Orthogonal Arrays

In orthogonal array, suitable levels can be designated like 1 for low level, 2 for medium level, 3 for high level etc.

3.3.2 Degree of freedom

The number of degree of freedom is an important value as it determines the minimum number of run.

It is equal to sum of "(Number of level-1) for each factor +(number of level-1) (number of level-1) for each interaction + 1".

3.3.3 Selecting an orthogonal array

After getting degrees of freedom, decide for suitable orthogonal array (OA).

3.3.4 Linear Graphs

Taguchi built up a less difficult technique for working with collaborations utilizing linear graph. They make simpler to assign factors and interaction to different columns of an array.

3.3.5 Perform the Matrix Experiment:

The following stage is to direct the matrix analysis and record the outcome. The Taguchi technique can be utilized in any circumstance where there is a controllable process. The controllable process can be actual experiment system of any mathematical expression or any computer models that can sufficiently show the outcomes to various product and process.

3.3.6 Determine the Optimum Levels and Analyze the Data:

Once the define set of experiments have been conducted then determine the optimal test parameter configuration within the experiment design.To analyze the result, the Taguchi method uses a statistical measure to performance called signal to noise (S/N) ratio.[1]

S/N ratio for "Larger- is -better",

$$S/N_L = -10\log_{10}[MSD] = -10\log_{10}\left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right]$$

Examples of quality characteristic are metal removal rate.

S/N ratio for "Smaller- is- better",

$$S/N_S = -10\log_{10}[MSD] = -10\log_{10}\left[\frac{1}{n}\sum_{i=1}^{n}y_i^2\right]$$

Examples quality characteristic are cracks.

S/N ratio "Nominal- the- best",

$$S/N_T = 10\log_{10}\left[\left(\bar{y}^2/s^2\right)-\left(1/n\right)\right]$$

3.4 Predict the Performance at These Levels and Perform Confirmation Run:

So as to validate the optimum conditions we anticipate the process execution under baseline and ideal setting of control factor. At that point it needs to perform affirmation analyzes

under these conditions and compare the outcome and expectation. On the off chance that the after effects of confirmation tests concur with the forecasts, at that point we execute result.

4. CONCLUSION

A review of literature on optimization of a process using Taguchi Method has been done. Taguchi Method is now widely used for realistic problems particularly related to manufacturing processes. Quality ought to be planned into a product. Standards of Taguchi strategies which help in choosing optimal product and process parameters encourage this goal.The main achievement of Taguchi Method is reducing quality cost by designing the products or processes insensitive to the variation in noise variables.

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