

Overview on Taguchi Method

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Abstract: Taguchi Method is a statistical approach to optimize the process parameters and improve the quality of components that are manufactured. The objective of this study is to illustrate the procedure adopted in using Taguchi Method to a lathe facing operation. The orthogonal array, signal-to-noise ratio, and the analysis of variance are employed to study the performance characteristics on facing operation. In this analysis, three factors namely speed; feed and depth of cut were considered. Accordingly, a suitable orthogonal array was selected and experiments were conducted. After conducting the experiments the surface roughness was measured and Signal to Noise ratio was calculated. With the help of graphs, optimum parameter values were obtained and the confirmation experiments were carried out. These results were compared with the results of full factorial method.

Keywords: Anova, Design of Experiments, Facing Operation, Orthogonal Array, S/N Ratio, Taguchi Method.

I. INTRODUCTION

Taguchi method is a statistical method developed by Taguchi and Konishi. Initially it was developed for improving the quality of goods manufactured (manufacturing process development), later its application was expanded to many other fields in Engineering, such as Biotechnology etc. Professional statisticians have acknowledged Taguchi's efforts especially in the development of designs for studying variation. The enemy of mass production is variability. Success in reducing it will invariably simplify processes, reduce scrap, and lower costs" (Box and Bisgaard 1988). The main objective in the Taguchi method is to design robust systems that are reliable under uncontrollable conditions (Taguchi1978, Byrne1987 and Phadke1989). Success in achieving the desired results involves a careful selection of process parameters and bifurcating them into control and noise factors. Selection of control factors must be made such that it nullifies the effect of noise factors. Taguchi Method involves identification of proper control factors to obtain the optimum results of the process. Orthogonal Arrays (OA) are used to conduct a set of experiments. Results of these experiments are used to analyze the data and predict the quality of components produced. Here, an attempt has been made to demonstrate the application of Taguchi's Method to improve the surface finish characteristics of faced components that were processed on a lathe machine. Surface roughness is a measure of the smoothness of a products surface and it is a factor that has a high influence on the manufacturing cost. Surface finish also affects the life of any product and hence it is desirable to obtain higher grades of surface finish at minimum cost.

II. LITERATURE REVIEW

The method aims to adjust the design parameters (known as the control factors) to their optimal levels, such that the system response is robust – that is, insensitive to noise factors, which are hard or impossible to control (Phadke1989). In the 1980s Genichi Taguchi (1985; 1986; 1993) received international attention for his ideas on variation reduction, starting with the translation of his work published in Taguchi and Wu (1979).

A. Process Optimization

Process optimization is the discipline of adjusting a process to optimize some specified set of parameters without violating some constraint. The most common goals are minimizing cost, maximizing throughput, and/or efficiency. This is one of the major quantitative tools in industrial decision-making. When optimizing a process, the goal is to maximize one or more of the process specifications, while keeping all others within their constraints.

B. Process Optimization Tools

Many relate process optimization directly to use of statistical techniques to identify the optimum solution. This is not true. Statistical techniques are definitely needed. However, a thorough understanding of the process is required prior to committing time to optimize it. Over the years, many methodologies have been developed for process optimization including Taguchi method, six sigma, lean manufacturing and others. All of these begin by an exercise to create the process map.

III. TAGUCHI'S METHOD

The Full Factorial Design requires a large number of experiments to be carried out as stated above. It becomes laborious and complex, if the number of factors increase. To overcome this problem Taguchi suggested a specially designed method called the use of orthogonal array to study the entire parameter space with lesser number of experiments to be conducted. Taguchi thus, recommends the use of the loss function to measure the performance characteristics that are deviating from the desired target value. The value of this loss function is further transformed into signal-to-noise (S/N) ratio. Usually, there are three categories of the performance characteristics to analyze the S/N ratio. They are: nominal-the-best, larger-the-better, and smaller-the-better. Taguchi's techniques have been used widely in engineering design (Ross 1996 & Phadke 1989). The Taguchi method contains system design, parameter design, and tolerance design procedures to achieve a robust process and result for the best product

quality (Taguchi 1987 & 1993). The main trust of Taguchi's techniques is the use of parameter design (Ealey Lance A.1994), which is an engineering method for product or process design that focuses on determining the parameter (factor) settings producing the best levels of a quality characteristic (performance measure) with minimum variation. Taguchi designs provide a powerful and efficient method for designing processes that operate consistently and optimally over a variety of conditions. To determine the best design, it requires the use of a strategically designed experiment, which exposes the process to various levels of design parameters. Experimental design methods were developed in the early years of 20th century and have been extensively studied by statisticians since then, but they were not easy to use by practitioners (Phadke 1989). Taguchi's approach to design of experiments is easy to be adopted and applied for users with limited knowledge of statistics; hence it has gained a wide popularity in the engineering and scientific community.

A. Taguchi Specified Three Situations

- Larger the better (for example, agricultural yield);
- Smaller the better (for example, carbon dioxide emissions); and
- On-target, minimum-variation (for example, a mating part in an assembly).

B. Taguchi's Rule for Manufacturing

Taguchi realized that the best opportunity to eliminate variation is during the design of a product and its manufacturing process. Consequently, he developed a strategy for quality engineering that can be used in both contexts. The process has three stages:

- System design.
- Parameter design.
- Tolerance design

System Design: This is design at the conceptual level, involving creativity and innovation.

Parameter Design: Once the concept is established, the nominal values of the various dimensions and design parameters need to be set, the detail design phase of conventional engineering. This is sometimes called robustification.

Tolerance Design: With a successfully completed parameter design, and an understanding of the effect that the various parameters have on performance, resources can be focused on reducing and controlling variation in the critical few dimensions.

IV. STEPS INVOLVED IN TAGUCHI METHOD

The use of Taguchi's parameter design involves the following steps.

- Identify the main function and its side effects.
- Identify the noise factors, testing condition and quality characteristics.
- Identify the objective function to be optimized.
- Identify the control factors and their levels.
- Select a suitable Orthogonal Array and construct the Matrix.
- Conduct the Matrix experiment.
- Examine the data; predict the optimum control factor levels and its performance.
- Conduct the verification experiment.

A. Approach To The Experimental Design

In accordance with the steps that are involved in Taguchi's Method, a series of experiments are to be conducted. Here, facing operation on mild steel components using a lathe has been carried out as a case study. The procedure is given below.

Identification of Main Function And Its Side Effects: Main function: Facing Operation on MS work piece using lathe machine.

Side Effects: Variation in surface finish.

Before proceeding on to further steps, it is necessary to list down all the factors that are going to affect or influence the facing process and from those factors one has to identify the control and noise factors. The "Factors" that affect facing operation on a lathe machine are listed in the table .1.

TABLE I: Factors That Affect Facing Operation

Control factors	Noise Factors
Cutting speed	Vibration
Depth of cut	Raw material variation
Feed rate	Machine Condition
Nose radius	Temperature
Coolant	Operator Skill

After listing the control and the noise factors, decisions on the factors that significantly affect the performance will have to be ascertained and only those factors must be taken in to consideration in constructing the matrix for experimentation. All other factors are considered as Noise Factors.

Identifying the Testing Conditions and Quality Characteristics To Be Observed:

- **Quality Characteristic:** Surface finish.
- **Work piece material:** Mild Steel.
- **Cutting tool: Tungsten:** Carbide Tipped tool.
- **Operating Machine:** Lathe machine.
- **Testing Equipment:** Portable surface tester.

Identify The Objective Function:

Objective Function: Smaller-the-Better.

S/N Ratio for this function:

$$\eta = -10 \log_{10} \left(\frac{1}{n} \sum_{i=1}^n y^2_i \right) \quad (1)$$

Where, n= Sample Size, and y= Surface Roughness in that run.

Methodology Used: Taguchi Techniques: Taguchi's Signal-to-Noise ratios (S/N), which are log functions is based on "ORTHOGONAL ARRAY" experiments which gives much reduced "variance" for the experiment with "optimum settings" of control parameters. Thus the marriage of Design of Experiments with optimization of control parameters to obtain BEST results is achieved in the Taguchi Method. "Orthogonal Arrays" (OA) provide a set of well balanced (minimum) experiments & desired output, serve as objective functions for optimization, help in data analysis and prediction of optimum results.

V. MATHEMATICAL MODELING

"ORTHOGONAL ARRAYS" (OAs) experiments Using OAs significantly reduces the number of experimental configurations to be studied Montgomery, (1991). The effect of many different parameters on the performance characteristic in a process can be examined by using the orthogonal array experimental design proposed by Taguchi. Once the parameters affecting a process that can be controlled have been determined, the levels at which these parameters should be varied must be determined. Determining what levels of a variable to test requires an in-depth understanding of the process, including the minimum, maximum, and current value of the parameter. If the difference between the minimum and maximum value of a parameter is large, the values being tested can be further apart or more values can be tested. If the range of a parameter is small, then less value can be tested or the values tested can be closer together. The Taguchi method is a powerful tool for designing high quality systems. To increase the experimental efficiency, the L18 mixed orthogonal table in the Taguchi quality design. Ross (1988) is used to determine the significant machining factors. In the experiments, we select six influential machining parameters, such as cutting tools of different materials, depth of cut, cutting speed, feed rate, working temperature and ultrasonic power, each of which has three different levels (high, medium and low levels).

VI. CONCLUSION

Taguchi started to develop new methods to optimize the process of engineering experimentation. He believed that the best way to improve quality was to design and build it into the product. He developed the techniques which are now known as Taguchi Methods. His main contribution lies not in the mathematical formulation of the design of experiments, but rather in the accompanying philosophy. His concepts produced a unique and powerful quality improvement technique that differs from traditional practices. He developed manufacturing systems that were "robust" or insensitive to daily and seasonal variations of environment, machine wear and other external factors. The Taguchi approach to quality engineering places a great deal of emphasis on minimizing variation as the main means of improving quality. The idea is to design products and processes whose performance is not affected by outside conditions and to build this in during the development and design stage through the use of experimental design. The method includes a set of tables that enable main variables and interactions to be investigated in a minimum number of trials.

VII. REFERENCE

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