http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 3 (9):1538-1540, 2000

A Different Approach of Experimental Design: Taguchi Method

Hülya Atil and Yakut Unver
Faculty of Agriculture, Ege University, Turkey

Abstract: Achievement in experiments based on properly design product. In some cases, it is necessary to study on a lot of combinations of experiment. This is difficult to apply it for user and it needs more time. The Taguchi method of design of experiments is a statistical tool based on the systematic approach of conducting minimal number of experiments using orthogonal arrays. Traditionally, this method has been used to predict the significant contribution of each design variables and the optimum combination of the design variables by conducting a real time experiment. In this study, Taguchi Methods having more advantages than real time experiments is determined.

Key words: Experimental design, taguchi method

Introduction

The technique of laying out the conditions of experiments involving multiple factors was first proposed by Sir. R. A. Fisher in 1920s. The method is popularly known as the factorial design of experiments. A full factorial design will identify all possible combinations for a given set of factors. Since most industrial experiments, agricultural machinery, energy in agriculture, agricultural tractors and livestock production mechanisation usually involve a significant number of factors, a full factorial design result in a large number of experiments. To reduce the number of experiments to a practical level, only a small set from all the possibilities is selected (Ykiz, 1978). The method of selecting a limited number of experiments, which produces the most information, is known as a partial fraction experiment. Although this method is well known, there are no general guidelines for its application or the analysis of the results obtained by performing the experiments. Dr. Taguchi, who saw these difficulties wanted to do something to cease them (Nellian, 1996).

As a researcher in Electronic Control Laboratory in Japan, Dr. Taguchi carried out significant research with Design of Experiment Techniques in the late 1940s. His aim was make powerful and easy to apply experimental technique and apply it to improve the quality of manufactured products (Ross, 1988 ; Roy, 1990).

A different approach of experimental design of Taguchi popularly known as "Taguchi Methods". It was introduced in the USA, in the early 1980s. Recently, it became an effective method using in engineering areas.

Physiology of Taguchi: According to Taguchi, the most important thing prior to analysis is establishment of the experiment. Only by this way, it is possible to improve quality of the process. This method could achieve the target value and minimised the variability around the target value by minimum cost (Fig. 1).

Five major points of the Taguchi quality philosophy are:

1. In a competitive market environments, continual quality improvements and cost reductions are necessary for business survival
2. An important measurement of the quality of a manufactured product is the total loss generated by that product to the society
3. Change the pre-production experimental procedure from varying one factor at a time to varying many factors simultaneously, so that quality can be built into the product and the process
4. The customer's loss due to poor quality is approximately to the square of the deviation of the performance characteristics from its target or nominal value. Taguchi changes the objectives of the experiments and the definition of quality from "achieving conformance to specifications" to "achieving the target and minimising the variability"
5. A product performance variation can be reduced by examining the. non-linear effects of factors on the performance characteristics. Any deviation from a target leads to poor quality (Kacker, 1986)

According to Taguchi "Quality is the loss imparted to society from the time the product is shipped". This loss, would include the cost of customer dissatisfaction that leads to the loss of company reputation.

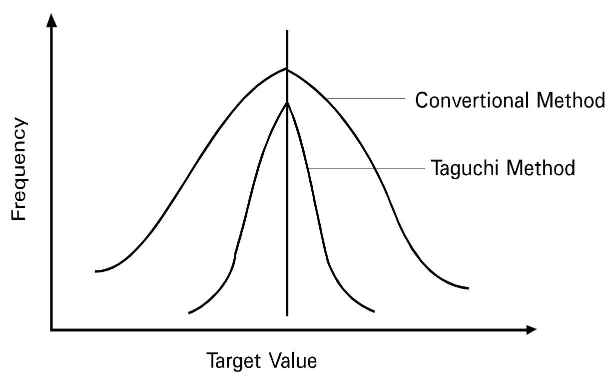

Fig. 1: Comparison of conventional and Taguchi methods

Fundamental Taguchi Concepts

1 Quality should be designed into the product from the start, not by inspection and screening. Quality improvements should occur during the design stages of product or process, and continue through to the production phase. This is often called an "off-line" strategy. Taguchi emphasises that quality is something that is designed into a product, to make it robust and immune to the uncontrollable environmental factors in the manufacturing phase (Feigenbaum, 1983)

2. Quality is best achieved by minimising the deviation from the target, not a failure to confirm to specifications. By means of minimising deviation from the target, process becomes the resistant to uncontrollable environmental factors-e.g. noise, temperature and humidity
3. Quality should not be based on the performance, features

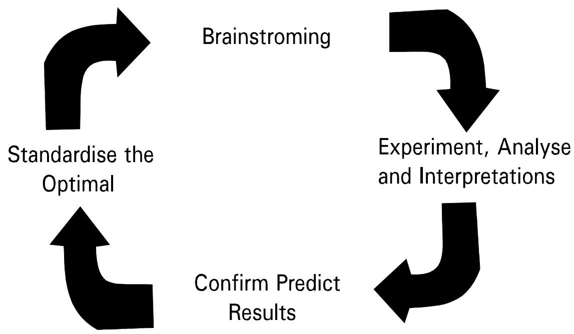

Fig. 2 : Diagram of Brainstorming (Maynard, 1995)

or characteristics of the product. Adding features to a product is not a way of improving quality, but only of varying its price and market it is aimed at. The performances of product, can be related to quality, but should not be basis of quality

4. The cost of quality should be measured as a function of product performance variation and the losses measured system-wide

From given design parameters, the deviations from a target are measured in terms of the overall life cycle costs of the product. This includes costs or re-work, inspection, warranty, servicing, returns and product replacement.

Brainstorming: Brainstorming is a necessary first and the most important step of Taguchi procedure. This stage is an activity, which promotes group participation, encourages creative thinking and generates much idea in a short period of time (Fig.2).

In this stage:

1. When there is more than one criterion of evaluation, decide how each criterion is to be combined
2. Determine the factors and noise factors
3. Determine the factor levels
4. Determine the condition of repetitions (Roy, 1990)

The experiment stage is where resulting data is examined and an interpretation of results is conducted. The variability control factors are determined and the optimal values are selected therefore the variability of the product is minimised. The target control parameters are also determined during this stage. To confirm the predicted results, a confirmatory experiment is conducted. This is an essential stage in order to confirm that the new parameter settings do provide optimal performance. The optimal settings will become a standard (Roy, 1990; Maynard, 1995).

Total Loss Function: In early 1980s Dr. Taguchi, proposed the following statement to the quality of product:

"Quality is the financial loss to society after the article is shipped".

This is one of the many concepts, which was developed by Dr. Taguchi. However, the above statement somehow depicts inequality, since a loss to society is not a desirable characteristic. The idea of quality in related to something, which is new, beautiful, and good which in the engineering sense, must have many features or functionalities. We can rearrange the above definition and still retain the basic concept of Quality to denote a positive attribute as follows:

"Quality is the avoidance of financial loss of society after the product is shipped".

The important point here is the fact that quality is related to monetary loss and not to any other factors or conditions. Even tough actual loss may be the loss. of functionality to the product, or other losses such as pollution, time, noise, etc., the overall effect is a financial loss.

A poorly designed product gives losses from the first step to the last step of process. There are two major categories of loss to society with respect to the product quality (Kacker, 1986):

1. The first category relates to the losses incurred as a result of harmful effects of society (e.g. pollution)
2. The second category relates to the losses arising because of excessive variation in functional performance (This category refers to total loss function)

In the Fig. 3, loss function is shown as the target value of given design parameter and a function of the deviation of ideal value.

where;

T: Target value of parameter

UAL : Upper acceptable limits of design parameter

LAL : Lower acceptable limits of design parameter

Normally the product is functionally acceptable if the value of the specified parameter is within the range between UAL and LAL. Actually, it is not easy to apply in real life. Therefore, Dr. Taguchi, determined the loss function as a deviation from ideal values.

As a result, making a product within the specification limits, it does not necessary mean that the product is of good quality, since good quality is now defined as keeping the product characteristics on target with low variation.

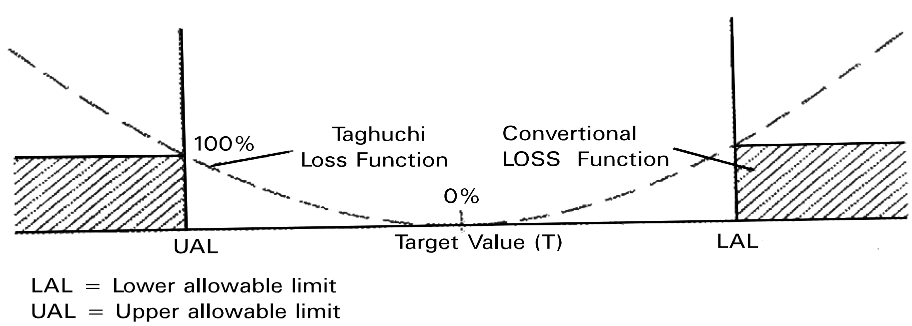

Fig. 3: Taguchi and conventional loss function (Roy, 1990)

Orthogonal Arrays (OA): A term of “Orthogonal Array” firstly used by Bose and Bush (1952). According to Taguchi, quality can be obtained by minimising the variation around the target value. It is obvious that factors and their levels are effect the variation. Therefore it is necessary to determine the levels of design parameters and their combinations. Taguchi has developed a system of tabulated designs (arrays) that allow for the maximum number of main effects to be estimated in an unbiased (orthogonal) manner, with a minimum number of runs in the experiment. An “Outer Array” is used to reduce the number of noise conditions obtained by the combination of various noise factors (Bendell *et al.*, 1989; Roy, 1990).
Taguchi suggested the use of Orthogonal Arrays, in the experiment implementation stage, to investigate and predict noise factors, which might affect the quality of a given product during the product-manufacturing phase. There are various OA tables developed by Taguchi for different factor levels. More information about the tables can be obtained from Roy (1990).

Table 1: Table of orthogonal arrays for different factor levels (Yyimaz, 1999)

Orthogonal Arrays (OA)	Number of factors	Levels of factors	Number of experiment for OA	Number of experiment for full factorial design
L4 (2^3)	3	2	4	8
L8 (2^7)	7	2	8	128
L9 (3^4)	4	3	9	81
L12 (2^{11})	11	2	12	2048
L16 (2^{15})	15	2	16	32768
L16 (4^5)	5	4	16	1024
L18 ($2^1 \times 3^7$)	1	2	18	4374
	7	3		

Table 1 shows that number of necessary experiment is fewer in OA design than full factorial design To illustrate, for 7 factors with 2 level (2^7) in full factorial design 128 experiments are necessary while in OA only 8 experiments are enough.

Signal to Noise Ratio (S/N): Noise factors are known as uncontrollable factors. These are classified as below:
-that are not controllable
-whose influences are not known
-which are intentionally not controlled (Nutek, 1997)
The ideal product will only respond to the operator's signals and will be unaffected by random noise factors (weather, temperature, humidity, etc.). Therefore, the goal of your quality improvement effort can be stated as attempting to maximise the signal-to-noise (S/N) ratio for the respective product. Taguchi, developed a formulation which a ratio of controllable factors (Signal factors) to uncontrollable factors (Noise factors) S/N based on variance is independent of target value and is consistent with Taguchi’s quality objective. These are:

Smaller-the-better: In cases where you want to minimise the occurrences of some undesirable product characteristics, you would compute the following S/N ratio:

$$S/N(S) = -10 \times \log_{10} [(1/n) \times \Sigma(y_i^2)$$

Where, S/N(S) is the resultant S/N ratio; n is the number of observations on the particular product and *y* is the respective characteristic. For example, in Agricultural Machinery there are two adjustments, threshing drum and concave, for combine harvester. The precision of adjustment affects the product going in a circle after reaping. It can be analysed via this S/N ratio. The effect of the signal factors is zero, since zero error in adjustment is the only intended or desired state of the combine harvester. Note how this S/N ratio is an expression of the assumed quadratic nature of the loss function. The factor 10 ensures that this ratio measures the inverse of "bad quality;" the more error in adjustment.

Nominal-the-best: Here, you have a fixed signal value (nominal value), and the variance around this value can be considered the result of noise factors:

$$S/N(N) = 10 \times \log_{10} (\text{Mean}^2/\text{Variance})$$

This signal-to-noise ratio could be used whenever ideal quality is equated with a particular nominal value. For example, the size of piston rings for a tractor engine must be as close to specification as possible to ensure high quality.

Larger-the-better: Examples of this type of engineering problem are fuel economy (miles per gallon) of an automobile, strength of concrete, resistance of shielding materials, etc. The following S/N ratio should be used:

$$S/N(L) = -10 \times \log_{10} [(1/n) \times \Sigma(1/y_i^2)]$$

Results and Discussion

The design of experiments using Taguchi method is more efficient compared to statistical methods. By choosing proper level combinations of various independent variables, the number of experiments is reduced considerably. At the same time, there is no loss of any information due to reduction of number of experiments.
Taguchi’s target was minimising the variation around the target and improve the quality. Using and learning this technique for engineers, scientists and researches, time needing in researches is become less.
Improvement in computer technology, it is becoming easier to use Taguchi Methods in applications. The most common analyse technique by computer is Qualitek-4. It will investigate in another article.

References

Bendell, A., J. Disney and W.A. Pridmore, 1989. Taguchi Methods: Applications in World Industry. Springer, Berlin, ISBN: 9783540506577, Pages: 399.

Bose, R.C. and K.A. Bush, 1952. Orthogonal arrays of strength two and three. Ann. Math. Stat., 23: 508-524.

Feigenbaum, A.V., 1983. Total Quality Control. 3rd Edn., McGraw-Hill, New York, ISBN: 9780070203532, Pages: 851.

Kacker, R.N., 1986. Taguchi's quality philosophy: Analysis and commentary. Qual. Prog., 19: 21-29.

Maynard, C., 1995. Quality Engineering. Curtin University, Western Australia.

Nellian, S., 1996. Integration of Taguchi design of experiments and finite element method for robust design. M.Sc. Thesis, Department of Mechanical Engineering, Massachusetts University, USA.

Nutek, L., 1997. Design of Experiments and the Taguchi Approach. Nutek Inc., USA.

Ross, P.J., 1988. Taguchi Techniques for Quality Engineering. McGraw-Hill Book Co., New York.

Roy, R.K., 1990. A Primer on The Taguchi Method. Van Nostrand Reinhold, New York, USA., ISBN: 13-9780442237295, Pages: 247.

Ykiz, F., 1978. Kysmi tekerrurlu denemeler ve bu deneme planlarynyn olutpturulmasynda galois alanynyn ve ortogonal dizilerin kullanyimasy. Uygulamaly Ystatistik, 1: 15-16.

Yyimaz, T., 1999. Cevrim dypy (off-line) kalite kontroiu taguchi yontemi ve uygulamasy. M.Sc. Thesis, Ega University, Izmir, Turkey.