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Reduction Of Cost Of Quality By Using Robust Design: A Research Methodology

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Abstract: **CoQ and Taguchi Design are to be integrated together for time and resource savings and determination of important factors affecting operation, performance and cost; and quantitative recommendations for design parameters which achieve lowest cost, high quality solutions. Taguchi's parameter design method is a powerful tool for optimizing the performance characteristic of a product/process. The aim of a parameter design experiment is to identify and design the settings of the process parameters that optimize the chosen quality characteristic and are least sensitive to noise (uncontrollable) factors. Finally methodology for reducing Cost of Quality by using robust design is to be developed.**

Keywords: **robust design, cost of quality, parameter design, control factors, noise factors, signal to noise ratio, taguchi quality loss function and tolerance limit.**

1. INTRODUCTION

Cost of quality is a term that's widely used and widely misunderstood. The "cost of quality" isn't the price of creating a quality product or service. It's the cost of NOT creating a quality product or service. Every time work is redone, the cost of quality increases viz. reworking of a manufactured item, retesting of an assembly, rebuilding of a tool, correction of a bank statement, reworking of a service, such as the reprocessing of a loan operation or the replacement of a food order in a restaurant. In short, any cost that would not have been expended if quality were perfect contributes to the cost of quality.

Robust Design method, also called the Taguchi Method, pioneered by Dr. Genichi Taguchi, greatly improves engineering productivity. By consciously considering the noise factors (environmental variation during the product's usage, manufacturing variation, and component deterioration) and the cost of failure in the field the Robust Design method helps ensure customer satisfaction. Robust Design focuses on improving the fundamental function of the product or process, thus facilitating flexible designs and concurrent engineering. Indeed, it is the most powerful method available to reduce product cost, improve quality, and simultaneously reduce development interval.

Our present literature focus on the aspect of reducing cost of quality by implementing robust design as a tool. The dimensional tolerance plays an important role in acceptance and rejection of a product. Any product that fails to reach the target value is termed as loss in robust design, in contrast to traditional design approach where product with in a tolerance range are accepted as product of good quality. Significant research has been done on various aspects of quality still the area of taguchi quality loss function is unexplored in various fields of manufacturing such as dimensional tolerance of a product, relating cost of quality of a product with robust design, etc. Methodology for reduction in cost of quality by implementing robust design is explained in the further literature.

2. COST OF QUALITY

CoQ is usually understood as the sum of conformance plus non-conformance costs, where cost of conformance is the price paid for prevention of poor quality (for example, inspection and quality appraisal) and cost of non-conformance is the cost of poor quality caused by product and service failure (for example, rework and returns).

2.1 Steps in implementing COQ activities:

2.1.1 Identification of Problem:

Phase 1: Identification of non-conformance cost

Phase 2: Quantification of Cost of Quality: Records from Production, Operation, Accounting records were used in the gathering of information of quality costs at the company.

Table 1: Generic CoQ models and cost categories

Generic model	Cost/activity categories
P-A-F Models	Prevention + appraisal + failure
Crosby's Model	Prevention + appraisal + failure + opportunity
Opportunity or intangible cost models	Conformance + non-conformance Conformance + non-conformance + opportunity Tangibles + intangibles P-A-F (failure cost includes opportunity cost)
Process cost models	Conformance + non-conformance
ABC models	Value-added + non-value-added

2.1.2 Identification of Cost associated with the problem:

These are Prevention cost, Appraisal cost, Internal Failure cost and External Failure cost. E.g. Scrap costs: labour, consumables and other costs that cannot be recovered, re-work and repair such as gears and steel casting, re-inspection and retesting of reworks viz. conducted by the production senior personnel, etc.

I. <u>Prevention costs</u>: These costs are associated with the design, implementation and maintenance of the total quality management system. Prevention costs are planned and are incurred before actual operation.

II. <u>Appraisal costs</u>: These costs are associated with the suppliers and customers evaluation of purchased materials, processes, intermediates, products and services to assure conformance with the specified requirements.

III. <u>Internal failure costs</u>: These costs occur when the results of work fail to reach designed quality standards and are detected before transfer to customer takes place.

IV. <u>External failure costs</u>: These costs occur when products or services fail to reach design quality standards.

3. ROBUST DESIGN

Robust design is an "engineering methodology for improving productivity during research and development so that high-quality products can be produced quickly and at low cost". The idea behind robust design is to improve the quality of a product by minimizing the effects of variation without eliminating the causes (since they are too difficult or too expensive to control). His method is an off-line quality control method that is instituted at both the product and process design stage to improve product manufacturability and reliability by making products insensitive to environmental conditions and component variations. The end result is a robust design, a design that has minimum sensitivity to variations in uncontrollable factors. Robust Design, which is capable of:

i. Making product performance insensitive to raw material variation, thus allowing the use of lower grade alloys & components in most cases,

ii. Making designs robust against manufacturing variation, thus reducing labor &material cost for rework & scrap,

iii. Making the design least sensitive to the variation in operating environment, thus improving reliability and reducing operating cost, and

iv. Using a new structured development process so that engineering time is used more productively.

3.1 Steps in Implementing Robust Design:

3.1.1 System Design:

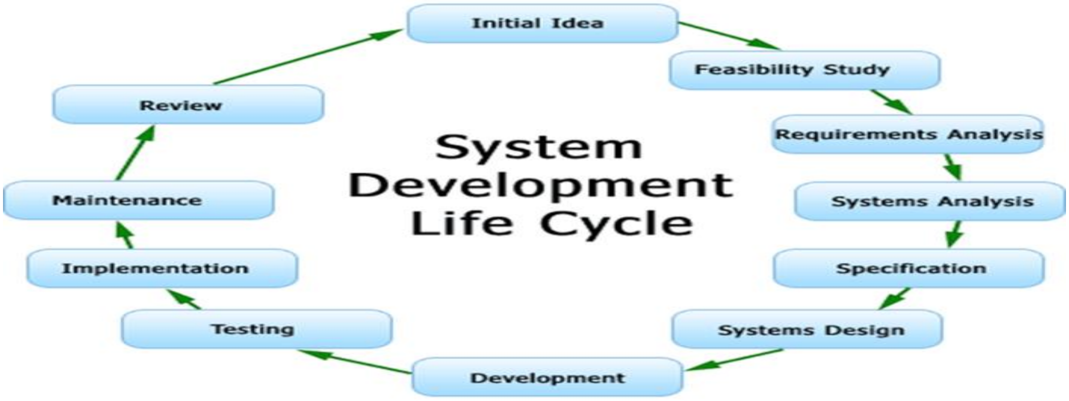
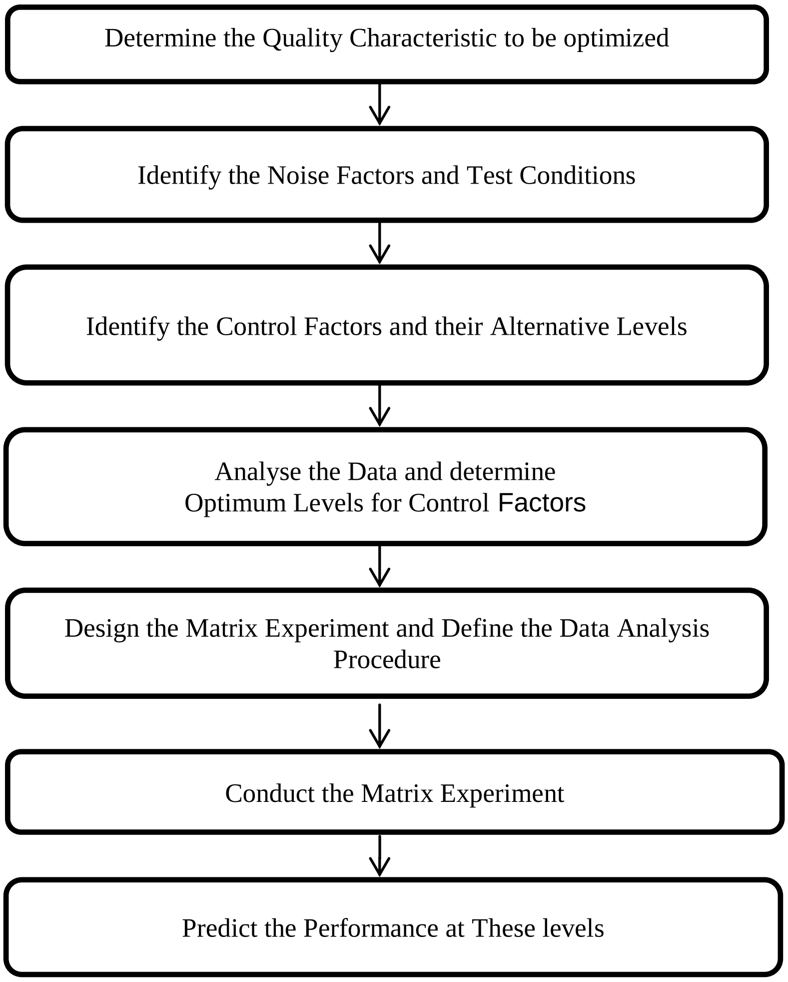


Figure 1: System Design

System design involves the development of a system to function under an initial set of nominal conditions. System design is the process of defining the architecture, components, modules, interfaces, and data for a system to satisfy specified requirement. It is the initial stage of product development. System design requires technical knowledge from science and engineering.

3.1.2 Parameter Design:



Flow chart 1: Steps in implementing Robust Design

The following are the steps to be implemented in Parameter design:

I. Determine the Quality Characteristic to be optimized:

The first step in the Taguchi method is to determine the quality characteristic to be optimized. The quality characteristic is a parameter whose variation has a critical effect on product quality. It is the output or the response variable to be observed. Examples are weight, cost, corrosion, target thickness, strength of a structure, and electromagnetic radiation.

II. Identify the Noise Factors and Test Conditions:

The next step is to identify the noise factors that can have a negative impact on system performance and quality. Noise factors are those parameters which are either uncontrollable or are too expensive to control. Noise factors include variations in environmental operating conditions, deterioration of components with usage, and variation in response between products of same design with the same input.

III. Identify the Control Parameters and Their Alternative Levels:

The third step is to identify the control parameters thought to have significant effects on the quality characteristic. Control (test) parameters are those design factors that can be set and maintained. The levels (test values) for each test parameter must be chosen at this point. The number of levels, with associated test values, for each test parameter define the experimental region.

IV. Design the Matrix Experiment and Define the Data Analysis Procedure:

The next step is to design the matrix experiment and define the data analysis procedure. First, the appropriate orthogonal arrays for the noise and control parameters to fit a specific study are selected. Taguchi provides many standard orthogonal arrays and corresponding linear graphs for this purpose. After selecting the appropriate orthogonal arrays, a procedure to simulate the variation in the quality characteristic due to the noise factors needs to be defined. A common approach is the use of Monte Carlo simulation (Phadke, 1989). However, for an accurate estimation of the mean and variance, Monte Carlo simulation requires a large number of testing conditions which can be expensive and time consuming. As an alternative, Taguchi proposes orthogonal array based simulation to evaluate the mean and the variance of a product's response resulting from variations in noise factors. With this approach, orthogonal arrays are used to sample the domain of noise factors. The diversity of noise factors are studied by crossing the orthogonal array of control factors by an orthogonal array of noise factors as shown in Figure 4. The results of the experiment for each combination of control and noise array experiment are denoted by Yi, j.

V. Conduct the Matrix Experiment:

The next step is to conduct the matrix experiment and record the results. The Taguchi method can be used in any situation where there is a controllable process (Phadke, 1989; Wille, 1990). The controllable process can be an actual hardware experiment, systems of mathematical equations, or computer models that can adequately model the response of many products and processes.

Noise Orthogonal Array

	1	2	3	4
N1	1	1	2	2
N2	1	2	1	2
N3	1	2	2	1

Control Orthogonal Array

	A	B	C	D	Y i,j				Mean	Std
1	1	1	1	1						
2	1	2	2	2						
3	1	3	3	3						
4	2	1	2	3						
5	2	2	3	1						
6	2	3	1	2						
7	3	1	3	2						
8	3	2	1	3						
9	3	3	2	1						

Figure 2: Orthogonal Array Based Simulation Algorithm

VI. Analyze the Data and Determine the Optimum Levels:

After the experiments have been conducted, the optimal test parameter configuration within the experiment design must be determined. To analyze the results, the Taguchi method uses a statistical measure of performance called signal- to-noise (S/N) ratio borrowed from electrical control theory (Phadke, 1989). The S/N ratio developed by Dr. Taguchi is a performance measure to choose control levels that best cope with noise (Bryne and Taguchi, 1986; Phadke, 1989). The S/N ratio takes both the mean and the variability into account. In its simplest form, the S/N ratio is the ratio of the mean (signal) to the standard deviation (noise). The S/N equation depends on the criterion for the quality characteristic to be optimized. While there are many different possible S/N ratios, three of them are considered standard and are generally applicable in the situations below:

i. ***Biggest-is-best*** quality characteristic (strength, yield),

ii. ***Smallest-is-best*** quality characteristic (contamination),

iii. ***Nominal-is-best*** quality characteristic (dimension).

Whatever the type of quality or cost characteristic, the transformations are such that the S/N ratio is always interpreted in the same way: the larger the S/N ratio the better. As an example, Figure 5 presents plots of S/N for two control parameters (temperature) t1 and t2, studied at 3 levels. An examination of the S/N plots reveal that parameter level setting for t2 has a larger effect on the quality characteristic then t1. Clearly both parameters should be set at level one to optimize the quality characteristics.

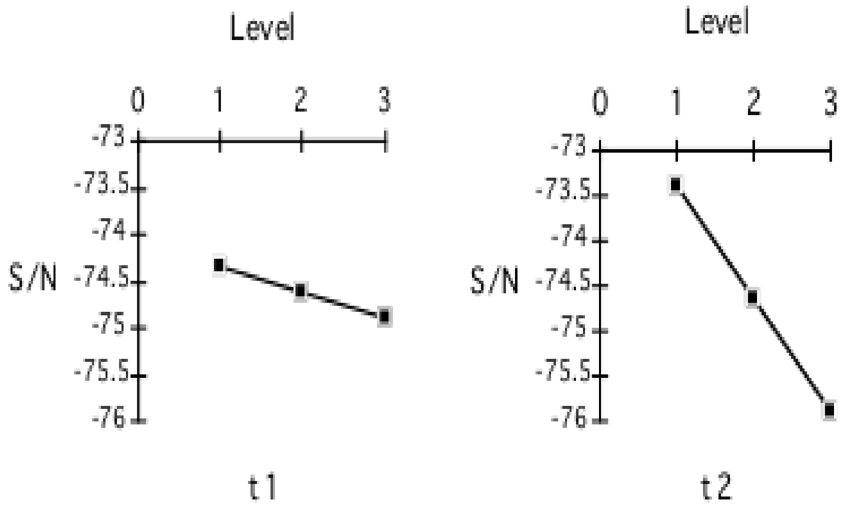


Figure 3: S/N Ratios for two control Parameters

VII. Predict the Performance at These Levels:

Using the Taguchi method for parameter design, the predicted optimum setting need not correspond to one of the rows of the matrix experiment. This is often the case when highly fractioned designs are used (Bryne and Taguchi, 1986; Phadke, 1989). Therefore, as the final step, an experimental confirmation is run using the predicted optimum levels for the control parameters being studied.

3.1.3 Tolerance Design:

The final step in Taguchi's robust design approach is tolerance design; tolerance design occurs when the tolerances for the products or process are established to minimize the sum of the manufacturing and lifetime costs of the product or process. In the tolerance design stage, tolerances of factors that have the largest influence on variation are adjusted only if after the parameter design stage, the target values of quality have not yet been achieved.

Most engineers tend to associate quality with better tolerances, but tightening the tolerances increases the cost of the product or process because it requires better materials, components, or machinery to achieve the tighter tolerances as we discussed in earlier chapters. Taguchi's parameter design approach allows for improving the quality without requiring better materials or parts and makes it possible to improve quality and decrease cost. (Phadke, 1989)

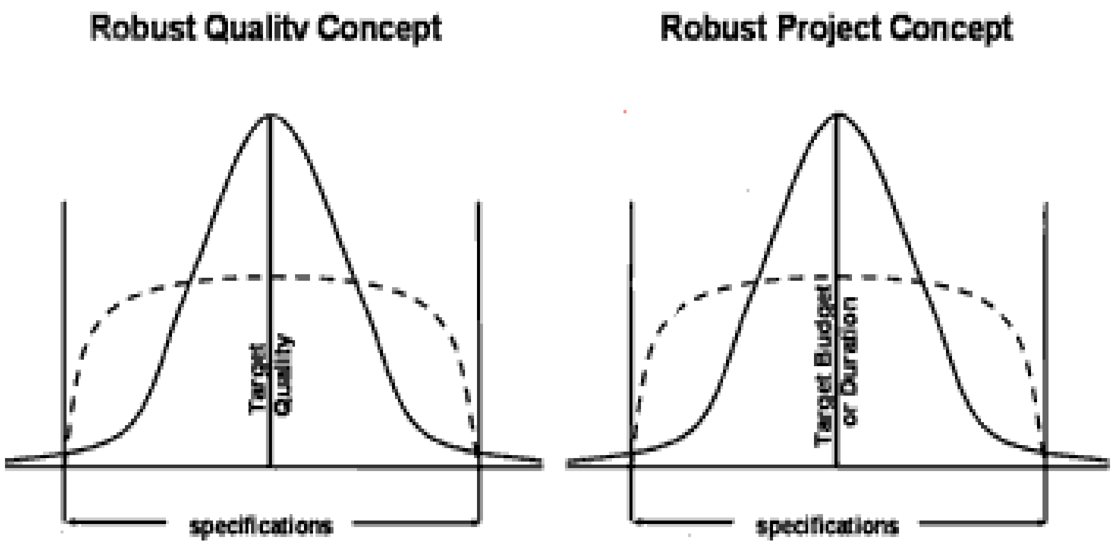


Figure 4: Tolerance design

4. MINITAB SOFTWARE

Minitab uses Monte Carlo simulation and parameter optimization. It helps you assess product results and identify the best strategy for meeting product specs. In our methodology it is basically used for outputs obtain from Design of Experiments (DOE) by using taguchi design. The following outputs and their graphs were of utmost importance to determine the optimum level of parameters, viz.

4.1 Calculation of mean, Standard Deviation and Signal to Noise ratio

4.2 Graphical representation for optimum value at various levels obtained from robust design approach

5. MEASURE OF COST OF QUALITY

The robust design approach reduces the loss due to poor quality due to work carried out at optimum level conditions. It will basically deal with the following approach:

5.1 The cost of quality at previous level were studied.

5.2 The cost of quality at optimum levels obtained from Robust Design approach is also studied.

5.3 Comparison from the results are drawn.

6. CONCLUSION

Effective analysis can be carried out by the various steps implemented for reducing cost of quality by using robust design methodology. . The dimensional tolerance plays an important role in acceptance and rejection of a product. Any product that fails to reach the target value is termed as loss in robust design, in contrast to traditional design approach where product with in a tolerance range are accepted as product of good quality. Significant research has been done on various aspects of quality still the area of taguchi quality loss function is unexplored in various fields of manufacturing such as dimensional tolerance of a product, relating cost of quality of a product with robust design, etc. Robust design is the ultimate analysis for reduction in cost of quality of any component.

REFERENCES

[1] Zillur Rahman and Faisal Talib, "Taguchi's Robust Design Method", American J. of Engineering and Applied Sciences Publications, 2010

[2] Dobrin Cosmin, Stănciuc Ana-Maria, "Cost of Quality and Taguchi Loss Function", Inzinerine Ekonomika-Engineering Economics, 2006

[3] Adil and A. Moutawakil, The Quality Cost Reduction in Hollow Glass Manufacturing by Taguchi Method, Journal Of Scientific Research Publications, 2011

[4] Edwin B. Dean, "Taguchi Approach to Design Optimization For Quality And Cost: An Overview", International Journal of Latest Trends in Engineering and Technology (IJLTET), 2006

[5] Shinn-Liang Chang, Jia-Hung Liu, Kai-Wei Jin, Ching-Hua Hung, and Shang-Hsin Chen, "Design Optimization for Robustness Considering the Gear Transmission Error", Advance online publication, 2002

[6] Mohd. Muzammil, Prem Pal Singh, and Faisal Talib3, "Optimization of Gear Blank Casting Process by Using Taguchi's Robust Design Technique", American J. of Engineering and Applied Sciences Publications, 2003

[7] Prof. K.Gopinath & Prof. M.M. Mayuram," Gear Manufacturing", International Journal of Latest Trends in Engineering and Technology (IJLTET), 2008

[8] N. M. Vaxevanidis, G. Petropoulos, J. Avakumovic, A. Mourlas, "Cost of Quality Models and Their Implementation In Manufacturing Firms", International Journal for Quality research UDK, 200

[9] Joseph Juran, "Quality Cost Analysis: Benefits and Risks", Juran's Quality Control Handbook, McGraw-Hill, 2006

[10] Shyam Mohan., "Robust Design," International Journal of Innovative Technology and Exploring Engineering (IJITEE), 2002

[11] Dasthagiraiah, N. V. Subba Reddy , N. Ramanamma, K. Harshavardhan Reddy, V. Naresh Reddy, K. Rama Devi, "Analyse Gear Failures and Identify Defects in Gear System for Vehicles Using Digital Image Processing", IOSR Journal of Electronics and Communication Engineering (IOSR-JECE), 2013

[12] Mats Akerblom, "Gear Noise and Vibrations", American J. of Engineering and Applied Sciences Publications, 2012

[13] B P Gautham, Nagesh Kulkarni, Janet K. Allen, "Robust Design of Gears with Material and Load Uncertainties", IOSR Journal of Engineering (IOSRJEN), 2004.