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**LOSS FUNCTION: AN ANALYTICAL TOOL OF
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Loss Function: An Analytical Tool of Taguchi Techniques for Quality Engineering

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Abstract – *The Taguchi philosophy is a new point of view in the statistical decision instead of classical dichotomic type of decision good/bad, with the principal goal of improving quality of products in the industrial practice. In the present paper are introduced some new adaptive models of Taguchi's loss functions using statistical software. We propose quality loss laws, which are symmetrical and asymmetrical distributions, and therefore more adequate models, which give a better approximation in the real world.*

This paper presents a new approach to determining economical values for manufacturer lower and upper specification limits using a newly derived hybrid function for expected cost. The identification and use of specification limits are essential in protecting the producer from shipping defective products that pass unnoticed due to measurement error. This cost function is composed of four parts: a generic Taguchi loss function, a function for rework cost, a function for scrap cost, and a function that describes a variance to cost tradeoff. The expected cost function does not assume the process mean to be equal to the target value of the process nor is it restricted to being symmetrical. The cost function is implemented among different production systems and optimal values of manufacturer lower and upper specification limits are determined for each system.

In this study, the Taguchi method is utilized to discover the optimal cutting parameters in turning operations. The orthogonal array, the signal-to-noise proportion, and investigation of fluctuation are utilized to study the execution qualities in turning operations of AISI 1030 steel bars utilizing Tin covered tools. The model was created at first for unidiameter case and afterward acclimates to other workpiece geometries. An Adaptive Neuro Fuzzy Inference System (ANFIS) is proposed in this paper to control a consistent cutting power turning process under different cutting conditions. The ANFIS comprises of two parts: indicator and the fuzzy rationale controller. The step size of the indicator and the scaling components of the fuzzy controller are balanced for guaranteeing soundness and acquiring optimal control exhibitions. The Taguchi-genetic method is connected in this paper to hunt down the optimal control parameters of both the indicator and the fuzzy controller such that the ANFIS controller is an optimal controller. PC reenactments are performed to check the viability of the above optimal fuzzy control plan composed by the Taguchi-genetic method.

Keywords: *Quality loss functions, statistical distributions, software application, Scheduling, Heuristics, Algorithms, Taguchi Loss Functions, optimum specification limits, loss function.*

INTRODUCTION

Taguchi techniques for quality engineering gives engineers a powerful analytical tool that can aid in reducing developmental costs and time. Because of their relevance and usefulness, these techniques have been widely adopted. The three step method (system design, parameter design and tolerance design) based on the role of variation in determining the economic and process performance of products has revolutionized modern quality thinking. The concept of designing products with the performance insensitive to environmental conditions through the use of design of experiment techniques is a cornerstone of this methodology for

quality engineering. The "robust design" concept advocates the use of experimental techniques to determine the "best" nominal values for the important control variables. According to Taguchi, "The role of design optimization is to minimize sensitivity to all noise factors - external noise, manufacturing variation and deterioration of parts."

Typically, these losses are represented by a quadratic function that assigns a pecuniary cost to specific performance variable at a specific time, usually the time of product manufacture. Based upon this analysis, quality improvement may be realized through minimization of the loss function.

In this paper, we explore the effect of time on the loss function when a quality characteristic variable is allowed to vary over time. In a previous paper, it was hypothesized that the performance characteristics of manufactured products would change due to wear, aging and deterioration.^{^]} These changes greatly impact the reuse

of products such as was suggested in the demanufacturing concept. Quality characteristics are random variables with probability density functions characterized by means and variances. Here, we assume that the quality characteristic means and variances are functions of time. Since products have variable useful lives, it is necessary to consider product reliability.

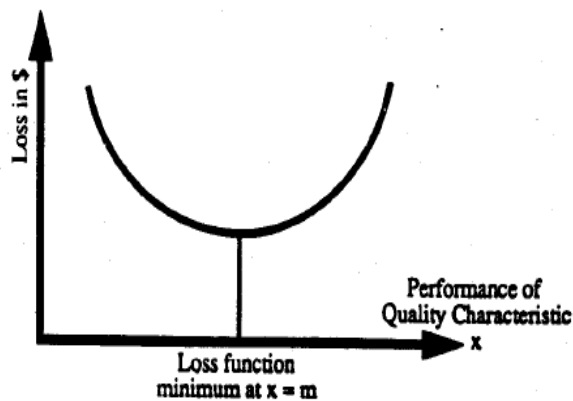


Figure 1: Taguchi's Loss Function

From the practical point of view, the goal of Taguchi methods is to find a trade-off between quality loss and product price. The equilibrium between levels of different factors, robust tolerance design, and costs is based on two main concepts proposed by Taguchi: quality loss function and signal/noise ratio.

In the competitive market, the company that holds customer confidence with on-time delivery of defect free, reliable products and services is the company that will succeed. Customer satisfaction cannot be a frill or a fluke; it is imperative for companies wishing to earn or maintain world-class stature. Quality is then a gateway to success in the global free-for-all for customer satisfaction and loyalty. Quality in products and product related processes is now, more than ever, a critical requirement for success in manufacturing.

In 1986, Taguchi presented the quadratic quality loss function for reducing deviation from the target value. The objective of this quality improvement method is to minimize total losses to society. Taguchi's concept is different from the traditional concept of conformance to specifications.

Subsequently, the quadratic quality loss function has been applied in online and off-line quality control, for obtaining the economic design of control charts, of sampling plans, and of specification limits. The advantage of the quadratic loss function is that it is

simple and many mathematical methods are readily available.

In order to reduce expected losses with respect to the quadratic loss function, the process mean should be close to the target and process standard deviation should be small. Thus, if the quality characteristic concentrates on the target value with minimum standard deviation, then it is said that the product has minimum quality loss. However, evidently the quadratic loss function is inappropriate in many situations.

According to Taguchi's quality engineering philosophy and methodology, there are three important steps in designing a product or process: system design, parameter design and tolerance design. The aim of system design is to create a product that indeed possesses the properties intended for it at the planning stage. This involves the development of a prototype, choice of materials, parts, components, assembly system and manufacturing processes, so that the product fulfils the specified conditions and tolerances at the lowest costs.

Parameter design tries to determine the connections between controllable and noise factors, in order to ascertain the best combination of factor levels in the manufacturing process, having the purpose of achieving robustness, and improving quality, without increasing costs.

In the last stage, tolerance design tries to narrow the ranges of the operating conditions, so that the most economical tolerances are obtained. According to Taguchi's viewpoint, the quality loss function is a measure for the evaluation of deviations from the target values of the product, even when these lie within specifications. The literature indicates three type of tolerances: "the nominal - the best", "the smaller - the better", "the larger - the better", and, therefore, there are three resulting classes of loss functions. "The nominal - the best" type is required in many cases when a nominal characteristic can vary in two directions. Various studies proposed different loss functions for evaluating the quality level in one-dimensional case.

Many researchers proposed quadratic loss function, based on approximating the continuous loss function by its Taylor theory expansion up to its quadratic term. In 2007 Fathi and Poonthanomsook used series expansion up to quartile form and developed corresponding quartile loss functions. Traditionally,, attributes of products are assessed utilizing a stage function approach. An outline target value is produced and specification limits are situated to demonstrate the maximum deviation permitted from the target value. Assuming that the trademark measurement falls inside this specification range, the product is regarded adequate. In the event that the measurement of the trademark falls outside this

range, the product is rejected. Figure (2) shows this relationship.

Taguchi showed that any deviation from a trademark's target value brings about a loss and a higher quality trademark measurement is one that will bring about negligible variation from the target value. Particularly, if a trademark measurement is the same as the target value the loss is zero, generally the loss could be measured utilizing a quadratic function. Primarily Taguchi loss functions have been utilized to measure physical aspects of a produced product. Caporaletti et al. furnish a great illustration of an provision of Taguchi methods, that joins outline of trials and Taguchi loss functions, in an assembling process environment. Chan et al. and Heredia et al. likewise utilizing Tlfs as a part of an assembling environment however in a various decision making setting.

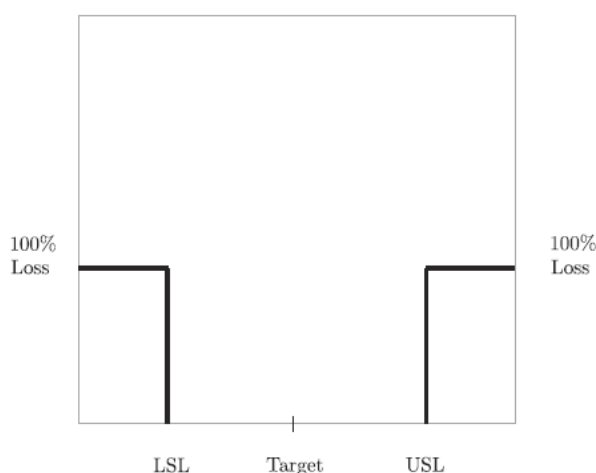


Figure 2. Traditional specification function.

Snow records four sorts of loss functions that may be utilized to figure out a metric's utility. On account of the two sided equivalent specification function and the two sided with specification inclination function, variation is permitted in both bearings from the target value. Case in point, if a shaft has a diameter target value of .010", a two sided measure up to specification function may set the lower specification at .008" and the upper specification limit could be set at .012". These settings might permit measure up to deviation from the target value in both bearings. The two favored specification inclination function is proper when deviation is permitted in both bearings from the target value yet less variation is permitted in one bearing. Utilizing the shaft diameter target value of .010" again as a case, we could set the upper specification limit at .014" and the lower specification at .008". These settings might permit more deviation from the target value in the upper specification limit bearing. In each of these figures the target demonstrates the ostensible value. USL and LSL shows the upper specification limit and the lower specification limit separately. The loss

function is a means to quantify, on amonetary scale, the loss incurred when a product or its production process deviates from the customer-desired value in terms of one or more key characteristics. This loss includes long-term losses related to poor reliability and the cost of warrantee, excess inventory, customer dissatisfaction, and eventually, loss of market share. Even though researchers attempt to construct many types of quality loss functions, there is a general consensus that the Taguchi loss function may be a better approximation for the measurement of customer dissatisfaction with product quality. Taguchi proposed three models of loss functions, which are .smaller the better., .bigger the better., and .nominal the best.. In the .smaller the better. model, the zero point is the assumed best target value. The .larger the better. case assumes some larger value as the target.

METHODOLOGY

The methodology of Taguchi's quality loss function has proved to be an efficient optimization tool for multiple characteristics. The method has been employed in the past for optimization of several processes such as gas Tungsten arc welding⁶, face milling⁷ and hot turning⁸. Multi-performance characteristic optimization using Taguchi's quality loss function employs weighting factors in the total loss function to obtain multi-response signal-to-noise ratio⁹. This paper presents the methodology of Taguchi's loss function concept for simultaneous minimization of burr height and burr thickness in drilling as a case study.

An integrated model of Taguchi loss function is proposed to solve the supplier selection problems. The Taguchi loss function is applied to calculate the loss of each selection criteria. Supplier evaluation and selection problem has been studied extensively. In contemporary supply chain management, the performance of potential suppliers is evaluated against multiple criteria rather than considering a single factor-cost. The contemporary supply management is to maintain long term partnership with suppliers, and use fewer but reliable suppliers. Extensive multi-criteria decision making approach have been earlier proposed for supplier selection, such as the analytic hierarchy process (AHP), analytic network process (ANP), case-based reasoning (CBR), data envelopment analysis (DEA), fuzzy set theory, genetic algorithm (GA), mathematical programming, simple multi-attribute rating technique (SMART), and their hybrids.

In view of the survey of the literature addressing the supplier selection problem using different tools/methods, it has been found that there is a constant need to enhance the effectiveness of the purchasing decision.

RESULT AND DISCUSSION

The best results obtained with the adapted models are with the values of the correlation coefficient closed to one and the coefficient of variance very small. In the presented case results values for correlation coefficient greater than 0.98 are obtained for polynomial, sinusoidal, generalized hyperbolic cosines, generalized shifted gamma and values for the coefficient of variance less than 0.15 are obtained for polynomial, sinusoidal, adapted hyperbolic cosines, generalized hyperbolic cosines, and generalized shifted gamma.

In this paper we suggest using the Taguchi loss functions as a simple method to incorporate multiple objectives into a single objective function for search algorithms. A weighted Taguchi loss function can be easily incorporated into any search algorithm that uses a single objective function and offers several benefits. TLFs place a higher premium on those measurements that result in less variation from the target value and can transform characteristics having different units of measure and varying magnitude of scale into a common measurement. Higher weights may be assigned to those characteristics deemed more important and lower weights to those characteristics of lower importance. Multiple criteria can be incorporated into weighted Taguchi loss function that can be easily utilized as a single objective function within a search algorithm. Some multi-criteria manufacturing applications include. Some non-manufacturing applications that use Taguchi Loss Functions in a multiple criteria decision making context include Supplier evaluation and selection. Others include employee performance appraisal, and evaluation of domestic air travel industry There are literally over a hundred applications of Taguchi Loss Functions in ABM/Inform but there is no documented use of TLFs as proposed in this manuscript. Given these factors the application of Taguchi loss functions can be an excellent tool when faced with determining the utility of competing scheduling policies or practices.

CONCLUSION

Design and process target values for manufacturing may be determined using the Taguchi loss function concept. However, the original loss function assumed that the quality characteristics were time invariant. Products, when used, are subjected to aging, wear, corrosion and other factors which contribute to changes in the quality characteristics over time. In this paper we have removed the assumption that quality characteristics are time invariant This results in the expected cumulative loss function expressed by equation (15). As shown by the example, this function suggests that design target values might well be selected at locations other than the minimum expected loss from the time invariant equation.

The expected cumulative loss function of equation (15) has a rather simple structure and lends itself to ready application in those problems where the reliability and the wear rise effects upon the quality characteristics are known. When considering reuse of parts through remanufacturing or manufacturing, the expected cumulative loss equation better represents the losses associated with a product as the product and its components change with time.

In this paper, the upper and lower specification limits were derived using a newly derived hybrid function for expected cost. This cost function includes Taguchi loss function, rework cost, scrap cost and a variance-to cost- tradeoff. The cost function is implemented among different production systems and optimal values of manufacturer lower and upper specification limits are determined for each system. It is one way to consider costs while determining the specification limits.

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