

An Application of Taguchi Loss Function in Apparel Industry: A Case Study

Md. Imrul Kaes¹, Nusrat Tarin Chowdhury²

Abstract

Ready Made Garments (RMG) sector is the single most important and biggest manufacturing industry in Bangladesh which is earning nearly about eighty percent of the country's total foreign currency. Having more than six hundred garments factories, almost all the sewing machines and their spare parts are imported from foreign countries. At the time of manufacturing these spare parts, produces set some tolerance with the nominal value which is quite acceptable to the buyers. But Genichi Taguchi believes that for parameter design any deviation from nominal value causes loss to the society including producer and buyer even though parameters are well within specification limits designed by the producer or given by the buyer. This paper deals with a case study which shows the monetary loss from a sewing machine part though the producer is supplying the part within specification limit by applying Taguchi Loss function.

Keywords: Taguchi Loss function, Goal post view of quality, nominal value, tolerance, upper specification limit, lower specification limit.

1. Introduction

In recent years, Bangladesh has been successful in expanding exports particularly in the RMG, Textile and clothing sectors. RMG alone accounts for more than 80% while more than 50% of the exports are destined of EU block. Bangladesh has been successful in expanding exports, particularly in textile and clothing. Nevertheless, this progress is threatened by the country's poor reputation for conformity to standards, which in turn undermines all efforts to convince markets to trust Bangladesh sourced products and their associated certification. In these circumstances, as RMG sector is very important for this country, this research aims to provide a guideline regarding how to calculate quality loss using Taguchi Loss Function (TLF) (kaes and A. Azeem Report 2009),

A loss function is a way of expressing the effects of an event in a numerical manner. One of the best known loss functions is a Taguchi loss function, named after its creator, Genichi Taguchi. A Taguchi loss function deals with the effects of a performance variation. The function states that the loss this causes to the company varies in proportion to the square of the deviation by which the actual performance varies from the actual output. The quality loss function developed by Genichi Taguchi considers three cases, nominal-the-best, smaller-the-better, and larger-the-better (A. A. Hasin, report 2007).

Taguchi says that as soon as quality characteristics depart from its exact mean or target, performance starts deteriorating with increased customer dissatisfaction, although the measurement may be well within the specification limits. Thus departure from mean is a quality loss, because the part may require rework at extra time and cost. Taguchi expresses this quality loss as a quadratic function, known as Quality Loss Function (QLF).

Taguchi provides an effective technique to assess the benefit a product is going to deliver prior to production. His methodology can be utilized as a troubleshooting methodology for problem solving; a simple quadratic loss function that is associated with the deviation from the best possible target value of quality characteristics being assessed. Verification of the methodology can be seen in reduced variability about a target showing a decrease in loss that is inversely proportional to the

¹ Senior Lecturer, BGMEA University of Fashion & Technology (BUFT), Bangladesh.

² Assistant Professor, Bangladesh University of Engineering & Technology (BUET), Bangladesh

increase in quality. The quality loss is taken to mean a cost to the customer (and the effect to the market share) as well as the company cost overheads through scrap or rework and loss of productive time. Hence this has been termed by Taguchi as a "loss to the whole society".

Taguchi insists that quality should be ensured at the design stage, not a factor to be controlled at the production stage. If the design is robust, then not many things are left for control at the shop floor. Taguchi methodology emphasizes the importance of parameter design in the total design process - a stage which is often neglected in industrial design practice. The methodology involves the identification of those parameters which are under the control of designer and then the establishment of series of experiments to establish that subset of those parameters which has the greatest influence on the performance and the variation of the design (W.M. Chan and R. N. Ibrahim Report 2004). The designer thus is able to identify the components of a design which most influence the desired outcome of the design process.

With parameter design, the process involves testing the nominal features or process elements to determine the product or process operating parameters least susceptible to the influences of environment and any uncontrollable factors ("noise" as Taguchi calls it). Then tolerance design can be used to further tighten the tolerance of factors shown to have a large impact on variation. By utilizing the Loss Function here, the benefit of upfront cost effective requirements identification for investment is obvious T. (A. Festervand, R. B. Kethley, and B. D. Waller Report-2001).

2. Traditional Goal Post View of Quality

Quality is a concept whose definition has changed over time. In the past, quality means "conformance to valid customer requirement". That is as long as an output fell within specification limits around a target value (also called nominal value); it is deemed conforming, good or acceptable. This is known as goal post definition of quality. The nominal value and specification limits are called the voice of the customer. Figure 1 shows the goal post view of losses arising from deviations from nominal value. That is, losses are the minimum until lower specification limit (LSL) or upper specification limit (USL) is reached. Then suddenly, losses become positive and constant, regardless of the magnitude of the deviation from the nominal value.

An individual unit of product or service is considered not to conform to a specification if it falls outside the boundary (USL or LSL) or boundaries (USL and LSL). Individual unit specifications are made up of a nominal value and an acceptable tolerance from the customer's needs. The tolerance is an allowable departure from a nominal value established by designers that is deemed non harmful to the desired functioning of the product or service. Specification limits are boundaries created by adding and / or subtracting tolerances from a nominal value, for example:

$$\begin{aligned} \text{USL} &= \text{upper specification limit} \\ &= \text{nominal} + \text{tolerance} \end{aligned}$$

$$\begin{aligned} \text{LSL} &= \text{lower specification limit} \\ &= \text{nominal} - \text{tolerance} \end{aligned}$$

There are some situations for which deviation from target on either side is possible. In other words, whether there are two sided specifications or a one sided specification, the goal is to have increased consistency, implying minimal variation in performance and thus increased predictability and reliability of the outcomes.

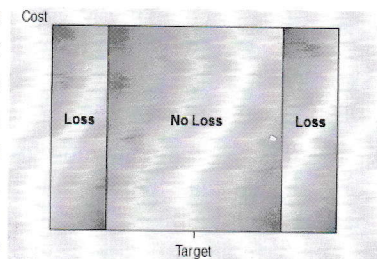
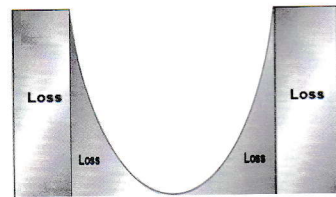


Figure 1: Goal post view of quality.

3. Quality Loss Function

Figure 2 shows more realistic loss curves in which losses begin to accumulate as soon as a quality characteristic of a product or service from the nominal value. As with the goal post view of quality, once the specification limits are reached, the loss suddenly becomes positive and constant, regardless of the deviation from the nominal value beyond the specification limits.

The continuous improvement view of quality was developed by Genichi Taguchi. The quality loss function (QLF) or Taguchi Loss Function, called the Loss curve in Figure: 2 expresses the loss of deviating from the nominal specifications. A parabolic representation that estimates the quality loss, expressed monetarily, the results when quality characteristics deviate from the target values. The cost of this deviation increases quadratically as the characteristic moves further from the target value.



Nominal Value Figure
2: Realistic view of quality.

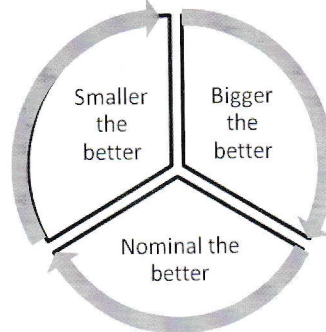


Figure 3: Classification of losses.

The standard representation of the loss function demonstrates few of the key attributes of loss. The target value and the bottom of the parabolic function intersect, implying that as parts are produced at the nominal value, little or no loss occurs. Also, the curve flattens as it approaches and departs from the target value. Any departure from the nominal value results in a loss. Three kinds of losses may take place:

Smaller the better: some quality factors are such that their values needed to be set as small as possible, preferably zero. Bigger the better: some quality factors are such that their values need to be set as high as possible, if possible at infinity.

Nominal the best: some quality factors are such that the best value would be the target value; neither higher nor lower values are desired (J. M Snow Report 1993).

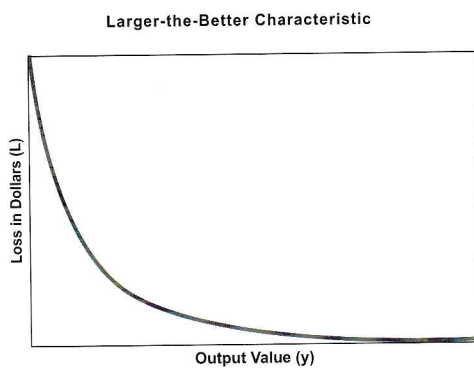


Figure 4: Loss curve related to larger the better situation.

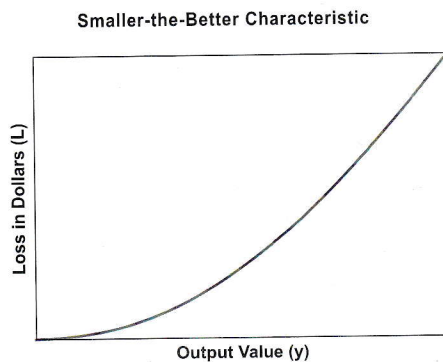


Figure 5: Loss curve related to smaller the better situation.

Table 1: Taguchi Loss Equations.

Taguchi Loss Function		
	For Single Piece	For Multiple Piece
Smaller the better	$L(y)=ky^2(1)$	$L(y)= k(\sigma^2+(y^*-m)^2) (4)$
Bigger the better	$L(y)= k(1/y)^2(2)$	$L(y)=k/\mu^2 [1+3\sigma^2/\mu^2] (5)$
Nominal the better	$L(y) = k(y-m)^2(3)$	$L(y)= k[\sigma^2+(y^*-m)^2]$ $L(y)= k[s^2+(y^*-m)^2] (6)$

Table 2: Notations of parameters Where,

y = the measured value of the quality characteristic for a particular item of product.
m = the nominal value, or target value for quality characteristic.
A = the loss (cost) of exceeding specification limits (the cost to scrap a unit of output)
d = the allowable tolerance from the nominal value that is used to determine specification limits.
$k = A/d^2 =$ a constant.
σ = population standard deviation.
s = sample standard deviation, when is unknown.
μ = population mean, if it is unknown then y^* is used.
y^* = average or mean of the measured values.

The distribution of output from a process before improvement is shown in curve A, while the distribution of output after improvement is shown in curve B. The losses incurred for unit to unit variation before process improvement is greater than the losses incurred from unit to unit variation after process improvement.

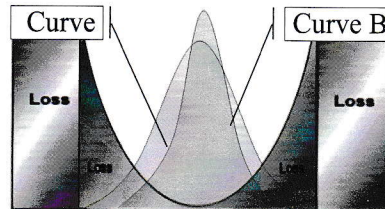


Figure 6: Loss curve before and after improvement.



Figure 7: Sewing needle connecting rod

4. Case Study

For case study, sewing machine needle connecting rod has been selected which is supplied by a well reputed Chinese company as spare parts. They manufacture the part by casting and mechanical working, heat treatment and superficial treatment are important processes of this manufacturing. The small hole diameter of the sewing machine needle connecting rod has a target value 7.95 mm. The limit has been set at 7.95+0.012 mm i.e. it is a smaller the better case. We applied Taguchi Loss Function, which does not accept any deviation from the target of 7.95 mm and benefit loss is required with certain cost associates. It is estimated that average cost of benefit loss will be \$3.20 at a deviation of 0.012 mm. 100 needle connecting rod diameters (mm) have been measured.

Table 3: Specification sewing needle connecting rod.

Design parameters	Specification
Material	S15C
External diameter	11.1
Internal diameter of the large hole	8.72+0.012
Internal diameter of the small hole	7.95+0.012
Thick measure	19.1-0.1
Distance measure	47.6±0.1
Surface treatment	S4
H.L.	0.2-0.3
H.V.	550-750

Table 4: Diameter of 100 needle connecting rod.

7.956	7.960	7.951	7.954	7.952
7.961	7.955	7.958	7.957	7.962
7.961	7.957	7.954	7.959	7.957
7.951	7.962	7.961	7.959	7.958
7.955	7.953	7.954	7.955	7.951
7.959	7.950	7.951	7.960	7.952
7.953	7.955	7.961	7.950	7.960
7.954	7.950	7.961	7.954	7.953
7.955	7.952	7.960	7.951	7.951
7.958	7.950	7.957	7.956	7.959
7.961	7.951	7.951	7.958	7.961
7.955	7.956	7.956	7.956	7.959
7.954	7.959	7.957	7.959	7.950
7.960	7.959	7.957	7.959	7.957
7.954	7.962	7.957	7.953	7.953
7.954	7.955	7.959	7.962	7.956
7.952	7.958	7.956	7.957	7.955
7.961	7.954	7.959	7.959	7.958
7.960	7.953	7.959	7.955	7.953
7.954	7.958	7.950	7.960	7.958

The information those have been derived from the Table 3 and Table 4 are shown in the Table 5.

Table 5: Experiment parameters.

Sample Standard Deviation, s	0.003 mm
Mean, y*	7.956 mm
Sample Size, n	100
Target, m	7.95 mm
Tolerance	0.012 mm
Upper Control Limit, UCL	7.962 mm
Maximum Loss Per Part	3.2 \$

Using equation (1) and equation (2), the data of Table 6 and Figure 6 have been found.

Table 6: Monetary loss when diameter deviated from target.

Diameter	Deviation	Loss,\$
7.950	0.000	0.00
7.951	0.001	0.02
7.952	0.002	0.09
7.953	0.003	0.20
7.954	0.004	0.36
7.955	0.005	0.56
7.956	0.006	0.80
7.957	0.007	1.09
7.958	0.008	1.42
7.959	0.009	1.80
7.960	0.010	2.22
7.961	0.011	2.69
7.962	0.012	3.20

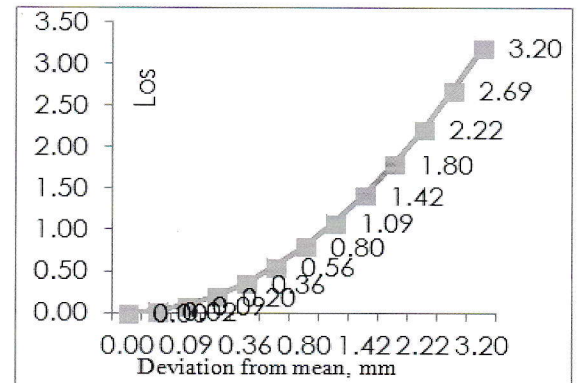


Figure 8: Monetary loss when diameter deviated from target

Table 7: Results of the experiment.

Taguchi Constant, k	22222.22222
Average Loss Per Part, \$	1.1002
Total loss for the whole sample \$	110.0177

Table 8: New specification limit for maximum future allowable loss.

Expected Loss per part, \$	=	0.100
Tolerance, mm	=	0.0003
Upper Specification limit, USL, mm	=	7.9503

If the manufacturing company decides to keep the loss within ten cents per part, they should have the tolerance within +0.0003 mm and upper specification limit (USL) 7.9503 mm which has been derived by using equation (2).

5. Conclusion

A detail analysis has been done to customize Taguchi Loss function to the apparel industry situation. It might open up a new view of seeing quality, especially for the buyers in terms of monetary loss and for the suppliers for goodwill/business loss and above all the loss of whole society. This Taguchi Loss Function can be used not only for mechanical parts but also for service organizations as well.

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