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Establishment of QC Target based on Quality Cost

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ABSTRACT

On-line QC by Taguchi has two approaches of: the cost-oriented (cost-emphasis) QC and the process-oriented (quality-emphasis) QC. The main concern of this paper is to estabilish and recommend a desirable one as a QC target.

Simulation is employed to solve the question, and the failure cost (A), appraisal cost (B), and prevention cost (C) are adopted as decision variables.

In conclusion, the process-oriented QC is the recommendable approach as far as there is no remarkable cost difference between the two approaches and possible to apply on.

1. Introduction

The term of establishment of QC target is able to interpret in two ways. The one, which is well-known, is to find a target value of quality characteristics of process distribution for economic control.

Springer (1951), Bettes (1962), Hunter and Kartha (1977), Carlsson (1984), Hunter and Pallesen (1984) and etc. suggest the most economic values as a control target under different conditions.

The other one means an approach manner of quality control. Taguchi (1984), (1986) describes on the two approaches of the cost-emphasis QC and the quality-emphasis QC in his on-line quality control. And Lee, Sang-Do and Lee, Dong-Choon (1985) named cost-emphasis QC by Taguchi as the cost-oriented QC, and quality-emphasis QC as the process-oriented QC, and they suggested the two cost functions as a criterion for choosing one.

Now a days, Taguchi philosophy prevails not only in Japan but in other countries. Even though Taguchi's methodology has some criticism such like Shaimin (1986) did. Taguchi (1984) insisted

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on the quality-emphasis (process-oriented) QC and exhibited the superiority by a numerical example. Against that point, Lee Sang-Do and Lee Dong-Choon (1985) suggested that the decision making should be base on total loss function which included inspection cost, process control cost, and penalty cost.

On the other hand, it is known that the quality cost has the big 3 cost items such appraisal, prevention, and failure cost. So we can suppose that the loss function suggested by Taguchi will be changed according to the constitutional ratio of the cost items. So, this paper introduces the Taguchi philosophy and methodology firstly, and then finds the better approach by simulation to establish QC target.

2. The Concept of Taguchi Philosophy and Methodology

2.1 Taguchi Philosophy

Taguchi (1986) says that the quality of a product is the (minimum) loss imparted by the product to the society from the time the product is shipped. Where, the loss is restricted to two categories:

(1) Loss caused by harmful side effects

(2) Loss caused by variability of function

For example, Losses by air pollution, waste water, etc., so called negative utilities of production belong to (1), and losses by consumer's dissatisfaction, added warranty cost to the producer, and losing market share in the long run belong to (2).

To minimize loss, it is important to produce product at optimal levels and with minimal variation in its functional characteristics.

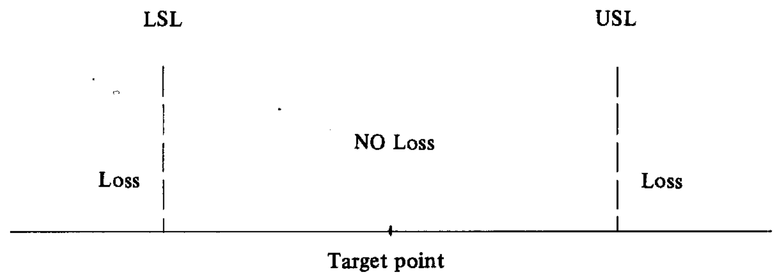

Fig. 1. Pass / Fail Interpretation of Loss

Fig. 1. Shows the pass or fail interpretation of loss. The factors which affect the product's function characteristics are of two types:

Controllable factors and noise / Uncontrollable factors. And noise factors are of three types: outer (external) noise, inner (internal) noise, and between product (variational / unit-to-unit) noise as shown in Fig. 2.

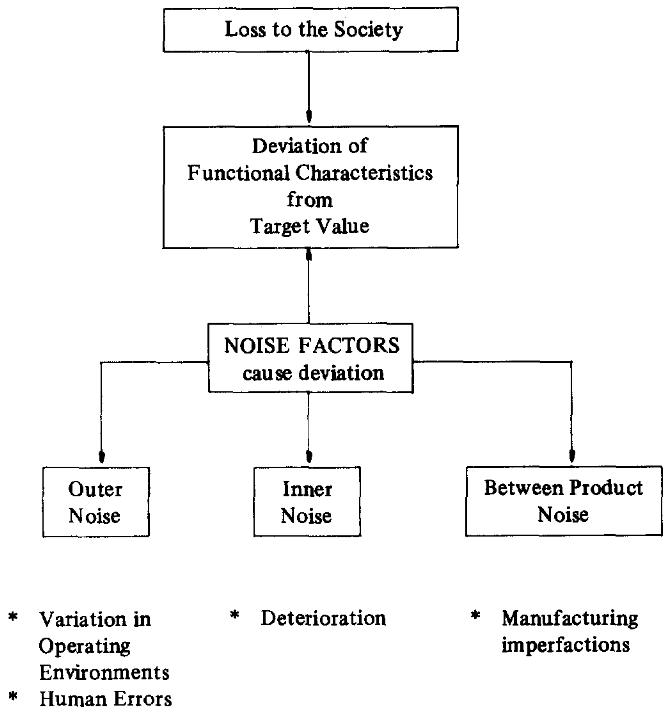

Fig. 2. Conceptional Relations between Loss and Noise Factors.

2.2 Taguchi Methodology

It is important to understand clearly on differences between the general concept on quality control and Taguchi methodology. In general concept on QC, we discriminate the process variation (i.e, noise) in chance cause and assignable cause, and try to eliminate the assignable cause by the proper counter measurement. But in Taguchi method, identifying the most guilty noise factors and attempting to control them is not true goal. Instead, it prefer to select values for controllable factors such that the product (or process) is least sensitive to changes in the noise factors. That is, instead of finding and eliminating causes (noise factors), the intent is to remove or reduce the impact of the causes.

Fig. 3 shows how the off-line quality control and on-line quality control are engaged (See, Byrne & Taguchi (1986)). Off-line QC activities involve both of product design and process design stages. And on-line QC includes the activities which try to keep the process distribution to meet specification.

Off-line quality control has three steps, so called robust design, that are involved in the engineering optimization of a product or process. The first step is system design, and which involves the selection of material, parts, equipment, and tentative product parameter values for product and process.

The second step is parameter design which determines the best combination of the product parameter values and the operating levels of process factors, which are least sensitive to change in environmental conditions and other noise factors. This is the key step for achieving high quality without an increase in cost.

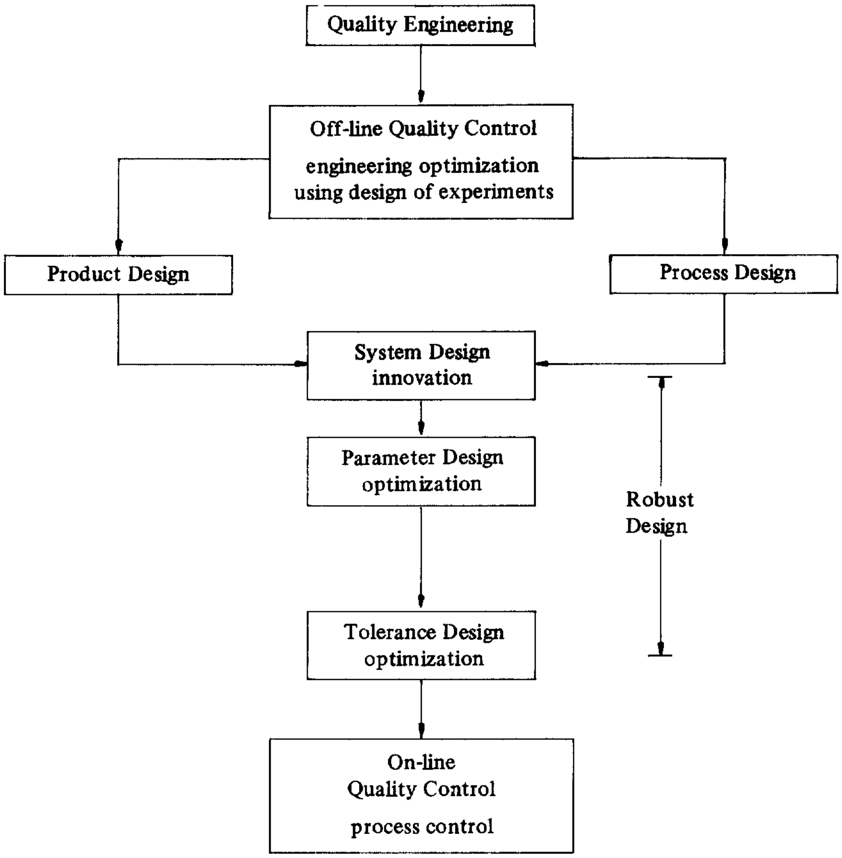

Fig. 3. Off-line QC and On-line QC.

And the last one is tolerance design which involves tightening tolerances on product parameter of process parameter of which variations impart large influence on the output variation.

Byrne and Taguchi (1986) pointed out that most American engineers jumped from system design to tolerance design, omitting the parameter design step which the Japanese do so well.

2.3 On-Line Quality Control

After a production process and operating conditions have been determined through off-line quality control stage, the following sources of product variability remain:

- variability due to materials and purchased components
- process drift, tool wear, machine failure, etc.
- variability in execution
- human error.

These sources of variability are dealt with by quality control, that is on-line or real-time quality control (See, Taguchi (1986)).

There are two types of approach in on-line quality control such as the cost-oriented (emphasis) and the process-oriented (quality-emphasis). Exhibit 1. shows the features of the both methods

Exhibit 1. The Features of the Cost-oriented QC and the Process-oriented QC

View Point	Cost-oriented Q.C.	Process-oriented QC
Controlling Philosophy	minimize total cost deduction of fraction defective	minimize deviation of product produce the products in a way
Optimization	cost	quality
Variation index	fraction defective defect	process capability loss function
Quality evaluating measure	fraction defective defect	signal to noise
Key activities	system design tolerance design product inspection* design review	system design parameter design* tolerance design process adjustment*
Inspection stage and number	along to the structure of process	along to process variation
Prevails in	U.S.A., Europe	Japan

3. Loss function of On-line QC and Simulation for Establishment of QC Target

3.1 Loss function

The total loss function, including the process control cost and the penalty cost due to variability, is given by the following equation. Detailed description about the functions is in reference (6), (7), and (8).

$$L=\frac{B}{n}+\frac{C}{U}+\frac{A}{\Delta^2}\left(\frac{D^2}{3}+\frac{n/2+l}{U}\cdot D^2\right) \quad (1)$$

$$U=\frac{D^2}{D_0^2}\cdot U_0 \quad (2)$$

$$n=\sqrt{\frac{2U_0B}{A\cdot D_0^2}}\cdot\Delta \quad (3)$$

$$D=\left\{\frac{3C}{A}\times\frac{D_0^2}{U_0}\times\Delta^2\right\}^{\frac{1}{4}} \quad (4)$$

where,
- A : Loss of a defective
- B : Measuring cost
- C : Adjusting cost
- n : Optimum measuring interval (units)
- n_0 : Current measuring interval (units)
- U : Forecasted average adjusting interval (units)

U_0 : Current average adjusting interval (units)
D : Optimum control limit
D_0 : Current control (adjusting) limit
l : Time lag of measurement (units)
Δ : tolerance

In equation (1), A, B, and C is a representative item of failure, appraisal, and prevention cost, respectively.

As mentioned above in introduction, A, B, and C varies in accordance with the types of manufacturing process and quality management policy, and then the value of equation (1) will be changed.

In this point, simulation is needed to see whether the process-oriented QC is always desirable approach than the other one or not.

3.2 Simulations for Loss Function

(1) Numerical Example and Simulation Program

Let (L_0) and (L) a loss function for the cost-oriented QC and process-oriented QC, respectively.

$$L_0 = \frac{B}{n_0} + \frac{C}{U_0} + \frac{A}{\Delta^2}\left\{\frac{D_0^2}{3} + \left(\frac{n_0}{2} + l\right) \cdot \frac{D_0^2}{U}\right\} \tag{5}$$

$$L = \frac{B}{n} + \frac{C}{U} + \frac{A}{\Delta^2}\left\{\frac{D^2}{3} + \left(\frac{n}{2} + l\right) \cdot \frac{D^2}{U}\right\} \tag{6}$$

And the process capability is computed from the next equations.

$$C_{p_0} = \frac{2\Delta}{6\sqrt{\frac{D_0^2}{3} + \left(\frac{n_0}{2} + l\right) \cdot \frac{D_0^2}{U_0}}} \tag{7}$$

$$C_p = \frac{2\Delta}{6\sqrt{\frac{D^2}{3} + \left(\frac{n}{2} + l\right) \cdot \frac{D^2}{U}}} \tag{8}$$

For the simulation, let us give a numerical example from Taguchi (1984).

[Numerical example]

In a continuous emulsion coating process, the viscosity of emulsion is controlled. The specification of coating thickness is $m + 8$ (μm), the loss when thickness becomes out of specification is 30,000 (won) per m^2. When the viscosity of emulsion, X, is changed by one pois, the effect on thickness is 1.5 (μm).

The average adjusting interval is 12,000 m^2 (equivalent to once a half day). The measurement cost, B, of viscosity, X, is 20,000 (won). The adjusting cost, C, of viscosity is 100,000 (won) and the time lag of measurement, l, is 30 m^2. Determine the optimum measuring interval, n, the optimum control limit, D, and the saving per week of 40 hour operation.

Solution:

$$\Delta = \frac{\text{Tolerance of objective characteristic}}{\text{linear coefficient}} = \frac{8}{1.5} = 5.3$$

So the parameter values from equation (2) - (8) are summarized as Table 1.

Table 1. Computational Results for the Numerical Example.

Production Units / Day : 12,000 m^2 / Day	
Cost Oriented QC	Process Oriented QC
n_0 = 6,000 (m^2) (the number of times : 2)	n = 745 (m^2) (the number of times : 16)
D_0 = 0.9 (pois)	D = 0.4 (pois)
U_0 = 12,000 (m^2) (1 time / day)	U = 2,400 (m^2) (5 times / day)
Cp_0 = 2.6	C_p = 6.2
L_0 = 518 won	L = 154 won

Saving loss / Month (518 – 154) * 12000 * 30 day = 131,040,000 won

BASIC language is used for simulation and executed 100 times by SPC 3000. Failure cost (A), appraisal cost (B), and prevention cost (C) was given by random number of uniform distribution. A, B, and C is given by a proportion to total quality cost. So, the sum of A,B, and C is always equal to 1.

(2) Simulation Result and Discussion

In simulation result, the appearance frequency L_0 or L at MARK column is 59 and 41, respectively. Where, MARK indicates the less loss function L_0 or L, and DIFFERENCE is an absolute difference between L_0 and L. It means that the process-oriented QC is not always less cost than the cost-oriented QC.

And if we see C_p column, C_p is a constant value of 2.580762 when it appears L_0 at MARK column, while, C_p has much bigger value and varies when it appears L at MARK column. It means process-oriented QC is an approach to enhance the process capability.

4. Conclusions and Further Research

So far here, this paper introduced the philosophy and methodology of Taguchi, and proved the hypotheses as mentioned in introduction, by computer simulation with a given numerical example. The results are summarized as follows:

(1) Taguchi insists on the fact that the process-oriented QC is better (less cost) than the cost-oriented QC, but it is occasionally difficult to say so.

(2) The C_p values of the cost-oriented QC are all same values of 2.580762. It seems to be well matched to the philosophy of the cost-oriented QC. But in opposition, it might be contradictory to the

well-known fact that the more money we spend in prevention, the less deviation comes out, and the bigger C_p goes in a restrict region.

(3) The process-oriented QC which has process adjustment in accordance with process deviation from target value, is clearly better approach to enhance the process capability.

(4) If there is no remarkable difference in cost and it is possible to apply on, the process-oriented QC is more recommendable approach because the consistency is much better than the cost-oriented QC.

The quality cost function with parameter A, B, and C and its effect on the function by the regression analysis is under research by the authors of this paper.

REFERENCES

1. Bettes, D. C. (1962), *"Finding an Optimum Target Value in Relation to a Fixed Lower Limit and an Arbitrary Upper Limit"*, Applied Statistics 11-12, p. 203-210.
2. Bisgaard Soren, Hunter William G., and Pallesen Lars. (1984), *"Economic Selection of Manufactured Product"*, Technometrics, Vol. 26, No. 1, p. 9-18.
3. Byrne Diane M., and Taguchi Shin. (1986), *"The Taguchi Approach to Parameter Design"*, ASQC Quality Congress Transaction – ANAHEIM, p. 168-177.
4. Calrlson, O. (1984), *"Determining the Most Profitable Target Value for a Production Process under Different Sales Conditions"*, Journal of Quality Technology, Vol. 16, No. 1, p. 44-49.
5. Hunter, G. H. and Kartha, C. D. (1977), *"Determining the Most Profitable Target Value for a Production Process"*, Journal of Quality Technology, Vol. 9, No. 4, p. 176-180.
6. Lee, Sang-Do, and Lee, Dong-Choon. (1985), *"Cost-oriented QC and Process-Oriented QC; Which is more Desirable Approach?"*, Journal of the KSQC, Vol. 13, No. 2, p. 2-7.
7. Shainin Dorian. (1986), *"Better than Taguchi Orthogonal Tables"*, ASQC Quality Congress Transaction – ANAHEIM, p. 446-451.
8. Springer, C. H. (1951), *"A Method for Determining the Most Economic Position of a Process Mean"*, Industrial Quality Control, Vol. 8, No. 1, p. 36-39.
9. Taguchi Genichi. (1984), *"Quality Engineering in Japan"*, Proceedings of International Quality Symposium, Taipei, p. 29-38.
10. Taguchi Genichi. (1986), *"Introduction to Quality Engineering"*, Asian Productivity Organization, Tokyo.