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## Tolerance optimization design based on the manufacturing-costs of assembly quality

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### Abstract

Tolerance design plays a major role in the quality of the product life cycle. Its purpose not only can ensure the products quality. At the same time, it monitors the product manufacturing costs. The traditional tolerance design devotes to the optimization target of minimizing the manufacturing cost. But due to the manufacturing process of a product, there is a nonlinear relation between tolerance and cost. It disregards the problem of quality loss which cannot reach the effect of the high precision and low cost. Depending on the relationship between the manufacturing costs and tolerance, the tolerance optimization design method under the multiple correlation characteristic products is put forward, deducing the features related to quality of the product within multiple function relation between the loss and tolerance. Concentrating on the loss to the quality problems in the manufacturing process, manufacturing cost and quality loss tolerance model is created. The purpose is to improve product quality and reduce costs. Example results show that the product of multiple correlation characteristics of manufacturing cost and quality loss of tolerance optimization design model has certain validity, and compared with the traditional this tolerance design having great superiority.

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*Keywords:* quality loss; multiple correlation characteristic; manufacturing cost

### 1. Introduction

Tolerance design is an important part of the product information in the product design, manufacturing, assembly, etc. As the rapid development integration of CAD, CAPP and CAM in the field of automation, tolerance has become the link between one of the main content of the data exchange and sharing. According to the new generation geometrical product specification (geometrical product specifications, GPS) requirements, an urgent need to create to meet the function and the actual measurement and evaluation methods of the mathematical model for geometric tolerance of tolerance optimization design [1-2]. Hillary has made use of computer-aided parts geometry, the concept of dimension, form and position tolerances, algebraic equations to depict the geometry of the parts of the dimension and tolerance design. From now on Computer Aided Tolerance design has been widely concerned [3-4]. Zhang presented the simultaneous tolerance

which works in concurrent engineering contexts. The method can determine an appropriate machining process without using functional tolerances, and optimal machining tolerances, but decrease manufacturing costs [5]. Weill R proposed the tolerance requirements from the design stage to the manufacturing stage of the method to solve the problem of technology in the design of tolerance, which presented research of CAT [7]. Mao presented a nonlinear method for robust tolerance design based on actual manufacturing contexts, where simulation annealing (SA) is utilized to the nonlinear optimization [8]. In comparison with other models, the method is much more effective with manufacturing resources.

In fact, even if the product complies with the technical specification, the quality of its characteristics may far from the target, can also produce quality loss [9-10]. On the one hand, we consider the possibility of improving the accuracy of one or several parts to improve. On the other hand, we also

want to consider improving the precision of parts has increased the cost of weighing the gain and loss, only when the yield is higher than the costs by improving quality cost [12-15]. It can be stated that the design of tolerance is an optimal value. Tolerance optimization design is tantamount to seek the best balance between quality and manufacturing costs in the product performance. To proposed an algorithm to solve the discrete tolerance allocation. By this method, tolerances can be assigned in a way of fulfilling defined critical measures and minimizing manufacturing costs. Loss functions may be required [16].

When we implement the computer aided tolerance optimization design, determine the objective function model is the vital step, and that directly determines the tolerance optimization results. In the objective function, the cost of processing is the primary goal, which seeks to minimize the total processing cost, but also making the design of the quality of the product within the specified requirements, namely seeking quality loss cost minimized [17-18]. The comprehensive minimum cost as the target tolerance robust design. Wei and Lee proposed a model for determining the process tolerances of needing to take into account the capability of the process of producing workplace. In this model, a process tolerance can be obtained effectively and accurately without additional tolerances [19-20]. Wu analyzed quality of symmetric and asymmetric loss function respectively, which undertakes to improve in the tolerance of the robust design method on the basis of square quality loss model to optimize the processing cost and quality loss cost minimum [21]. Marseille analyzed the quality loss function be linear and square asymmetry in detail to get the optimization design method of tolerance found [22].

The traditional tolerance design for optimizing considers the design of the smallest manufacturing cost as the goal, but this kind of design method does not take into account the quality of the product. Tolerance loose product manufacturing cost is small, but its size characteristics change will bring larger mass loss. In the tolerance design, the following situations are frequently encountered. Firstly, the dimension of a composition link or the distribution of a closed link is complicated. Secondly, historical statistics may be inadequate, and hence the manufacturing cost-tolerance function relationship is notoriously difficult to describe. Thirdly, the relationship between the assembly performance and the dimension of a composition link is blurred. However, an experimental design method is a preferable choice. By utilizing this method, the effect tendencies among dimensions of a composition link to assembly requirements or costs can be achieved by experimental analysis. Thus, tolerances of composition links are set up. On the contrary, tight tolerance products whose diminutive size characteristics of the change sand mass loss small, but the manufacturing cost is high. Most of the tolerance optimization design model considered the manufacturing cost of tolerance design problem, without the quality loss problem. Built on the Taguchi quality loss function and studying of the extension, the quality loss function expression is obtained. In this paper, a comprehensive model based on balancing the manufacturing cost and the quality loss is proposed. To realize the multiple

correlation product quality characteristics of tolerance optimization design, the hinge assembly as the instance of the model is set up.

**2. Manufacturing-cost mathematical model**

*2.1. Taguchi quality loss function*

In the process of product design, if the quality of product features is not in accordance with the target, it may cause the quality of the product loss, and the greater the deviation, the mass loss is bigger. Taguchi quality loss function can effectively show the product quality loss. According to the Taguchi quality loss function, the product quality loss is linked to the tolerances specified value, quality loss from the target of the deviation, the deviation from the ethical relationship of value and target value. Setting up the quality of the product features on  $y$ , and the target for  $m$ . If  $y$  indicates  $m$  be not 0, it has caused economic losses, and the more deviation, the greater the loss. Quality loss function is the quantitative expression of the relationship between economic loss and function.

Eye features of loss function refer to the deviation between the quality characteristic, target value, and the relationship between monetary losses of function. When finding the minimum deviation and best quality, the quality loss obtains the smallest value. The opposite is also true. This quality characteristic of the model is:

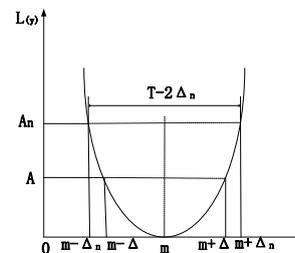


Fig.1. Quality characteristic of model

The second quality loss function is:

$$L(y) = K_Q(y - m)^2 \tag{1}$$

Here the type of  $K_Q$  is the coefficient of quality loss which reflects the unit square deviation of monetary loss.  $M$  is the subject value and  $y$  is the quality features of the product.

*2.2. Quality loss mathematical model*

Owing to the product influenced by all kinds of random factors in the processing, the output characteristic value  $y$  is a random variable. So the quality loss function  $L(y)$  is also a random number. In order to the mass loss quantitative, the quality cost usually is defined as the average of the product quality loss, which is defined as:

$$C = E[L(y)] = \int f(y)L(y)dy \tag{2}$$

The  $f(y)$  is the probability density function of  $y$ . This article mainly aims at the probability density function of normal distribution to analysis which showed in Fig.2.

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