Research on Robust Optimization Design Method Based on Random Probability Test

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Abstract. The modern robust design is based on the engineering model, and the design method is combined with the calculation technique and the optimization technique. In this paper, a robust optimization design method based on stochastic simulation test is proposed by combining the optimization design method with the robust design idea. Through the analysis of the robustness of product design approach established robust optimal design objective function; through the variable difference transmission, control design parameters of a differential effect on function design and keep the robustness of design solution; analysis of robust optimization design of quality characteristics of randomness, using probability theory and statistics, computing and processing by using the method of stochastic simulation test statistic characteristic of the quality of the products. In order to prove stochastic simulation test of robust optimization design method of the correctness, reliability and practicability, this paper to a secondary cylindrical gear reducer design example, according to the characteristic of the gear transmission design, of robust optimization design mathematical model is solved by using the constraint random direction method and the design results of general optimization and robust optimization design results are compared and analyzed. The results show that the robust optimization design shows that the gear transmission system anti-interference ability and good quality stability and high reliability.

Keywords: Robust design; optimization design; robust optimization design; probability statistics; random simulation test method

1 Introduction

Machinery industry is an important industry of a country, and it is also a pillar industry. Mechanical product design level directly affects the quality of the product. 70% of the cost of the product is determined at the design stage. Therefore, study on design method of mechanical products, and strive to improve the design level of mechanical products, to improve the economic benefit and enhance the market competitiveness of products is important. Since the optimization design was founded in the early 60's, it has played an important role in the field of engineering design. With the continuous progress of computer technology [1], the optimization design method and its theory has been developed and widely used in many fields of science and technology. After years of development and research and exploration of many experts and scholars, the optimal design has formed a set of relatively complete theoretical system and methods. But there are some deficiencies in the following aspects: (1) the ability of the general optimization design method to tolerate parameter

variation is poor, and the design result in the field of production is poor. (2) The general optimization design method, product quality control (quality fluctuations in the size of the control) can only rely on product inspection, due to the design of affecting product quality parameters variation is not considered, also can't control the quality fluctuations. After more than 20 years of development, it has formed a number of effective solutions to the engineering problems, and achieved remarkable social and economic benefits. However, from the existing information and practical applications, there are some problems in the following aspects: (1) The traditional robust design of mathematical model research is very little, so the study of robust design in the design of mathematical model is necessary. (2) There are some defects in the application of traditional robust design signal noise ratio. Therefore, how to design the product quality characteristics of the measure function to be further studied. From the above analysis, we can see that the robust design idea and optimization technology, computer technology combined to form a robust optimization design method. According to the method of product design, both at the design stage to ensure product quality robustness (by considering the variation of the design variables, and using optimization design mathematical model of many mature methods, better solve the multi variable and multi-objective, constrained problem solving. Based on the above considerations, this paper from the analysis of the robust design of statistical theory, stochastic properties of function design of computer simulation, robust optimization design mathematical model is established, based on stochastic simulation method to solve the robust optimization design mathematical model [2].

2 Robust Optimal Design Quality Criteria

Of robust optimization design mathematical model research, we must first solve is how to determine the product quality characteristics of metric function, that is, through the function expression to meet the purpose of robust design, so as to achieve the robustness of product design. In this chapter, we first review several robust design methods of the quality criteria, combined with the robust design of the original intention, and put forward a robust optimization design quality characteristics of the metric function, that is, quality criteria. Robust design is to make the design of products in both the manufacturing and use when structural parameters occur variation, or in structures within a specified life happen aging and deterioration (in a certain range) can maintain a engineering design method of product performance is stable. If the quality of the product is close to the value of the target value, it can be considered that the functional properties are more close to the target value, the better the quality, the farther away from the target value, the worse the quality. The quality characteristics of the product is y, the target value is Y0, considering the randomness of Y, if the average loss of the product is calculated, then there are the following formula:

$$E\{L(y)\} = E\{(y - y_0)^2\} = E\{(y - \bar{y})^2 + (\bar{y} - y_0)^2\}$$

$$= \sigma_y^2 + \delta_y^2$$

Fig. 1. System average loss calculation formula

2.1 Function Quality Loss Function

$$y = \beta_0 + \sum_{i=1}^{n} \beta_i x_i + \sum_{i=1}^{n} \beta_{ii} x_i^2 + \sum\sum_{i<j} \beta_{ij} x_i x_j + \varepsilon$$

$$SN = 10\lg\left(\frac{1}{\mu_y^2 + \sigma_y^2}\right) = -10\lg\left(\mu_y^2 + \sigma_y^2\right)$$

$$\hat{\mu}_y^2 = (\bar{y})^2 - \frac{S_y^2}{N} = \frac{1}{N}\left(S_m - S_y^2\right)$$

Fig. 2. System correlation formula

G. aThci put forward a new concept of product quality, he believes that the quality of the product after the market is given to the loss of society". Due to the quality of the products is fluctuant, and the product by the user using a period of time, due to the decrease in wear and accuracy, the output characteristics of not up to the target value. All of these will bring losses to the users, is the quality definition of "give society loss". For such losses, GTagcuhi is proposed to measure the quality loss function. The quality characteristics of some products is in the allowed limit is not negative, the bigger the better, the worst zero. When the output characteristic value is increased, the performance becomes better, the mass loss becomes smaller, and the ideal value is infinite. And the smaller the better. Signal to noise ratio as the quality criterion of robust design, for product quality index obey normal distribution or approximate normal distribution, and the mean and variance into changes in the proportion of, for the quality indexes of the product does not obey normal distribution or approximate normal distribution, the signal-to-noise ratio will not be able to accurately measure the quality characteristics of product design; and some of the products design cannot be determined the quality indexes of the product whether to obey normal distribution or approximate normal distribution, the blind use of signal to noise ratio as the product quality standards, may make the design result and the actual situation of different, and thus lose the practical value in engineering. In addition, the signal to noise ratio does not show that the mean value is close to the target value [3].

2.2 New Robust Design Quality Criteria

The formula of the quality loss function proposed by GaTgUchi can be seen that the goal of robust design is to minimize the loss of the quality of the design product. To this end, this paper considers the purpose of the robust design from the above, to study the way to achieve robust design purposes, to establish a mathematical model of robust optimization design. Under the condition of known design variables, the statistical characteristics of design function can be obtained by the method of mathematical statistics. In this paper, a two objective function of robust optimization is proposed, which overcomes the requirement of the

statistical distribution of the product quality characteristics in the signal to noise ratio. The precision of the optimization iteration can indicate the degree of the design value close to the target value. For general mechanical design problems, according to the theory or experience to derive the formula for the quality characteristics, no response surface fitting, the direct use of the formula to establish mathematical models. In order to fit the response surface as a quality criterion of robust design, first a few test separate the influence of product quality characteristics (response) or noise factors influence each other sieves of the main design parameters, from these tests fitted linear model, that is to say, the response model is built in test design based on design variables and response variables (or a few) function. Orthogonal experiment is needed to establish the fitting response surface, and the implementation of the test is a time-consuming and laborious process, which makes the design cycle extended and the design cost increased. A large number of analysis and test are needed to fit the model of response surface model which is close to the actual quality characteristic, but it is inevitable that there will be a lot of errors. In addition, when the relationship between the response variables and the independent variables is known, the fitting response surface is used as the quality criterion of robust design, which makes the problem complicated [4].

2.3 Stochastic Simulation Test Method

If the mean and variance of the design parameters are known, the mean value and variance of the product quality criteria can be obtained by the method of computer stochastic simulation. Stochastic simulation test method is based on statistical sampling theory, with computer as the computation method, the design parameters (random variables), the stochastic simulation, a series of random numbers, through function of design parameters and quality standards, random number of random variable function (quality standards), using the mathematical statistics theory, computing the eigenvalues function. Random simulation test is to use random variables to estimate the sample mean as the theoretical mean. The convergence and the error of the method determine the reliability and reliability of the simulation process. Therefore, it is necessary to make a qualitative analysis of its convergence and error.

3 System Performance Optimization and Design

When determining the objective function of robust optimization design (the objective function represents the quality criteria of the product), it is often related to the analysis of the random characteristics of Y, especially the less of the mean forest, and the variance. St.. Y random characteristics analysis is accurate, the relationship between the objective function can fully reflect the robustness of design products. So it is very necessary to study the method of mean and variance of quality characteristics. As mentioned before, the product quality index y is a linear or nonlinear function of controllable factors X and uncontrollable factor Z, and Y is also a random variable due to the randomness of X and Z. Basic problems in analysis of random statistical properties of Y is when the known variables x` and Z, the probability density function and the mean and variance, how to seek out because the probability density function of the variable y f or the corresponding mean production, with the variance. By probability theory, we can know that the statistical properties of a random variable can be described by probability density function, and can be used to describe the characteristics of the random variables (such as mean, variance or higher order). In this paper, the calculating

method on the statistical properties of several design quality guidelines were comprehensive analysis and formula derivation, and analyzes the detailed theory of the stochastic simulation test method, gives the specific implementation process [5].

4 Conclusion

When the design variables due to the decrease in the production process of various uncertain factors influence variation or the gear manufacturing precision, material performance differences (such as the actual selected low level small gear material contact force or high-speed small gear material bending stress is less than design value), the actual reduction for low-speed small gear contact force may be greater than the material Xu contact stress, high speed small gear bending stress may be greater than the material allowable bending stress. When the product is in use, the possibility of failure is increased, and the quality stability of the product can not be guaranteed. The result of robust optimization design is slightly increased, but the increase is not large. This is because the robust optimization design is not only to ensure the optimal design solution, but also to ensure the robustness of the design solution. Therefore, in the robust optimization design, the variation of the constraint function caused by the variation of the design variables is considered, and the design of the feasible region is reduced. Robust optimization design solution of the stress difference were greater than 0, when the design parameters in actual production deviations occur, or lower gear manufacturing precision due to differences in the production process can still meet the gear contact stress and bending stress constraints. This allows the design of product tolerance parameter variation of the ability to enhance and improve the quality of stability.

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