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A Design Method of Predecisional Remanufacturing Based on Structural Similarity

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Abstract

Nowadays, the uncertainty of the remanufacturing cores increased the cost and difficulty in remanufacturing, and the mechanical and electrical products are rarely designed for remanufacturing. To solve these issues, the optimization design method based on structure similarity model is presented. With identifying the timing in predecisional remanufacturing, the design demands are presented. Since the concept of structural similarity is given, the quantitative mapping relationship between the structure parameters and its performance is analyzed. And the optimization design method for predecisional remanufacturing is given. Finally, the experiment on a typical shaft structure is given to validate the feasibility of this method.

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Keywords: structural similarity; predecisional remanufacturing; similarity model of performance; optimization design

1. Introduction

Remanufacturing is based on the product life cycle theory, to enhance the waste product performance by leaps and bounds as the goal, and to high-quality, high efficiency, energy saving, material saving and environmental protection as the standard, with advanced technology and industrial production as a means to repair, renovate collection of waste products of a series of technical measures or engineering activities[1].

Since a large extent (70%) of the products' performance depends on the design phase[2], it is necessary to consider the remanufacturing in design phase, moreover, it needs to consider the mapping relationship between the product's design parameters and the requirements of remanufacturing. However, the requirements of remanufacturing are not quantized in design phase, and due to the uncertainty in time and loading in using phase, the variation of products' performance is uncertain. Therefore, to analyze the requirements of remanufacturing with considering the uncertainty in design phase is the key issue in design for remanufacturing. Lot of studies has carried in the design for remanufacturing, Ijomah W.L. discussed the relationship between product characteristics and remanufacturability, and explain the effect of material, connection technology, cost and other factors on remanufacturability by engineering example[3]; Sundin E. studied the impact of various product characteristics on the remanufacturing process, such as durable, easy to verify, easy to identify and so on[4]; Kimura F. proposed a new modular design method for product remanufacturing design, which is based on the similarity of product versatility, functionality and life cycle[5]; Hatcher G.D. summarized the factors that influence the process of remanufacturing design from three aspects of technology, market and operation[6]. Liu Zhifeng proposed a method of analysis of the elements of remanufacturing design based on the application of quality house and QFD technology[7]; Liu Ming analyzed of the relationship between the parts of the failure state and remanufacturing[8]; Liu Mingzhou proposed the method of tolerance grade distribution of remanufacturing parts, using the selective assembly method based on the uncertainty analysis of remanufacturing assembly[9]. In these studies, it is still considering the parameters of parts in one or several types of products with traditional experience or method, and the uncertainty of cores has not been analyzed. Thus, the design method with the mathematical or quantitative

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model for general mechanical products is necessary in initial design phase.

With the above statements, in this study, the predecisional remanufacturing is presented to control and minimize the uncertainty of cores. And to meet with the timing requirements in predecisional remanufacturing, the optimization design of mechanical product is given with establishing the mapping relationship between the structural similarity and its performance.

2. Design for predecisional remanufacturing

2.1. Predecisional remanufacturing

Differing from the traditional remanufacturing, it has considered the performance of product in the whole life cycle in predecisional remanufacturing. With analyzing the variation of product`s performance in using, the predecisional remanufacturing, when the product might be remanufactured with an optimized economic and environmental benefits, could be decided (as show in figure 1).

When the product`s performance degraded into the inflection point, the product should be remanufactured, and this timing could be identified as the predecisional remanufacturing timing. Before this timing, the product might be remanufactured with a large waste in product, and after this timing, the product might be remanufactured with the low feasibility under the current technical conditions. Therefore, predecisional remanufacturing timing is the optimized time when the product in using should be remanufactured with considering the economic, environmental and technical aspects in the whole life cycle.

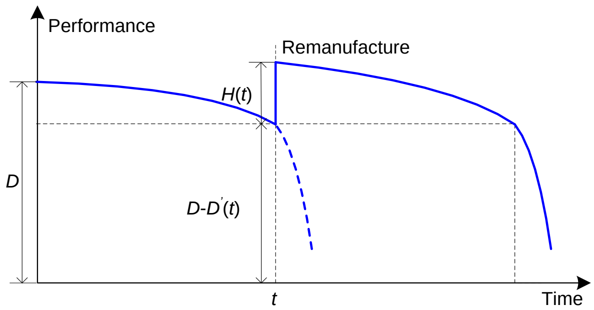

Fig. 1. Parts performance degradation curve in predecisional remanufacturing.

Thus, the predecisional remanufacturing timing is the key issue in predecisional remanufacturing. Since the performance of product is determined by the products' design, the predecisional remanufacturing timing should be analyzed in design phase. However, currently it has not considered the remanufacturing in most of products' design, the predecisional remanufacturing timing is not reasonable for product operation, and optimized remanufacturing timing of every component might not be unified in one predecisional remanufacturing timing. Therefore, in predecisional remanufacturing design, it is not to make decision for the optimized timing, but also to design the predecisional remanufacturing timing of each component with optimizing the structure parameters.

2.2. Timing requirements in predecisional remanufacturing

In predecisional remanufacturing, it should remanufacture the products in the optimized timing of the whole life cycle. Thus, the product's performance in the whole life cycle must be analyzed to select and determine the timing to obtain the best benefits for both remanufacturing company and customers.

Differing from other life phase, the main object in remanufacturing is component and part. And the remanufacturing process depends on the failure condition of each parts. Due to the different characteristics of the material, working environment, load and other factors, the failure conditions of different parts are different, and the optimized remanufacturing timing of each component and part are not uniform.

Besides, when remanufacturing parts with little failure and good performance, the remanufacturing is not significant to improve and the product's performance, which could result resources waste. On the other side, when remanufacturing parts with worse failure, the remanufacturing is also not reasonable with less feasible remanufacturing technology and high economic and resources cost[10]. Thus, the remanufacturing timing is so important that it might determine the process, cost and feasibility of remanufacturing. It is necessary to design the remanufacturing timing in the predecisional remanufacturing.

In the product, there will be a number of key components, and they play a decisive role in the overall performance of the product. Since to design the remanufacturing timing of all parts is not possible and significant, the key parts could be main objects in timing design for predecisional remanufacturing. Thus, the remanufacturing timing should be considered and analyzed in the structure design of the key parts.

In the structural design for predecisional remanufacturing, it is to design structural parameters of parts for optimized performance. Such as the strength parameters, it has to optimize parts` structure with required strength in multiple using phases. After deciding the predecisional remanufacturing timing of one product, the structural parameters of parts should be designed with reasonable performance to meet the requirements of the predecisional remanufacturing timing.

With above statement, informed by the relationship between the design parameters of the structure based on the traditional design theory, the predecisional remanufacturing timing should be converted into the performance requirements. In order to meet with the timing requirements in predecisional remanufacturing, the effect of design parameters and loading conditions on the performance of parts must be required. And