Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 48 (2016) 182 – 187

www.elsevier.com/locate/procedia

23rd CIRP Conference on Life Cycle Engineering

A timing decision-making method for product and its key components in proactive remanufacturing

Qingdi Ke[a] , Hui Wang[a*] , Shouxu Song[a] , BingBing Li[b]

[a]School of Mechanical and Automotive Engineering, Hefei University of Technology,No.193 Tunxi Road,Hefei,230009,China
[b]California State University Northrige,18432 Tribune St, Porter Ranch, CA 91326,US
* Corresponding author. Tel.: +86-13075577025; fax:+00-86-0551-62901775. *E-mail address:w1022125@163.com*

Abstract

Generally, the economic profits in product using are considered as the main factor in decision-making in remanufacturing. Since used key components are identified as the core in remanufacturing, each component and its own condition should be considered in decision-making. Thus, with mapping the relationship between product performance and its key components failure condition, a timing decision-making method in proactive remanufacturing is presented to conduct the remanufacturing with low consuming per year. Moreover, the remanufacturability of key components at the time with low consumption per year is evaluated. Finally, a diesel engine is given as an instance to validate the method.

Peer-review under responsibility of the scientific committee of the 23rd CIRP Conference on Life Cycle Engineering

Keywords: Optimization design; Structural strength parameter; Proactive remanufacturing; Remanufacturing timing

1. Introduction

Considering the design and management of the products' lifecycle, green remanufacturing engineering is a series of technical measures and engineering activities, such as repair and transformation of the used products with high quality, high efficiency, energy conservation and environmental protection [1].Because of the uneven uncertainty of the cores, the cores are often remanufactured with individual and characteristically performance in the enterprises. For this issue, the concept of proactive remanufacturing is proposed. In using stage, the products are remanufactured in the identified time in order to achieve optimized efficiency and benefits.

For the timing decision-making problem in remanufacturing, lots of studies have been done. OKUMURA et al. optimized the product design in its cycle life based on remanufacturing theory [2]. Zhichao Liu conducted a comparative life cycle assessment of an original manufactured diesel engine with a remanufactured counterpart based on E-Balance software, and evaluated the optical time for the diesel engine remanufacturing [3]. Yawei Hu studied on the remanufacturing decision making with estimating the probability density distribution curve of the residual life by particle filter algorithm [4]. Liu Ming analyzed the mapping relationship between components failure condition and there manufacturability with the rules of components performance degradation [5].Yao gave some relative concepts about the remanufacturability based on total remanufacturing process [6].Shanshan Zhou established the index of the comprehensive average cost of the heavy truck engine based on life cycle cost and environmental cost, to identify the optimal remanufacturing time point [7]. Sundin .E et al. described how to achieve a successful remanufacturing process with an efficient take-back system and good product designs [8] . In these studies, it has not considered that the key components, which are the remanufacturing objects, have different failures conditions, and each component has its own remanufacturability. Thus, the proactive remanufacturing is presented and a timing decision-making method for product and its key components is presented in this paper.

Peer-review under responsibility of the scientific committee of the 23rd CIRP Conference on Life Cycle Engineering
doi:10.1016/j.procir.2016.04.080

2. Proactive remanufacturing for product

2.1. Proactive remanufacturing

With considering the performance and function of product, proactive remanufacturing engineering is the series of engineering activities to actively remanufacture the products in the using stage with high quality, high efficiency, energy conservation, material conservation, environmental protection and long using time for products [9]. In current remanufacturing engineering, wasted products are considered as the remanufacturing cores, while the end-of-life time is the remanufacturing time. Since most the key components of wasted product is often overused, even broken with serious failure condition, the remanufacturability of end-of-life products are low, with the high cost for remanufacturing, and the loss of residual value. Meanwhile, due to the uncertainty of the 'core', the cost would be increased. Thus, in order to make full use of product residual value and eliminate the uncertainty of the cores, product should be remanufactured at some time interval (T_{AR}) before the end-of-life time. In proactive remanufacturing, when the products are remanufactured at the setting time interval, the product performance, including economic benefits, technical requirements, environmental emissions, etc. could be the best in the whole life cycle.

2.2. Mapping relationship

Mostly, the economic profits in product using are considered as the main factor in decision-making in remanufacturing. Since used key components, which are identified as the core in remanufacturing, have different failures conditions, it should consider the performance or failure condition in decision-making. If all components of product are remanufactured at the same time, some components could be still working ad not suitable for remanufacturing, while some over-used components just lost their remanufacturing value. Therefore, the remanufacturing time point of each component might be different. And to identify the remanufacturing time point of each component, the mapping relation between product performance and its key components failure condition should be analyzed.

Product performance is the integration of the function and quality, and the quality also is considered as the implement and perdurability of function. And the product performance is identified as the set of product's function. Product performance is often supported by multiple components, that is to say, components are the functional supporters of products. Components and their function are indispensability of each other and constitute an organic unity of product function [10]. And every component has different relationship with product function. When some components are failure, product performance might decline. With analyzing the structure of the product, the relationship between product performance and its key components performance ($P(\sigma_1)$,$P(\sigma_2)$,$P(\sigma_3)$, ... ,$P(\sigma_n)$) is set up. And the variation of product performance is depending on its key components performance and failure condition (as shown in 1).

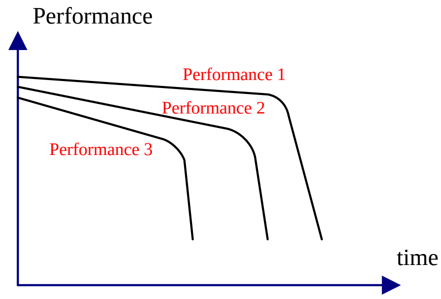

Figure 1 Variation of component performance

2.3. Quantitative model of remanufacturability

Remanufacturing engineering and failure analysis are two independent disciplines, each of which has its theoretical basis. To quantify the remanufacturability of key components, the residual strength theory is given [11].

The residual strength (Rs) can identified as a parameter which characterizes the remanufacturability of key components in strength. According to the main failure modes of components, several strength indexes related to the residual strength (Rs) can be obtained. To describe the relative dimension of Rs, the residual strength factor is introduced. The residual strength factor of components remanufactured at time t can be described:

$$r_j(t) = \frac{D^j - D_1^{\ j}(t) + H(t)}{D_0^{\ j}} \qquad (2.1)$$

Among above, Dj donates the allowed maximum cumulative damage defined in design for components ; D1j(t) donates the loss strength of components after time t ,thus, the residual strength is D-D1(t); D0j donates the loss strength after a life-cycle period; H(t) donates restoring strength of components which are remanufactured according to their damage conditions.

From the aspect of design, with the variable performance of components in three stages: manufacturing, using and remanufacturing, if the residual strength factor r ≥ 1, components have remanufacturing value. Considering the sake of the security, the residual strength factors should be multiplied by a factor of safety: r≥1.25.

3. Time decision-making with product performance

3.1. Time decision-making

Proactive remanufacturing is product-oriented, not component-oriented. Since the product is composed of multiple components, there are some key components with the high value and some other components that should be replaced in the process of remanufacturing. Thus, the remanufacturability of key components must be considered.