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Remanufacturing Process Planning

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Abstract

Remanufacturing is an active area of research due to its cost saving capabilities and emission-reduction benefits. After being disassembled, cleaned and inspected, the core components go through a series of reconditioning operations before being reassembled into the final remanufactured product, and tested to ensure quality. However, used core components have varying conditions, different defects, etc., which result in reconditioning process paths being specific to each component in the core. The reconditioning process sequence for a core component depends on its conditions. This paper analyses the conditions of the core components to determine an optimal reconditioning process sequence for these components

Keywords: Remanufacturing, Reconditioning, Process sequence

1. Introduction

In the recent decades, with the development of climate change and increased pollution, there has been a global rising concern about the environment, matched with tighter legislations to control the ecological impact of human products through their use and manufacturing. Production businesses go "green" by incorporating sustainable manufacturing and end-of-life (EOL) strategies to meet regulations, and attract the now environmentally conscious consumers. Besides recycling, repair and refurbishing, remanufacturing is another EOL strategy where a used product is brought, through a series of industrialized processes, to "like-new" conditions with warranty and performance at least matching the OEM level [1], and offers the used product another complete lifecycle.

One of the complicating characteristics in remanufacturing is the stochastic and sporadic nature in the condition and quantity of the returned cores which impacts on many levels in the planning and control [2, 3]. Returned products can range from minor scratches to extensive damage and thus inspection and sorting procedures are required to filter the valuable cores. High quality returns are preferred as the quality of the returns determines the level of the remanufacturing effort required, the processing time, the rate of remanufacturing success, the process sequence used, the amount of cost savings, and the amount of cores being scrapped [4, 5]. The extent to which remanufacturing is done and the definition of sufficient quality depend on the type of remanufacturers and the business model; independent remanufactures try to repair as many parts as possible, whereas OEM remanufacturers can be more selective on the cores to accept [6]. Inspection therefore plays an important role in order to sort the cores. During inspection, the remanufacturing suitability of a core is estimated and the processes to be used are evaluated based on the inspector's knowledge and scheduling constraints. The decision-making process and the ability to restore a core reliably have a strong influence on the success rate and profit of the remanufacturing initiative. Despite all the technical challenges and scheduling difficulties, the remanufactured product must be of high reliability and quality while being price competitive to be successful.

Reliable engineering expertise and capabilities is the backbone to a successful remanufacturing facility. Remanufacturing depends extensively on the skills of the technicians and the knowledge base related to the cores and their restoration [7]. However, OEMs who wish to maintain their competitive edge will not divulge their product design information to the independent remanufacturers who would have to rely on their own experience [2, 8, 9] combined with industry guidelines, such as QS9000[10].

Through the inspection and sorting process, cores are classified as to whether they can be reused, remanufactured, scrapped and recycled. In this paper, the cores that can be remanufactured are of concern. A conceptual framework and methodology are proposed to aid in the selection of the reconditioning process sequence based on the conditions of the cores and their engineering functions, which will be the guiding factor during the decision making processes.

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2. Literature review

2.1. FMEA

Parkinson [10] proposed a systematic approach to the planning based on the failure mode effect analysis (FMEA) method in order to increase the reliability of the remanufactured product. FMEA is used for risk management and the prevention of catastrophic failure of the product by first performing a product FMEA to identify the critical core components which need to be focused on. Second, the remanufacturing processes to treat them are established. Next, a process FMEA is used to determine the remanufacturing processes among inspection, cleaning, manufacturing operations that are most critical and the ways to diminish their risk priority number (RPN) are decided by a consensus of the technical team and the management. Finally, a cost benefit analysis using the RPN/cost ratio serves as a guide on where more resources should be allocated. This four-step approach can be applied repeatedly to improve the reliability of the remanufacturing system. Shu et al. [11] performed waste stream FMEA analysis to identify the failure and scrap modes of automobile parts against which Design for Remanufacture must cater for to facilitate remanufacturing.

2.2. Process planning

Kernbaum et al. [12] presented an approach for the design and evaluation of the remanufacturing processes for a facility. A mixed integer programming approach is used for the optimization of a remanufacturing process plan from cleaning to reassembly; they assessed the economic viability by considering all the relevant costs. The reconditioning process planning, however, is still performed by the user who inputs the process in the software through graphical user interface (GUI), which helps the users to visualize the sequences and types of operations.

Jiang et al. [13] defined reconditioning system planning as being made up of three closely related aspects, namely, restoration planning, process planning and technology planning. Assuming that the restoration and process planning have already been performed, they formulated a multi-criteria decision-making method that considers the economic and environmental aspects for the selection of the manufacturing technology portfolio. The analytical hierarchy process (AHP) was used to assign weights to the various criteria, and capture the singular and synergistic benefits of each technology for decision making.

2.3. Product design and remanufacturing

A valuable core is remanufactured such that its quality is at least as good as a new one. Fig. 1 depicts the technical factors influencing the reconditioning operations. Analogous to the case of new product development where manufacturing processes need to meet design requirements in order for the product to fulfill satisfactory functional capabilities with reliability, remanufacturing reconditioning operations, too, have the objective to restore the core to meet the performance criteria of the product in order that it can successfully perform its intended purpose. As such, product design considerations are important in the selection of the reconditioning processes so as to ensure that the remanufactured product will be of high quality.

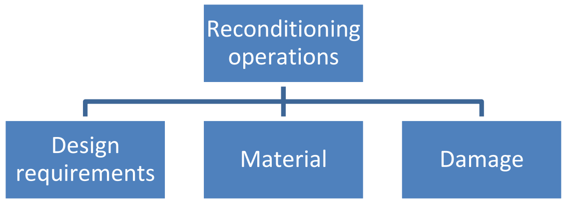

Fig. 1: Technical factors driving reconditioning operations.

Process planning is the specification of the manufacturing operations to be performed, the parameters of these operations and the order in which they will be executed. In the case of remanufacturing, the “raw” materials are the returned cores where the design and material have already been fixed. The reconditioning process can be defined in two interlinked stages, namely, restoration of defects and remanufacture to high quality.

2.4. Types of reconditioning operations

The remanufactured core should be ideally free from any damage from its previous use phase, as well as from secondary effects from the reconditioning processes. Therefore, in selecting the process sequence, the side effects of each step on the part need to be taken into consideration to avoid reworking. Hence, the types of reconditioning processes can be classified into five main categories as follows:

A. Remove surface and shape defects
B. Material addition or surface replacement
C. Restore material properties
D. Assembly and fastening manipulation
E. Surface finish

a) *Remove surface and shape defects*

Defects, such as cracks, scratches, nicks and burrs, burnt or corroded regions, and inclusions are removed by machining processes such as turning, milling, drilling, grinding, etc. Surface finish and tolerances are not of top priority but rather the removal of all stress raisers. However, if a part is in good condition and does not need to be further treated, machining with the final surface quality can be performed if technically feasible. When surface defects such as cracks are deep, the material around the defect is gouged out if refilling of such cut-out does not impair the strength and safety requirements of the part. Shape defects, such as bends, warps and dimples, are also removed if technically feasible and design considerations allow.