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A Model to Manage Remanufacture of Used-Products

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ABSTRACT

Remanufacturing of used-products is becoming an important activity in many production companies. This paper reviews key remanufacturing process, highlights eight unique characteristics of remanufacturing process environment and proposes a generic conceptual remanufacturing process model that considers the presence and interactions of these eight features. The generic conceptual model could be modified to suit remanufacturing process of any given used products to be remanufactured. Future research can modify the generic remanufacturing model to suit used automotive parts remanufacturing with unique characteristics and apply simulation technique to model and analyse the corresponding remanufacturing process.

Keywords: Control, planning, production, remanufacturing, used-products

INTRODUCTION

Over the years, stricter environmental legislations imposed on manufacturing companies had forced them to include their manufacturers' responsibility for products that have been used and retired. For example, automobile manufacturers in Europe must accept full disposal responsibility for cars manufactured from 2002 onwards and not pass on the cost to the final owners (EU Directive, 2000). In addition, customers have become increasingly concerned about the effects of disposing used-products to the environment. As reported in (Morel & Kwakye, 2012), more than 80% of the survey respondents agree that "an important deciding factor when buying a product is the product's impact on the environment". Strict governmental legislation

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and consumer concern on environment put pressure on manufacturing companies to designing products and corresponding production process that makes it possible to recover used-products through remanufacturing activity (Andrew-Munot et al., 2015). Remanufacturing can be defined as an industrial process whereby used, worn-out or broken products are converted into like-new conditions (Kim et al., 2006). Specifically, Nasr (2007) defines that a product is remanufactured if it fits several criteria. These criteria are: (i) main components comes from a used product; (ii) condition of the components are determined after disassembly process; (iii) components are thoroughly cleaned to remove rust and corrosion; (iv) missing, defective, broken or worn out parts are either restored to sound, functionally good condition, or replaced with new or remanufactured parts; (v) components/product are reprocessed either by machining, rewinding, refinishing, etc; and (vi) reassembly of product and to ensure it operates similar to the new product with respect to reliability, life-cycle and operational cost.

Unlike traditional manufacturing activities, remanufacturing activities is complex in nature due to the presence of several unique characteristics. Therefore, this paper proposes a generic conceptual remanufacturing process model with eight unique characteristics. This generic conceptual model is developed taking into account the key remanufacturing process and eight unique characteristics that are presence within the remanufacturing environment. This paper is organised as follows. Section 2 is a discussion on the remanufacturing process; Section 3 highlights the unique characteristics that are present within the remanufacturing environment and proposes a generic conceptual remanufacturing process model. Section 4 concludes the paper.

A REVIEW OF REMANUFACTURING PROCESS

Figure 1 shows a generic process for remanufacturing that commences with the arrival of used-products, which are then inspected, disassembled, reprocessed and reassembled to produce remanufactured products. This generic remanufacturing process, as described by Lund (1984) is one of the oldest description of remanufacturing process reported in the literature. Hammond et al. (1998) and Guide (2000) define remanufacturing process to include arrival of used-products, disassembly, cleaning, sorting/inspection, reprocessing, reassembly & testing. The exact number of processes and sequences for a specific product type depends on the conditions of the used-products (Ilgin & Gupta, 2012). For example, Andrew-Munot et al. (2013) give examples of remanufacturing process for photocopiers, automotive engines, ink cartridges and medical devices, which are the actual industry remanufacturing process. Therefore, it is clear that there are some processes that are similar and hence, general to remanufacturing process of all types of used-products.

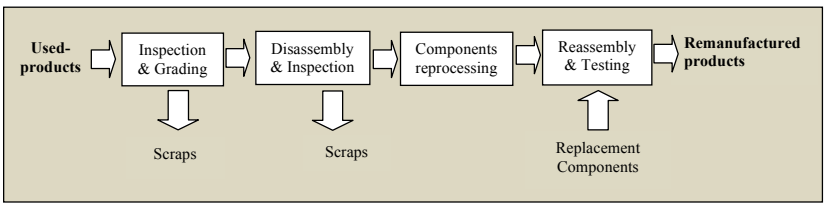

Figure 1. Generic remanufacturing process (Lund, 1984)

Used-Products

Generally, used-products can be obtained from two sources, the market-stream or the waste-stream (Jayaraman, 2006). Used-products from the market-stream (e.g. retailers) are usually products that still functions but are not required by the owners anymore. This could be an old model of a mobile phone that is traded-in for new model with new and stylish features. However, the waste stream used-products are no longer useful; some examples are damaged automotive vehicles and malfunctioned electrical home appliances. Between the two sources, used-products coming from the waste stream yields uncontrollable quality and uncertain quantity (Ghoreishi et al., 2011). Generally, the availability of used-products for remanufacturing is influenced by the number of new products sold in the preceding periods (Esenduran et al., 2012).

Process 1: Inspection and grading. Incoming, used-products are inspected to determine whether they are acceptable for remanufacture or not (scraps). Scraps are either sold to scrap brokers or disposed off. Used-products accepted for remanufacture, define as "*remanufacturables*", could be categorised into several quality groups, and highest priority is given to remanufacture the best quality group (Aras et al., 2006). Used-products obtained from the waste stream with uncontrollable quality conditions require longer and different inspection times for each unit, compared with those obtained from the market-stream. The market-stream used-products having controllable quality conditions, results in a higher proportion (yield) of "*remanufacturables*" compared with the waste-stream.

Process 2: Disassembly and Inspection. Used products accepted for remanufacture are disassembled completely into its constituent component. The disassembled components are inspected to assess whether the components can be reprocessed or disposed off as scraps. The market-stream used-products would give more components that are accepted for reprocessing (higher disassembly yield) compared with the waste-stream. The constituent components could also be categorised into several quality groups and priority is given to reprocess components with the best quality. The disassembly and inspection processes may occur either simultaneously or sequentially - this depends on the product structure and volume. For remanufacturables with simple product structure and in high volume, both the disassembly and inspection process could occur simultaneously. Similarly, for remanufacturables with complex product structure and in low volume, the disassembly and inspection process could occur simultaneously. However, for remanufacturables with complex product structure and in high volume, the disassembly and inspection process occur sequentially.

Process 3: Components Reprocessing. This usually involves process such as cleaning, repairing and surface finishing (Sundin & Bras, 2005). Depending on the component quality group, the exact number of reprocessing steps and time would be different. For instance, the best quality component may need simple reprocessing (e.g. cleaning & surface finishing) compared with components from the average quality group. For components with complex design, multiple reprocessing steps might be required to return the components to the original

condition. Some non-replaceable parts such as electrical wire or cellular phone casing are just replaced with new components.

Process 4: Reassembly and Testing. The reprocessed and replacement components are reassembled into remanufactured products, which are tested to ensure these products meet the specified function.

Remanufactured Products

Remanufactured products which are perfect substitutes for new products are sold in the primary market (Souza & Ketzenberg, 2002); this would be original equipment manufacturers (OEM) remanufactured products, which are as good as new products. The price of remanufactured products which are sold side by side with new products could be cheaper (Ferrer & Swaminathan, 2009) even at the same price as the newly products (Gallo et al., 2012). On the other hand, remanufactured products sold in the secondary market are popular among customers with financial restrictions, who are satisfied with their cheaper and low-level functions.

PROPOSED GENERIC CONCEPTUAL MODEL

As discussed in the review of remanufacturing process, unlike the traditional manufacturing process, remanufacturing process is uncertain with respect to several aspects. Andrew-Munot & Ibrahim (2013), emphasise that these uncertainties complicate production planning & control activities and therefore, need to be treated as important criteria in modelling & simulation of remanufacturing operations. These uncertainties become the unique characteristics of remanufacturing environment which are: (i) highly uncertain quality conditions of incoming used-products, due to their different degree of usage; (ii) uncertain quantities of used-products available for remanufacture; (iii) varying inspection yield from one batch to another; (iv) varying disassembly yield from one batch to another; (v) varying reprocessing efforts of constituent components from one unit to another and from one batch to another; (vi) reprocessing multiple types of constituent components; (vii) requirements to match and reassemble the same set of constituent components into a final product; and (viii) the need to balance customer demand with availability of used-products to avoid excess inventory build-up and maximise level of customer service. Therefore, based on the review of remanufacturing process and statements of unique characteristics above, this paper proposes a generic conceptual model for remanufacturing process environment, as shown in Figure 2. The generic conceptual model is characterised by key remanufacturing process as well as the presence of eight unique characteristics. The generic conceptual model could be further modified to model remanufacturing process and unique characteristics of any specific used-product to be remanufactured. Furthermore, this generic conceptual remanufacturing process model would become an important decision-making support tool for industry as well as academicians.

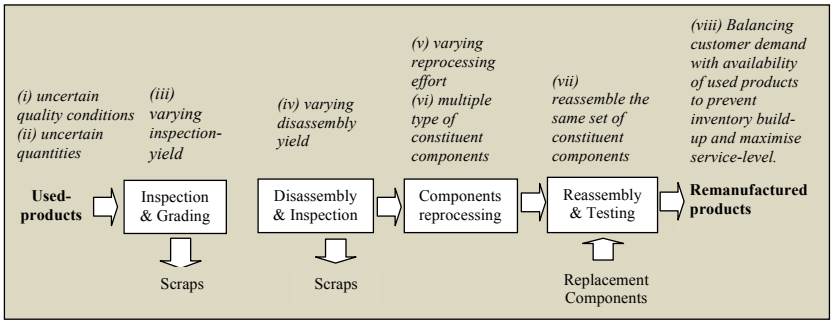

Figure 2. Proposed conceptual remanufacturing process model with eight unique characteristics

CONCLUSIONS

In the recent past, many companies have been involved in remanufacturing activities. This progress has been primarily motivated by three emerging factors: strict environmental regulations, increasing customer regard for green environment and economic benefits. This paper has highlighted the key remanufacturing process and corresponding unique characteristics also in addition to proposing a generic conceptual remanufacturing process model considering the presence and interactions of eight unique characteristics. The model could be further modified taking into account remanufacturing process and unique characteristics of any specific used-product to be remanufactured. Inevitably, the generic conceptual remanufacturing process model becomes a valuable managerial decision-making support tool. Given the existence of eight unique characteristics within the remanufacturing process environment, it is imperative that such unique characteristics and their interactions are treated as a set of critical criteria in the modelling and analysis of remanufacturing operations. Therefore, the future directions of this research work are to modify the generic conceptual model above for used-automotive parts remanufacturing process & corresponding unique characteristics. This used-automotive parts remanufacturing process would be modelled and analysed using simulation technique.

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