

An Insight into Used-Products Remanufacturing

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Abstract – Nowadays, remanufacture of used-products is gaining importance amongst many manufacturers as well as third party companies. This paper identifies the main drivers for remanufacturing to be product take-back legislations, environmental concerns and economic benefits. This paper also identifies the four main remanufacturing processes to be inspection & grading, disassembly & inspection, component reprocessing and reassembly. Finally, this paper presents several examples of remanufactured products and the two markets for selling them. This paper provides valuable insights on remanufacturing to potential remanufacturers, researchers and the general public. Remanufacturing in the long run can save materials, cost and the environment. **Copyright © 2015 Penerbit Akademia Baru - All rights reserved.**

Keywords: Used-products, product recovery, Remanufacturing

1.0 INTRODUCTION

Nowadays, remanufacturing is an important activity in many manufacturing companies, where independent or third-party business companies are also reaping the economic benefits of remanufacturing. The oldest and strongest remanufacturing sector is the automotive sector [1], [2], where the alternator has the highest remanufacturing rate [3]. Other industries where remanufacturing is gaining scientific significance are single use-devices for hospitals, such as wheelchairs and hearing aids [4], cellular phones [5], and truck tyres [6]. Generally, remanufacturing refers to an industrial process in which used/worn-out/broken products (henceforth called used-products) are transformed into "new products" [7]. In this paper these "new products" refer to remanufactured products to differentiate them from a completely new product.

Remanufacturing could be sometimes confused with other similar product recovery options like repair, refurbish and recondition. Repaired, refurbished and reconditioned products are very close to remanufactured ones and these terms can frequently be considered synonymous with each other [8]. Despite their similarities, the weightage and meanings of the terms are different with respect to functionality and performance. For example, to repair a broken product means to correct specified faults in a product. If the repaired products have warranties, the warranty does not cover the whole product but only covers the component that has been replaced. In refurbishing process used-products are cleaned up, nonworking parts are replaced, tested, repackaged and made available for resale. Refurbished products have warranty that is less than that of a new product. For reconditioning, a used-product is cleaned up and tested extensively with possible repair before repackaged for resale at a satisfactory working condition, with warranty less than that of a newly manufactured equivalent, in which the warranty applies to all major wearing parts. Finally, recycling describes the processing of

used material into new products through discarding used materials into production of different or same product.

This paper aims to provide valuable insights on remanufacturing to the general public, potential remanufacturers, as well as researchers. This is achieved by looking at several areas of remanufacturing activities and provides discussion on these areas. This paper is organised as follows. Section 2 discusses the main drivers for remanufacturing. Section 3 discusses and summarises the key steps of remanufacturing process. Section 4 discusses the types and market of/for remanufactured products, and finally, Section 5 concludes the paper by reiterating the managerial opportunities and issues associated with remanufacturing.

2.0 DRIVERS FOR REMANUFACTURING

More companies are engage in remanufacturing program because of the product take-back legislations, customers' awareness of environment issues and economic benefit. The product-take-back legislations as enforced by governmental bodies require companies to extend their manufacturers' responsibility to include products that have been used and retired. For example in Europe, directive Directive/2002/96/EC [9] on waste electrical and electronic equipment states that "*Where appropriate, priority should be given to the reuse of waste electrical and electronic equipment (WEEE) and its components, subassemblies and consumables. Where reuse is not preferable, all WEEE collected separately should be sent for recovery, in the course of which a high level of recycling and recovery should be achieved. In addition, producers should be encouraged to integrate recycled material in new equipment*". The environmental benefits of remanufacturing, as reported in [10] based on a study of compressors remanufacturing, is greenhouse gas emission that is about 90% less than the manufacturing of new product.

Customers' are increasingly concern about environmental issues. For example, [11] reported the percentage of consumers who are interested in some form of green products are between 15% and 46%. Also, product-take-back and reprocessing program creates the opportunity for manufacturers to boost the value of their products. For example, Hewlett-Packard [12] embraces the green environment culture through recycling programs, which help to reduce the environmental impact of the companies' activities. Similarly, in 2012, IBM [13] worldwide product end-of-life management operations processed 36,100 metric tons of end-of-life products for reuse or recycling, sending only 0.3 percent of the total to landfills or to incineration facilities for treatment.

Lastly, compare to manufacturing, remanufacturing incurred cost that is typically 40% - 65% less [14] and [15]; remanufactured products arually sold off at 45% - 65% of the prices of new products [16]. This is due to the availability of raw materials (recovered components), which are cheaper than those newly manufactured components; recovered components do not have to be redesigned and ordered from suppliers. Reuse of components in subsequent product generations, also results in cost savings [17]. In terms of energy and materials consumption, compare to manufacturing, remanufacturing contribute to less usage [18], [19], [20] and [21]. Up to now, environmental regulations and consumers' awareness has been considered as extra operational cost, rather than ways to produce profit and improvement corporate image. Nevertheless, with the increasing pressure to become environmentally responsible and sourcing for inexpensive raw materials, more companies are seeing remanufacturing as an alternate strategy to create profit, enhance company image and sustain competitiveness.

3.0 STEPS FOR REMANUFACTURING PROCESS

The general remanufacturing process as reported in [7] consists of four main stages that include inspection & grading, disassembly & inspection, components reprocessing and reassembly & testing (Figure 1). The exact number of process and sequence highly depend on the nature of used-products being remanufactured [22].

Stage 1: Inspection & Grading – Firstly, used-products are inspected to determine the remanufacturability status which could be acceptable for remanufacture (remanufacturables) or not (scraps). The inspection process is usually carried out visually for each unit of incoming used-products, i.e. 100% inspection [23]. Scraps are either disposed off or sold to scrap brokers, whereas remanufacturables are send to the next stage for disassembly & inspection process. Remanufacturables could be further classified into several quality groups, whereby the first priority is given to remanufacture the best quality group [24] and [25].

Stage 2: Disassembly & Inspection – Each unit of remanufacturable is disassembled into its corresponding modules, where each module is further disassembled into its constituent components. This process is usually carried out using general purpose tools such as power drill, although in some cases, robot arms might be necessary for disassembly of complex products [26] or hazardous parts [27]. Disassembly time would depend on the product structure complexity, in which complex product structure remanufacturables would require a longer disassembly time than simple product remanufacturables.

Disassembly and inspection process could take place simultaneously or sequentially, this depend on the product structure and volume. Simultaneous disassembly and inspection process could be carried out for high volume of simple product structure remanufacturables. Similarly, for low volume of complex product structure remanufacturables, disassembly and inspection process could be carried out simultaneously. On the other hand, for high volume and complex product structure remanufacturables, the disassembly and inspection process could be carried out in a two stage disassembly line [26].

After disassembly each unit of constituent component is inspected to determine its remanufacturability status, which is either acceptable for remanufacture (remanufacturables) or not (scraps). Scraps components are replaced with newly manufactured components, which could be ordered from external source (for contract or independent remanufacturers) or in-house production (original equipment remanufacturers). Remanufacturable components could also be classified into several quality groups, whereby top priority is given to reprocess the best quality group. Regardless of the product structure, the percentage of components not damaged during disassembly process is affected by the product design. Products that are originally design for disassembly would generate a higher percentage of not damaged components than those that are not originally designed for disassembly because of ease of removal. Therefore, it is very important to integrate product design into the product development process to increase usable components [28], [29] and [30].

Stage 3: Components Reprocessing – During this stage, components are cleaned, repaired (e.g. machining worn-out holes) and surface finished [31]. Depending on the component quality group, the exact number of reprocessing steps and corresponding time would be different. For instance, the best quality group would require less/simpler reprocessing steps and shorter reprocessing time compare to the worst quality group. In addition, for complex product design, multiple repair steps might be necessary that includes welding and trimming

to restore the component to its original condition. Likewise, there are some damage/broken components (electrical bulb, plastic cellular casing) which do not require any reprocessing and are simply replaced with new ones.

Stage 4: Reassembly & Testing – The reprocessed and possibly new components are reassembled to produce remanufactured products. This process usually involves general purpose tools. However, in some cases it is necessary to use robot arms to reassemble components (reprocessed & new) into complex product structures. Similar to manufacturing process, remanufactured products are tested to ensure that these products meet their specified function. In some cases, used-products are disassembled to harvest the usable components, just for the purpose of spare-parts (automotive clutch, automotive engine, starter motor, etc). Once reprocessed, the spare-component is assembled with new components to produce completely new products. Option 2, in Figure 1 shows the usage of reprocessed components in the case of spare-parts. The usual practice of producing remanufactured products is shown in option 1. As can be seen in Figure 1, the common steps of option 1 and 2 are inspection & grading, disassembly & inspection and components reprocessing.

To reiterate, the four main steps of remanufacturing process are inspection & grading, disassembly & inspection, component reprocessing and reassembly. However, depending on the type of products and companies, the four processes can be further expanded to twelve processes, as reported in [32] to include (i) warehousing of incoming used-products, parts, and outgoing remanufactured products, (ii) sorting of incoming used-products, (iii) cleaning of used-products, (iv) disassembly of used-products and subassemblies, (v) inspection of used-products, subassemblies, and parts, (vi) cleaning of specific parts and subassemblies, (vii) repair or renewal of parts, (viii) testing of parts and subassemblies, (ix) reassembly of parts, subassemblies and products, (x) testing of subassemblies and finished products, (xi) packing, and (xii) shipping.

4.0 REMANUFACTURED PRODUCTS AND MARKET

Basically, any manufactured products or devices can be remanufactured, provided that these are discarded used-products with lower materials and components reprocessing costs compared to the market value of remanufactured items [17]. In addition, as outlined in [33], used-products must be; (i) durable products, (ii) products that fails functionally, (iii) standardized products with interchangeable parts, (iv) products with high remaining value-added, (v) products with low acquisition cost, (vi) products with stable technology, and (vii) customer awareness of the remanufactured version.

Some of the products that match these criteria as reported in [34] are aerospace, bakery equipment, compressors, data communication equipment, gaming machines, high end electronics and electrical, industrial machinery, motor vehicle parts, laser toner cartridges, musical instruments, office furniture, photocopiers, refrigerators, robots and vending machines. In addition to remanufactured products (e.g. vending machine, washing machine, mobile phone, etc), there are also remanufactured parts/components for the purpose of spare parts (e.g. automotive clutch, automotive engine, starter motor, etc). Some examples of remanufactured products and parts are shown in Figure 2 and 3.

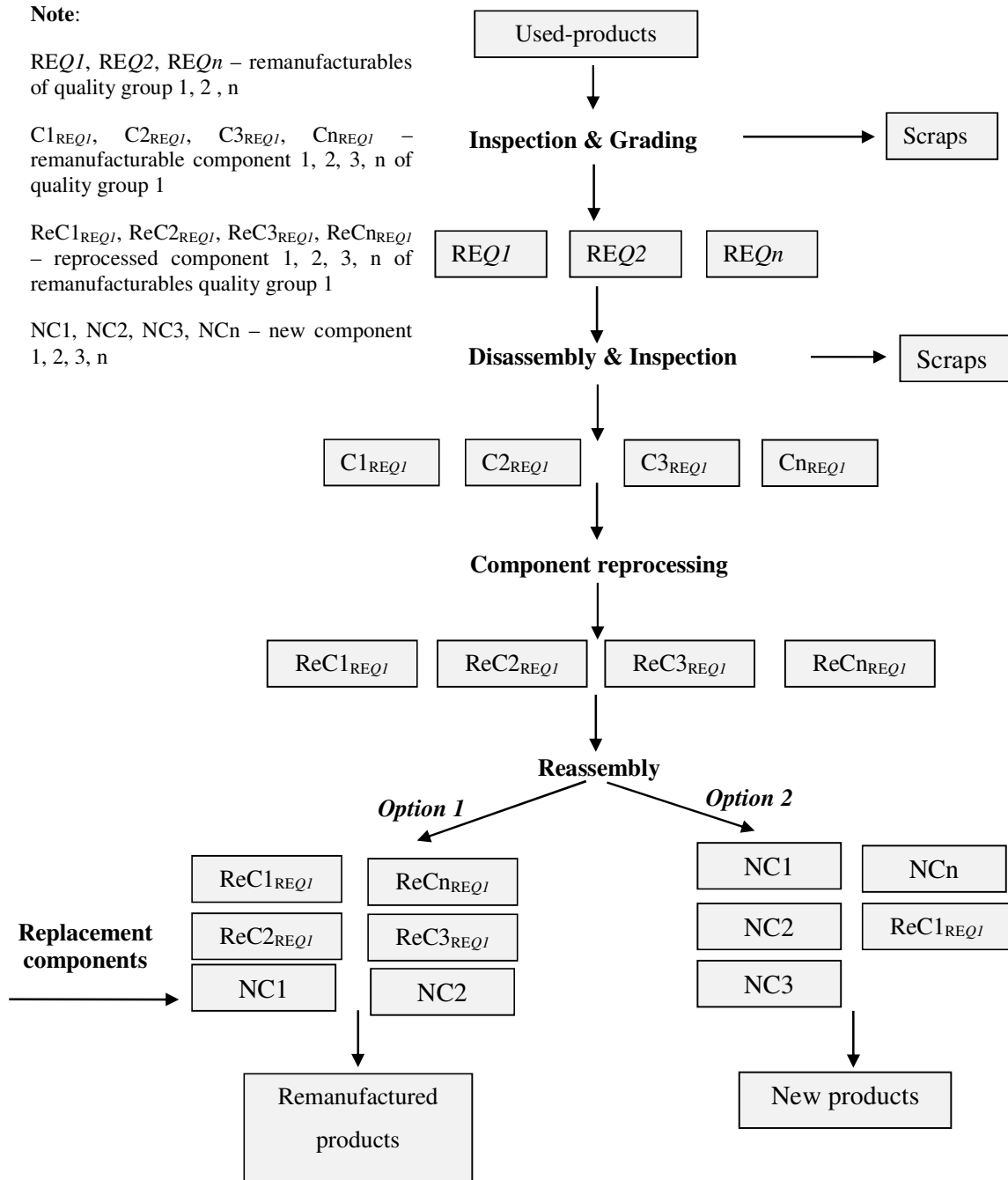


Figure 1: Schematic diagram for different usage of reprocessed components



(a) Vending machine [27]

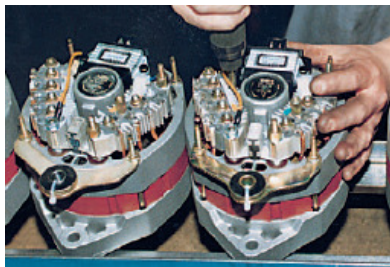


(b) photocopy machine [27]

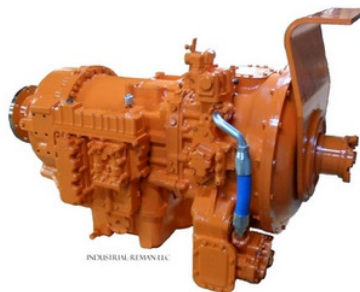


(c) mobile phone [27]

Figure 2: Some Examples of Remanufactured Products



(a) alternators [27]



(b) transmission system [35]



(c) tractors parts [36]

Figure 3: Some Examples of Remanufactured Parts

The market for remanufactured products could be primary-market or secondary-market. For the primary product market, remanufactured products are perfect substitutes for new products [37] and sold at cheaper price than the new ones [38]. This refers to original equipment manufacturers (OEMs) used-products that are remanufactured to quality standard as good as new, at the OEM's remanufacturing facility. Selling remanufactured products together with new ones, allows companies to segment their demand better and seizes sales to the "low-end" customers, who will not purchase the new product. This, however, requires the price and quantity of remanufactured products are properly selected [39].

Remanufactured products could also be sold at the same price as newly manufactured products [40]. However, selling remanufactured products in the same market with new products might cannibalize the sales of new products [41]. An example of company that produces remanufactured products for the primary-market is the Katun Corporation [42]. This company, is one of the world's leading providers of OEM-compatible imaging supplies, photoreceptors, & parts for copiers, printers, multi-function peripherals (MFPs) and other imaging equipment. Kartun Corporation remanufacturers cartridges for use in HP Color

Printers/MFP's. The company ensures customer satisfaction by offering the highest and most consistent remanufactured toner cartridge quality possible.

Within the secondary product market, remanufactured products are common amongst customers who might have financial restrictions. For instance, remanufactured multifunctional digital copiers or MFPs are sold to customers who are satisfied with the cheaper and lower-level functions MFPs [43]. In Nigeria for instance, as reported in [44], the demand for remanufactured mobile phones is projected to be higher than their availability. For the secondary-market, remanufactured products are typically produced by third-party remanufacturers who reap the economic benefits of remanufacturing. In this situation, remanufactured products (e.g., computer systems, auto components, and office equipment) have lower quality standard and price than newly manufactured products [45].

5.0 CONCLUDING REMARKS

With the increasingly strict environmental regulations, growing consumers' awareness of green environment and potential economic benefits, remanufacturing program is becoming popular amongst many companies. This article has highlighted and discussed several important issues related to used-products remanufacturing valuable to the general public, potential remanufacturers, as well as researchers. Firstly, this paper has identified and discussed three important factors (product take-back legislations, environmental concerns and economic benefits) that motivate more companies to engage in remanufacturing programs. Secondly, this paper has discussed and schematically summarized the four main steps of remanufacturing process. And finally, this paper has identified and discussed the various types of remanufactured products and corresponding markets. It is hope that this paper contributes valuable insights into managerial issues on remanufacturing program to the general public, potential remanufacturers, as well as researchers, and subsequently promotes remanufacturing programs.

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