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7.1 What makes cleaning a costly operation in remanufacturing?

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Abstract

Product remanufacturing is a widely accepted product reuse strategy in most industries due to its unique advantage of retaining a greater portion of added value in the initial manufacturing stage. Remanufacturing involves a sequence of operations including disassembly, cleaning, inspection, parts replacement, re-assembly and testing. Previous research has shown that the cost of cleaning is only second to the cost of parts replacement. The objective of this study is to illustrate the significance of the cleaning operation in automotive remanufacturing and to identify the factors influencing the cost of the cleaning process. Case studies on four UK remanufacturers, three automotive and one copier, were carried out. Seven key factors causing high cleaning costs were identified and categorised under two dimensions. These are the technical nature of the products and processes of cleaning and the business nature of the remanufacturer.

Keywords:

Automotive Industry; Cleaning; Remanufacturing

1 INTRODUCTION

Open loop supply chains were common in the early days of the manufacturing industry and even today it is the same for some industries and products. The continued extraction of natural resources and increasing adverse effects on the environment is pushing the society towards more sustainable way of manufacturing. In the context of sustainable manufacturing more attention is being paid to closing the manufacturing loop by developing methods to reuse products. One such method is remanufacturing while others are repair, recondition, repurpose and recycle. Product remanufacturing is a widely accepted sustainable product reuse strategy [1] in most industries due to its unique advantage of retaining a greater portion of added value during the initial manufacturing stages[2][3] and has developed to a faster growing business than some traditional industries [4].

Remanufacturing is quite an old concept for high value products and the term ‘remanufacturing’ has been used in literature with various meanings sometimes creating an ambiguity. In 1983 Lund[5] in his book on the experiences of United States’ remanufacturing industry comprehensively defines remanufacturing “as an industrial process in which worn-out products are restored to like-new condition through a series of industrial processes in a factory environment, a discarded product is completely disassembled, useable parts are cleaned, refurbished, and put into inventory. Then the new product is reassembled from the old and, where necessary, new parts to produce a fully equivalent and sometimes superior in performance and expected lifetime to the original new product”. Since then many research has been conducted on this subject in variety of industries contributing some improvements and simplifications to the definition and concepts of remanufacturing. For the purpose of this paper the definition published by the British Standards Institute is used. BS 8887-220:2010 - Design for manufacture, assembly, disassembly and end-of-life processing (MADE) and BS 8887-2 Design for manufacture, assembly, disassembly and end-of-life processing (MADE) Part 2: Terms and definitions, defines remanufacturing as ‘returning a used product to at least its original performance with a warranty that is equivalent to or better than that of the newly manufactured product’[6][7].

The remanufacturing process consists of several important steps (Please refer to Figure 1). Firstly the used product, which is known as the ‘Core’, is received at the remanufacturing facility. Then the product is fully disassembled in to part level and then each part is cleaned. For example in automotive gearbox remanufacturing, the parts would be gear box housing, all internal gears, shafts, bearings, connecting bolts and nuts, couplings and shifter mechanisms. The main purpose of cleaning is to facilitate inspection and damage correction, and thus make the parts to like new in condition. The process of cleaning requires one or multiple processes including both manual and machine operations. The correct extent of cleaning is cleaning the product up to like- new condition. However, it is difficult to measure the level of cleaning irrespectively as there is no standard yardstick available. In practice it is mostly done by visual inspection and then determining which is good enough by experience of the workers. This also causes a difference in cleaning efforts and hence costs for each remanufacturer.

The cleaned parts are then inspected for their quality and performance. Parts which fail the expected standard are either scrapped or sent for component remanufacture. Scrapped parts are replaced with new or remanufactured parts. Some critical parts which have limited operational life such as bearings are replaced with new parts irrespective of their condition to ensure the required quality and hence the required guarantee. Rebuilding of the product is then carried out by assembling the parts together according the original

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equipment manufacturers (OEM) specification. As the last step of remanufacturing the assembled product is subjected to an operational performance test which is similar to that used to test a new product during initial manufacture. In the event of using remanufactured components, the component should also be tested individually according to OEM standards before assembly to ensure successful component remanufacture.

Almost all the remanufacturing steps discussed above are highly labour intensive and time consuming unlike the operations in initial manufacturing which may use automation. This can make remanufacturing a costly operation so that sometimes it is not worth opting for remanufacture instead of the other end-of-life processes. Compared to the other steps of remanufacturing cleaning accounts for a considerable portion of the cost of automotive remanufacturing [8]. It is of paramount importance that the costs of product recovery activities are limited to make them economically viable and hence sustainable. Therefore this research aims at investigating factors for higher costs in the cleaning process of automotive remanufacturing and suggests ways in which these costs could be reduced.

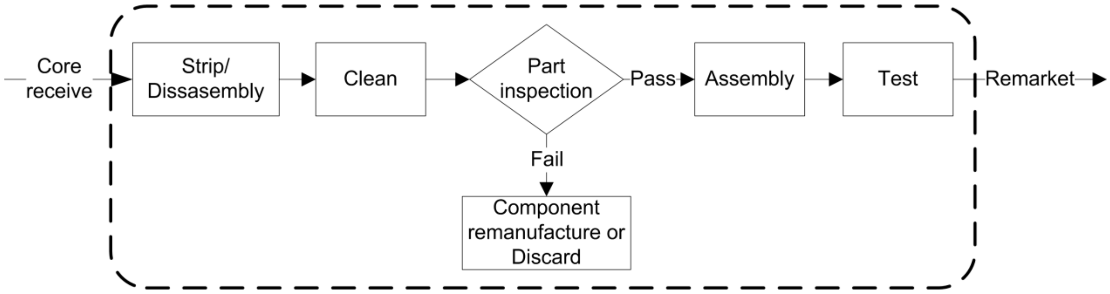


Figure 1: General process of Remanufacturing

2 LITERATURE REVIEW

Literature is enriched with a range of research on various aspects of remanufacturing in a variety of industries. It is stated that remanufactured products consumes about 50% to 80%less energy to produce when compared with a new product manufacture but with the comparable quality level [9]. Further there could be production cost savings from 20% to 80% compared with conventional manufacturing making remanufacturing a financially sound operation [2][9]. A study on environmental savings through remanufacturing of compressors has shown that the amount of greenhouse gas emission of remanufactured product is around 90% less than the manufacturing new compressor and it is 50% cheaper [10].

When it comes to automobile industry, it is estimated that 8-9 million vehicles are discarded every year in the European Union of which a major proportion is recycled meaning that an average value of 75% by weight of a vehicle is being recycled [11]. The above volume is comprised of the components that are discarded during remanufacture and components that are not considered for remanufacture. The large quantities discarded and high residual values of automobiles encourage reuse strategies to be followed. Hence it is important to develop cost effective strategies in remanufacturing. It has been found that the cost of cleaning seconds only to new parts replacement within reassembly operation in a survey undertaken in US automotive remanufacturing sector [8].

A study on the Swedish remanufacturing industry focusing on automotive and household appliances [12] has indicated that cleaning and damage correction steps are the most critical steps in the remanufacturing process. The cost for cleaning is largely from labour cost component among other capital and overhead costs. This is because there are few automated or machine assisted processes for cleaning. Other costs arise from consumables like chemical detergents and other factory overheads like electricity to operate cleaning machinery. So the time spent on cleaning is vital in controlling the cleaning costs involved. An assessment on US remanufacturing practices [13] indicates that cleaning accounts for the major portion of total remanufacturing processing time with an average of 20% spent on cleaning operation. One more reason for these excessive cleaning time is the requirement of multiple processing within the cleaning operation [4]. A study on energy intensities in diesel engine component manufacture in US[14] states cleaning remains a dominant energy consumer for remanufacturing of all of the engine components.

3 METHODOLOGY

A comprehensive literature survey on product remanufacturing was undertaken to figure out the issues of remanufacturing. The nature of the research objectives demands multiple case study approach as discussed in [15]. Four remanufacturing companies in the United Kingdom were chosen out of which three were in the automotive remanufacturing industry and the other in office equipment, (the photo copier) remanufacturing industry. Senior technical managers and operational level staff were interviewed onsite. Direct observations and company documents were used to understand the remanufacturing process in general and the importance and procedures of cleaning in particular.

4 CASE STUDIES

The entire process of remanufacturing from gate-to-gate was studied during case study visits. A comparison of case companies with regard to industry sector, category of remanufacturing, volume of operation and nature of cleaning operation is presented in Table *1*. Automotive transmission and engine components (such as gear wheels, shafts, couplings, valve bodies, torque converters, pistons, cylinder blocks, etc) require different degrees of cleaning and often done by different machine aids. Machine aided cleaning used in the case companies were, spray cleaning, baking, chemical bath agitating, shot blasting, and vibration grits cleaning. Manual washing, which is the most common, may still be required even after one stage machine aided cleaning.

Table 1 : Comparison of case companies

	COMPANY A	**COMPANY B**	**COMPANY C**	**COMPANY D**
Sector	*Automotive*	*Automotive*	*Automotive*	*Copier*
Nature of business	*Both automatic and manual transmission remanufacturing*	*Manual transmission and engine remanufacturing*	*diesel engines and transmissions, cylinder heads*	*Photo copier remanufacturing and after sales services*
Category	*Independent remanufacturer*	*Contract remanufacture*	*OEM*	*Independent catering for limited brands*
Company size (employees)	*25 approx.* *SME*	*75 approx.* *SME*	*300 approx.*	*15 approx.* *SME*
Average production (approx.)	*600 units/year*	*15,000 units/year*	*Complex*	*400 units/year*
Nature of cleaning operation	*Machine and manual* *Uses aqueous based detergents and degreasers*	*Varity of machines and manual* *Uses aqueous based detergents and degreasers*	*Varity of machines (Ex. vibration) and manual cleaning*	*Only Manual cleaning* *Uses aqueous based detergents*

Company A, uses a spray cleaner machine and manual cleaning of automobile transmissions parts. After cleaning they spray paints the gearbox cases in bringing those to like new condition. Whereas company B uses only cleaning techniques in bringing the gearbox casings to like-new condition. These include the spray machine wash and then shot blasting to get the natural aluminium outlook without painting it. For other inside components they use dipped cleaning with kerosene and aqueous detergents, vibration grits cleaning and manual cleaning. Company B spends 40% of its total remanufacturing time for cleaning operation during manual transmission cleaning. This has been largely contributed by the manual cleaning operation. Company C also uses manual cleaning and variety of machine cleaning techniques. It was mentioned that consumables of cleaning alone accounts for 10% from the total cost of remanufacturing in company C.

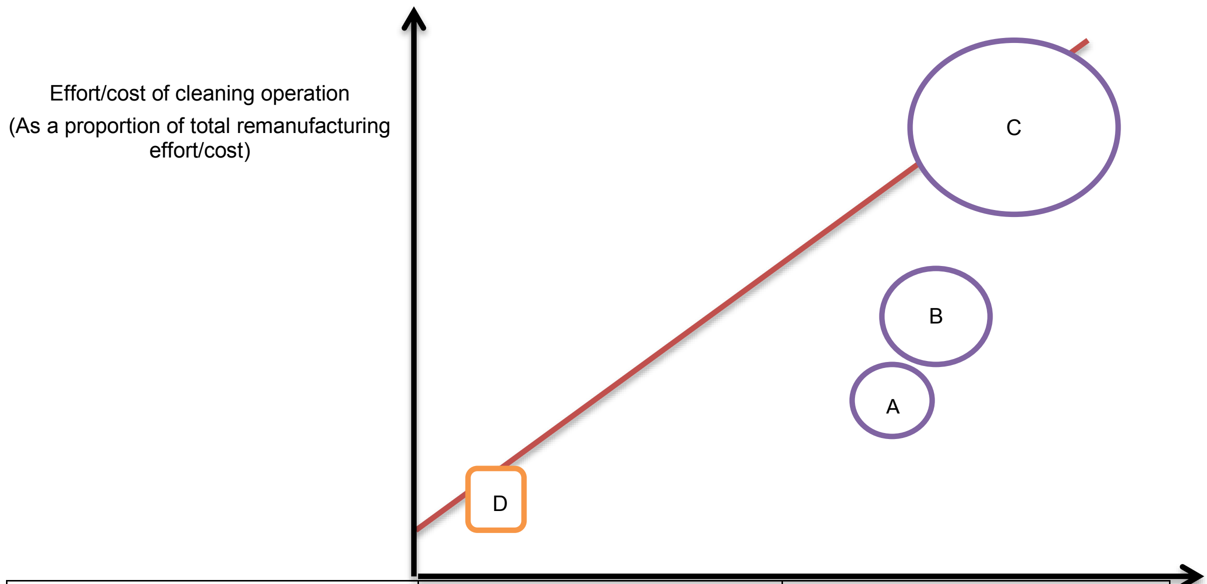
A study on automotive parts remanufacturing [8] reveals five main reasons for cleaning difficulties; namely the size of parts/orifices, environmental regulations, excess debris, material type and corrosion. These were enquired and confirmed by the case studies A, B and C. Additionally two new important factors were also found. These are the output form of the remanufactured product and the approaches to cleaning by individual remanufacturer. The attention to cleaning is higher in component remanufacture than whole unit remanufacture. For example during whole engine remanufacture versus piston remanufacture, there is much higher effort is needed for the later. This is because the customer is comparing the remanufactured component (piston) with its new counterpart. However during whole engine remanufacturing the attention/effort needed to clean the same piston would be much lesser. Some remanufacturers use finishing operations, like painting, to bring products to like new condition thus reducing the efforts of cleaning. These kinds of alternative approaches to cleaning by some remanufacturers may reduce the costs incurred for cleaning.

Attention for cleaning was comparatively low in company A, medium in Company B and high in company C. This may be due to the fact that OEMs and contract remanufacturers are much more concern about the brand value of products. Further they have to incur higher costs when complying with environmental regulations than for small scale independent remanufacturers who outsource the waste disposal. The use of technology also increases from company A to C as company wealth, volume and complexity of operation increases. Furthermore company C has to put an extra effort for cleaning as their output form of products includes remanufactured spare parts other than whole units. In contrast, company D, which is in the copier industry has a relatively lower extent of cleaning which requires only manual cleaning with aqueous detergents as it does not contain large amounts of debris and they use a final painting operation. Further copiers have fewer parts, less intricate components and simpler joining methods compared to automotive parts.

5 FINDINGS

Seven factors were identified which make cleaning costlier (please refer left most column in Figure 2). Out of which first five was mentioned in literature and also confirmed through the case studies. New two factors, output form and approaches to cleaning, were revealed through case studies. These seven factors can be categorised to two main dimensions. The first is the technical difficulty due to physical characteristics of the product and/or process which makes cleaning process more complex. This demands extended labour and machine hours adding up to the cost of cleaning. The first four factors in the list (Figure 2) belong to this category. The second dimension is the factors arising from the nature of the business of the remanufacturer. Characteristics like company scale, volume and variety of operation, output form and internal standards coupled with the brand image are concerned under business nature. The last three factors in the list could be categorised under second dimension. The costs associated with cleaning consumables, overheads and compliance to cleaning waste disposal regulations may increase due to the factors under second dimension.

Figure 2 shows the relative costs incurred for cleaning in each of the case studies. The circles represent automotive remanufacturers and square represents the copier remanufacturer. The relative size of object shows the size of the organisation in terms of employees and volume of operation. The figure is not to scale but represents a fair enough picture based on the information gained during the case studies. The x - axis represents the factors which make cleaning costlier and the y - axis represents the cost of cleaning as a proportion of total remanufacturing cost in each company.



FACTOR		
Part complexity (shape, size)	*Low*	*High*
Excessive debris	*Low*	*High*
Material type	*Easy (ex. Ferrous)*	*Difficult (ex. Aluminum)*
Corrosion	*Low*	*High*
Environmental regulations	*Low applicability*	*High applicability*
Output form	*Whole units (ex. Complete transmission or engine)*	*Part level (ex. Crank shaft, piston)*
Approaches to cleaning (due to brand consciousness and internal standards)	*Simple*	*Complex*

Figure 2 : Cost of cleaning vs factors affecting cleaning

It could be concluded that both dimensions equally contribute to the cost of cleaning. It is important to identify what are the factors that mostly affect in a given context and address them to bring down the cost of cleaning during remanufacture. Individual companies need to set their own targets in cleaning operations and invest accordingly in gaining a cost advantage.

6 SUMMARY

The factors making higher cleaning efforts have been identified. Those factors affect every remanufacturer depending on the nature of their operation and type of the products. The findings of previous research have been confirmed and some new factors were also identified. The research emphasises the significance of the cleaning operation as a high cost contributor for remanufacturing. Higher cost of remanufactured products may hinder their competitiveness in the market place which affects sustainable manufacturing. The authors believe that this knowledge would encourage product designers to consider more about the aspect of cleaning during the product design stage (Design for Cleaning) thus assisting them to design more sustainable and environmentally friendly products.

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