



REMANUFACTURING

Remanufacturing as a trend in early product
development

Lassi Mastomäki 540719

Tuomas Portin 606022

Tuukka Joonas 591991

Konsta Karppinen 586744

What is remanufacturing?

Remanufacturing is one way of recovering a product. Term “remanufacturing” contains its main definition: the product is being manufactured again. The more precise definition, according to Johnson and McCarthy is "the rebuilding of a product to specifications of the original manufactured product using a combination of reused, repaired and new parts"[1]. When considering a product development project, the recycling point of view has been a big topic in the past. However, the “remanufacturability point of view” could be even better in product development.

Recovering types

Before considering remanufacturing more closely, it is important to know how the recovering types are divided. According to Lindahl et al, the recovering forms are:

- Reuse
- Repair
- Refurbishing/Reconditioning
- Recycling
- Cannibalization
- Remanufacturing

Reuse means that components that are disassembled in product disassembling process are used again in new product. For instance, using glass bottles again after usage. *Repairing* is the fixing of the broken product. For instance, changing new windscreen to your car is repairing. *Refurbishing/reconditioning* is the process where old product is enhanced for instance, with paint or polishing. *Recycling*, is the process where manufacturing of the new product is based on old materials so, that amount of raw material is decreased. Recovering only some components to make new one is called *Cannibalization* (for instance, the use of smartphones processor in another device). Remanufacturing is a process, where old product is reconditioned in industrial-like process to function like a new product. [2]

Lifecycle approach

Lifecycle approach gives a good overall look at what remanufacturing means in practice. For the recycling, the waste is turned to material again, and reproduced from the beginning. Recycling decreases the need of the raw materials in manufacturing. However, remanufacturing brings sustainability to the next level; material transformation isn't needed anymore, and lifecycle can be continued “one step further” than in recycling process. This enables the lifecycle process to consume less energy and work in order to put waste back to the use. In the figure at right, the step saved can be seen. As the material transformation causes usually significant energy consuming, the remanufacturing is always a significant choice to consider, when enhancing products lifecycle process.

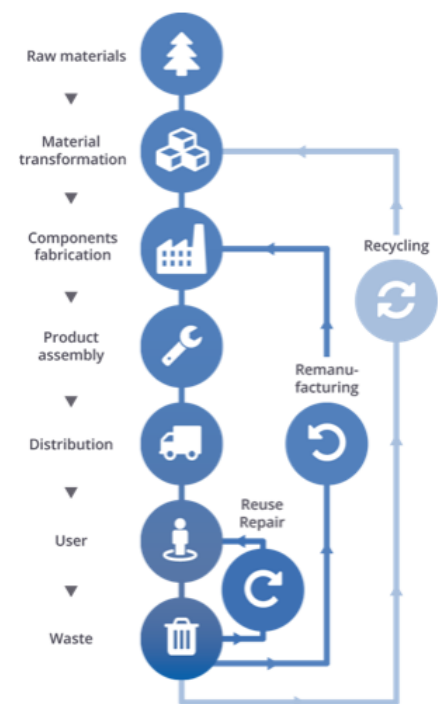


Figure 1 Product lifecycle process [3]

Manufacturing practitioners

Manufacturing practitioners can be divided roughly to three different types. *Original equipment manufacturer (OEM)* is the manufacturer that produces remanufactured products with original equipment used also when the product was made at first. *Independent manufacturers* are remanufacturers that have their own business that OEM does not affect. Independent manufacturers buy their remanufacturable parts itself and remanufacture and sell them without contact to the OEM. *Contract manufacturer* is a remanufacturer, that has a contract to manufacture the part. The parts made belong to the OEM company, but the OEM doesn't manufacture the parts itself.

Benefits of remanufacturing

Benefits of remanufacturing can be seen in many levels. This chapter is divided in three subheadings according to the approach: customer, environment, and manufacturer.

Customer approach

From a customer point of view, the benefits of remanufacturing can be difficult to see directly. Remanufacturing still has indirect benefits for the customer that comes from companies using remanufacturing. Remanufacturing often leads to lower product prices, as it is less expensive, both in terms of materials and energy. According to The European Remanufacturing Network remanufactured products are usually around 60-80% of the cost of the product if it were bought brand new. Another benefit is better availability of the products. For products that are manufactured to order overseas, a remanufactured product may be available with a shorter delivery time.[3] This is because remanufacturing is often done in more local factories rather than overseas.

Environment approach

When considering a new product, the sustainability aspect is in a significant role. New product should be manufactured so, that it is more sustainable than competitors' products or company's own, older products. As said earlier, recycling has been one of the interests in product design. However, company could "skip a step" in a product lifecycle process, and therefore save energy and work done in material transformation -phase (see figure 1, p. 2). This decreases, for instance, emissions created in the total lifecycle of the product compared to them, that are "only" recycled products. From a product developer point of view, the total emissions should be considered, and design time should be consumed in determining, how much remanufacturing is feasible to be used.

Another point of view is based on the same argument as recycling, material savings. When remanufacturing a product, a significant amount of new, virgin material is not used in the process, and hence saved. In the case of traditional lumber industry, which is being operated with sustainable ways, the raw material isn't a problem. However, for instance phone industry uses metals and other rather rare materials, that can be extracted only limited amount from the ground [5]. In these kinds of situations, remanufacturing is in important role to save or reduce the extraction of raw material, for instance rare metals.

Manufacturer approach

As a manufacturer, the remanufacturing can be attractive function for the product lifecycle process. As an OEM manufacturer, the investments for the remanufacturing process aren't big, since original equipment can be used in remanufacturing process [6]. Also, when considering material usage, remanufacturing has a head start in comparison of using just virgin materials. According to Nasr and Thurston, remanufacturing industry in the US was developed because of the economical efficiency,

not because of environmental or governmental concerns or regulations. Because of the lower amount of raw material used, and less energy consumed, the economical efficiency is higher with remanufactured products [7].

Remanufacturing in early product development

Product developers are usually working for a company and they are responsible for developing new products or improving existing products so that the company can meet customers' needs more effectively. Product developers have no control over the level of product demand, but they can influence how effectively product demand is met in terms of energy and material use, as well as waste emissions. Companies usually want to develop products to be more sustainable. The overall goal of more sustainable product systems can be translated to specific guidelines during the product development process. According to Nasr, these guidelines can be i) Minimize material and energy resources needed to satisfy product function and consumer demand ii) Maximize usage of expended resources iii) Minimize or eliminate the adverse impacts of waste and emissions.[7] These guidelines guide product developers and one key solution is to utilize remanufacturing.

DfRem

A term DfRem means *Design for Remanufacturing*. According to Yang et al the "Design for Remanufacturing (DfRem) is one of the key issues for companies which are engaging in or planning to go into remanufacturing". [8] Product developers must also consider remanufacturing at an early stage of product development. According to Gray and Charter design for remanufacturing is based on idea that product's remanufacturability is affected by the physical characteristics specified during the design phase.[4] This means that at the design phase, product development team has a chance to affect manufacturability. It is important to have the whole remanufacturing process in mind when designing products for remanufacturing. For example, designing a product to favour on one step of remanufacturing could make other remanufacturing steps too difficult or expensive to carry out [15].

However, design for remanufacturing may not be applicable to all products. Product design for remanufacture is enabled by business models which recognise the benefits of remanufacture [4]. Gray and Charter have investigated remanufacturing Industry in UK. They came to conclusion that there is a very significant proportion of manufactured products, which could be remanufactured if the business model and products were designed to facilitate remanufacture; but they are not remanufactured.[4] Therefore, the opportunity for increasing remanufacture in the UK and probably in other countries too is potentially high.

Applications

Example processes in industries

Remanufacturing is a widely used process in several different industries. It is used for both decreasing consumption of resources and decreasing financial costs. The term remanufacturing itself

might not be used in certain industry even if the activity itself occurs. The process is referred as overhaul or refurbishment in these occasions.

One good example of an industry where remanufacturing is used a lot is the photocopier and printer industry. According to Chiodo and Ijomah photocopiers of Xerox go through seven lifecycles. This naturally also means seven income streams. [10] The typical model for this industry is leasing. The photocopier is leased to the user company and at the end of its lifetime it is changed to a new one. The old one is remanufactured and given to another company. [11, p. 69] This method saves both costs and resources.

Toner and ink cartridges of printers are quite expensive especially if bought from OEM. They also contain plenty of valuable materials. Therefore the process of remanufacturing is quite common especially among toner cartridges. Noteworthy is that the end customer doesn't necessarily think the cartridge to be remanufactured due to branding of them. The remanufacturing is often done by third-party companies which have their own brands. [11]

Remanufacturing in automotive industry is widely spread especially in the European union. Remanufacturing is done for several different components. One example are car tyres which can be retreaded after they reach their end of lifetime. The focus for retreaded tyres is especially in the heavy traffic and landing gears of airplanes. [11, p. 62 – 63]

Electric vehicles have a lot of media coverage and their amount is increasing fast. One of the main challenges in EVs is the cost of lithium-ion batteries. Foster et al. studied the possibility of remanufacturing EV batteries that no longer provide required range. They concluded that it is possible to replace the substandard cells and then sell the battery again. This process could decrease the cost of battery by 40 %. [12] Therefore, the cost saving potential associated with remanufacturing of EV batteries is significant and could result in increase of the amount of remanufactured batteries.

Aerospace industry is one of the industries where the remanufacturing is not referred as remanufacturing at least in Europe. Nevertheless, the process itself is widely used. The key aim in remanufacturing activities in aerospace is to maintain the airworthiness of airplanes. This is done by overhauling of components and making performance updates. [11, p. 55] This way the lifetime of the airplane can be increased.

Airplane engines have specified amount of flight hours before they need either maintenance or large overhaul. The large overhauls are typically carried out by OEMs such as Rolls-Royce. The engines can be even removed from the airplane for this overhaul process which in fact can be remanufacturing. [11]

Hospitals and other health care facilities typically have specialised and expensive equipment that are used for patient care. Those equipment typically have a long lifetime. These equipment include MRI, CT, X-ray and cardiology equipment and remanufacturing is widely used to keep them in use [11, p. 100].

Many industries have different meanings and uses for terms such as refurbishing and remanufacturing. Medical industry has official definitions for those terms. Refurbishing means restoring the equipment to original condition whereas remanufacturing means changing the performance of the equipment. Changing the performance means that the equipment has to be recertified. [11]

It is widely known that modern consumer electronics, such as smart phones, are notoriously difficult to disassemble. Nevertheless, refurbished phones are sold with discounted prices and they can undergo a process which resembles remanufacturing [11, p. 68]. Utilising active disassembly methods could be one way to increase the potential of remanufacturing also for consumer electronics. Active disassembly means that the device can self-disassemble non-destructively when suitable external energy is applied. [10] This could both drive the costs of the devices down and decrease their environmental footprint. Active disassembly is something that could be considered in the very early stages of product development when different ideas and concepts are generated.

Challenges

One of the biggest challenges for a product developer is to make sure, that the remanufacturability point of view is considered as a part of a development project. Remanufacturing can be done in terms of economical affect, and economical arguments are relatively easy to be expressed to the lead of the company. However, remanufacturing from an environmental point of view isn't as easy to be argued. Also, some investments might have to be done in order to start remanufacturing.

Also, one challenge lies in logistics. Logistics play a significant role in remanufacturing industry. As the raw material flow is at least partially substituted with products that are at the end of their life cycle, the material flow is unique. The quality of the materials can be changed, and the quantitative amount of material can vary. These uncertainties make remanufacturing process more complex [9].

Future of remanufacturing

Remanufacturing industries all over the world are studying and innovating the nano-scale processing and manufacturing technologies. Nano cutting and nano welding technologies based on electronics, optics, magnets, and mechanics is aimed to develop. The development of these technologies aims to understand the matter and energy structures and how these can be utilized for the remanufacturing industry. This opens a new application field for the current remanufacturing. [13]

Remanufacturing is expected to grow in the U.S. from 2017 to 2025 at a CAGR (Compound Annual Growth Rate) of 6.6 percent. This indicates its significant role in manufacturing at the future. This also affects minimizing the environmental impact, as a part of the circulation economy. The materials can be increasingly re-use and recycle. In their work, designers strive to take better account of the aspects that affect remanufacturing to make it easier and faster. Products and their materials are selected with the entire life cycle in mind. The aim is to build the products so that the parts used in them are easy to disassemble and reuse. This reduces the cost and time required to reprocess the product. [14]

References

- 1) Johnson, M. R. & McCarthy I. P. (2014) Product Recovery Decisions within the Context of Extended Producer Responsibility. *Journal of Engineering and Technology Management* 34, 9-28

- 11) Parker, D. & Riley, K. & Robinson, S. & Symington, H & Tewson, J. & Jansson, K. & Ramkumar, S. & Peck, D. 2015. Remanufacturing Market Study. European Remanufacturing Network. EC-09 404 ERN WP2.2.
- 12) Foster, M. & Isely, P. & Standridge, C. & Hasan, M. M. 2014. Feasibility assessment of remanufacturing, repurposing, and recycling of end of vehicle application lithium-ion batteries. *Journal of Industrial Engineering and Management*, 7(3), 698-715. ISSN 2013-0953. DOI: 10.3926/jiem.939
- 13) Xu, B. Progress of remanufacturing engineering and future technology expectation. *Adv. Manuf.* 1, 8–12 (2013). <https://doi.org/10.1007/s40436-013-0003-8>
- 14) Jonathan Wilkins, 2019, The Rise of Remanufacturing Available at: <https://industrytoday.com/the-rise-of-remanufacturing/>
- 15) Sundin, Erik. *Product and process design for successful remanufacturing*. 2004. PhD Thesis. Linköping University Electronic Press. ISBN: 91-85295-73-6 (print), URN: [urn:nbn:se:liu:diva-5015](https://nbn-resolving.org/urn:nbn:se:liu:diva-5015)