Is the pace of technology development a threat or opportunity for sustainability? The case of remanufactured industrial robots

Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 73 (2018) 247–252

www.elsevier.com/locate/procedia

10th CIRP Conference on Industrial Product-Service Systems, IPS^2 2018, 29-31 May 2018, Linköping, Sweden

Is the pace of technology development a threat or opportunity for sustainability? The case of remanufactured industrial robots

Lisa Melander[a]*, Sofia Lingegård[b]

[a]*Chalmers Univeristy, Vera Sandbergs allé 8, SE- 412 96 Göteborg, Sweden*
[b]*KTH Royal Institute of Technology, Teknikringen 10B, SE- 100 44 Stockholm, Sweden*

* Corresponding author. Tel.: +46 723 752 906. *E-mail address:* lisa.melander@chalmers.se

Abstract

Remanufacturing has been identified as having much potential and providing a wide range of benefits. However, challenges remain for remanufacturing to be widely accepted, both from customers as well as within industrial firms. Business models for remanufacturing are complex and remanufacturing requires multiple competences across the firm. This paper is a study of the remanufacturing market for industrial products and is exemplified by a case study of a leading robot company in the US market. The study shows that rapid technology development impacts the remanufacturing possibilities and as such has an impact on sustainability. Technology development can be seen as a threat to remanufacturing e.g. making products become obsolete as well as leading to compatibility problems where it is difficult to find spare parts. Technology development also results in cheaper robots, making it difficult to provide economic incentives to buy remanufactured products. However, fast technology development can also be a possibility to firms that have well developed remanufacturing processes, as they are able to adjust to newer technologies. The study also points to the importance of cross-functional collaboration in the design phase of products, where remanufacturing needs to be considered. The article provides implications on how to manage rapid technology development in remanufacturing.

Peer-review under responsibility of the scientific committee of the 10th CIRP Conference on Industrial Product-Service Systems.

Keywords: Remainfacturing; technology development; sustainability, robot, case study

1. Introduction

Sustainability is becoming ever more important, where consumers, industries and government are becoming increasingly more aware of the need to limit our usage of virgin material. Circular economy, including re-use of goods and material, is growing in a number of areas. Resource efficiency and Product Service Systems (PSS) are important building blocks towards a more sustainable future. In this context, remanufacturing and refurbishment are important industrial processes. Remanufacturing allows the manufacturers to restore or upgrade used products to original or new specifications [1].

These industrial processes involve a number of steps in a process that varies among industries, products and companies. There are some well-known examples of remanufacturing and refurbishment, for example the recent possibility to buy remanufactured iPhones or the well-established remanufacturing of toner cartridges. There are both environmental and economic benefits to be gained in remanufacturing [1]. A recent study on remanufacturing point to that firms tend to emphasize profitability rather than sustainability concerns [2]. In addition, many of the products that are remanufactured today have not been designed for remanufacturing and business models for remanufacturing are complex [3].

A literature review on remanufacturing calls for more case study research in the field [4]. This paper focuses on the industrial market for remanufactured robots. Empirical data is collected through a case study of a robot remanufacturer in the US. The firm under study has been working in the remanufacturing robot market since 1990. Previous studies of industrial robots describes how a robot's life can be extended through refurbishment [5]. The firm is one of the largest industrial robot manufacturers, and one of the few manufacturers who conducts remanufacturing in-house. The

2212-8271
Peer-review under responsibility of the scientific committee of the 10th CIRP Conference on Industrial Product-Service Systems.
10.1016/j.procir.2018.03.313

aim of the paper is to investigate the dual-faced consequences of technology development in regards to sustainability in the context of remanufacturing by providing a new case. We study the remanufacturing robot business in the US, describing the market for remanufactured industrial robots, obstacles and possibilities as well as the future outlook of that particular market.

The paper is structured as follows. First, literature on remanufacturing is presented. Thereafter, our methodology is described and the empirical case is presented. Finally, discussion and conclusions are provided.

2. Theory

There has been many studies investigating remanufacturing, where a number of industries have been studied, such as household appliances, toner cartridges, forklift trucks [6], automotive parts and components [6-12], baby prams [13], photocopiers [14], cameras, toner cartridges [11], engines, turbo chargers, filling machines [9], office furniture, computers and heat exchangers [10].

There are a few terms in the remanufacturing industry that are sometimes not well distinguished in practice, such as remanufacturing, refurbishing and reconditioning. In this paper, we distinguish between these terms as follows [1, 6, 10, 15]:

- Remanufacturing: the process which allows the manufacturers to restore or upgrade used products (cores) to original or new specifications . The process follows a number of steps including inspection, cleaning, disassembly, repair, reassembly and testing.
- Refurbishing: not as extensive as remanufacturing, a few parts are replaced or the product is remanufactured.
- Reconditioning: restoration of parts to a satisfactory condition by e.g. painting.

Different industries and firms are at different levels of customer acceptance, technologies for remanufacturing as well as having reversed logistics for bringing used products back. A survey of Greek manufacturers shows that firms are not very involved in remanufacturing, however the main motivation behind remanufacturing is customer service [16]. Successful remanufacturing requires a developed collection system for used products, efficient remanufacturing processes and to cultivate a demand for remanufactured products [11].

In remanufacturing, cores are products that are brought back to the firm for remanufacturing. Matsumoto and Umeda [11] show that firms use components in new products, hence making no distinction between remanufactured and new products. Upgrading product to the latest standards including the newest technology is one way to improve environmental impact during use. Östlin, Sundin and Björkman [10] show how OEMs can use cores for either product remanufacturing, component remanufacturing or component cannibalization.

3. Method

This study applies a qualitative single case study methodology to gain rich insight into robot refurbishment in industrial markets. The single case study method is used as it pays attention to the context and enables telling a story [17]. The context of an industrial setting was chosen and a firm here called IndRob (fictitious name) was studied. IndRob was selected because it operates in an industrial market, is one of the world leading manufacturers for industrial robots that also has an in-house remanufacturing business.

IndRob is a leading supplier of industrial robots, modular manufacturing systems and services. Over 250 000 IndRob robots have been sold worldwide. The firm has over 100 service locations in 53 countries, where more than 1 300 robot specialists work. The firm aims to have an innovative service that will keep their customers' robots running throughout their entire life cycle. IndRob's service includes robot service, spare parts, training, replacement and remanufacturing. The firm offers a number of service agreements that can be tailored towards each customer. Spare parts are an important part of the service department, providing customers with fast deliveries. Customers' employees are offered training focusing on robots, process and applications and system training. Replacements involves exchanging existing robot arms or controllers, which is an alternative to a completely new installation.

Data was collected through interviews, factory visits and documents. Interviews were held with the manager for service, including remanufacturing, a service employee and the factory manager at IndRob in the US. The factory was visited at two occasions, studying the remanufacturing business. Documents related to robot remanufacturing as well as remanufacturing of other products produced by IndRob has been studied. A within-case analysis was conducted [18] where important milestones, the remanufacturing process, the remanufacturing market, external developments and internal firm issues were identified. Market developments, technology developments, the remanufacturing process and internal issues were coded to facilitate analysis of the data [19].

4. The remanufactured industrial robot case

4.1. Centralized specialists in remanufacturing

IndRob's remanufacturing business started in 1990 in the US and was set-up Czech Republic in 2004. At one point, every service location had small reconditioned centres in IndRob. Then a strategic decision was made to set up central reconditioning centres. IndRob has three certified robot remanufacturing centres: in the US, in Mexico and in Czech Republic. The US centre handles North America and parts of South America. They collaborate with the centre in Mexico as well as the centre in Czech Republic. The centre in Chez Republic manages the European market. Robots and parts are sold internally within IndRob between these three sites. A certified centre in China is being started. The regular service locations are allowed to sell remanufactured robots but they are not allowed to perform remanufacturing.

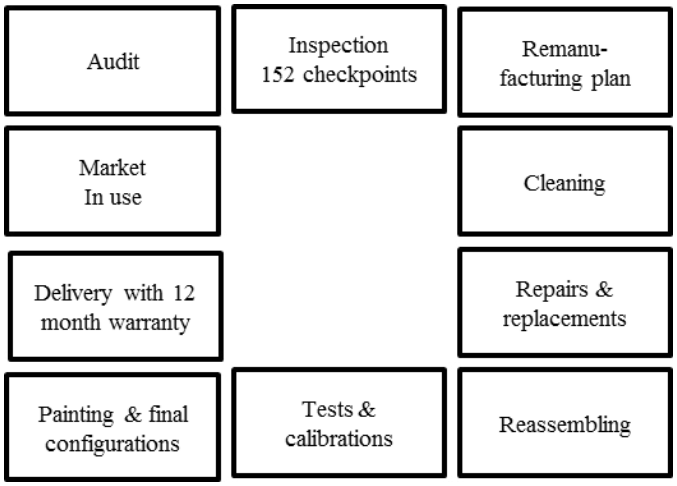

Fig. 1. Remanufacturing process at IndRob.

"I have mixed feelings about who should be allowed to do remanufacturing. I think that the service will be better if our service people can also do remanufacturing." By allowing remanufacturing in service locations, employees that have spare time can work on refurbishing robots. Employees will also grow their skills during this process. Also, by having centralized remanufacturing, there can be long transports of robots. However, there are a number of advantages of having a centralized remanufacturing, compared to having each service centre handle remanufacturing:

- Centralized competence
- Higher quality through controlled processes
- Investments in assets such as tools and test benches
- Buy back power
- Central inventory available
- Repaired parts available in the remanufacturing of robots

4.2. The robot remanufacturing market

Looking at the overall market, most manufacturers do not remanufacture their robots. Their strategy is to sell new robots. "We are the only one that I am aware of that have an in-house reconditioning center." However, on the internet there's a lot of people who sell used robots. There is quite a big difference between the used robot sales companies and IndRob's remanufacturing business. There are probably 40 different companies in the US selling used robots. Literally anyone that has any space can start such a company. Particularly in Michigan, with large automotive manufacturers there are a lot of opportunities to buy used robots when these companies change body shop. Then there are a hundred robots to replace. Many used-robots-dealers will try to buy these robots. They will store them and then sell them. They either break the robots down and sell parts and pieces or sell used robots.

Technical developments and the use of internet has changed the remanufactured robot market. Historically, robots were much less reliable than they are today. Previously, there was a lot of opportunity to do small upgrades, changes and remanufacturing on robots. Internet has changed the remanufacturing business. All things are available online, where people can find robots, prices and parts easily. The remanufactured robot market fluctuates quite a lot in the US. That is because the used robot market fluctuates. *"If I have a bunch of IndRob remanufactured robots, and then 1 000 used Fanuc robots hit the market. That will push my price down. But I don't sell used robots, I sell remanufactured robots."*

IndRob only remanufacture IndRob robots. IndRob has tried to remanufacture their competitors' robots but that was too challenging. The major issue was that the competitors controlled the prices of parts, making it much more difficult for IndRob to make a business case.

4.3. Remanufacturing on demand

IndRob keeps track of costs for each robot. IndRob usually doesn't have a lot of stock of remanufactured robots ahead of time. *"One of our key goals here are costs and we monitor our inventory very well."* An advantage for IndRob is short lead times. On average, IndRob can remanufacture and deliver a robot within four weeks. In comparison, the shortest lead time on new robots from the factory in the US is also four weeks, but can often be longer. However, IndRob often does not stock remanufactured robots. IndRob will rather keep their stock at the used robot value and then remanufacture on demand. However, IndRob does have some remanufactured robots ready for delivery. *"We have a smaller amount that we can deliver immediately. And the rest on demand."*

4.4. Selling new robots or selling remanufactured robots-

There is a belief that the remanufactured robot business is hurting new products sales. *"There is a force within IndRob that says: I don't like this."* That force is focusing on selling and manufacturing new robots. There are some people who sell new robots who believe that remanufactured robots compete with new robot sales. They believe that the remanufactured business is cannibalizing on new robot sales.

The customer base for remanufactured robots is quite different from new robot sales. Remanufactured robots are sold mainly to two customer groups. The first are first time buyers of robots who usually buy one robot to test if works in their production. The second group is customers that may have a particular style of robots. They have a specific production where a remanufactured robot is suitable. It can also be that the customer does not want to learn a different language, which is used on new robots. Sometimes IndRob can get a premium price for a remanufactured robot. IndRob can of course offer remanufactured robots to IndRob's standard customers, but these customers would rather purchase a new robot. Newer robots consume less energy and uses the newest technology. Large customers such as automotive manufacturers are not interested in buying remanufactured robots. Engineers at large manufacturers typically always want new robots. Because of the benefits of new technology of the new robots. Comparing the technology of the new robot with the old robot, are usually very significant. *"That's why we go to a first-time user. We sell a lot of robots to new users. They want to try out and see if a robot works."*

However, looking at the whole robot market, it would be a powerful message to say to the customer that IndRob offers

many alternatives. *"Not only can I sell you new robots, I can sell you used and I can sell you remanufactured. Whatever you need, whatever you can afford. We have more than one solution. We are going to follow you through the lifecycle of your asset. We will be here and help you. We have alternatives and options. As well as the option to buy back your equipment."*

4.5. IndRob's remanufacturing process

A remanufactured IndRob robot is as good as new, with identical quality, performance, support and warranty. IndRob has remanufactured over 12 000 robots and has an inventory of hundreds of used and remanufactured robots. IndRob lists the following benefits of remanufactured robots:

- Cost-efficient and reliable solution
- Lower investment cost
- Harmonizing with existing robot fleet
- No extra parts or training needed
- Fast overnight delivery
- Compliant to the latest safety standards
- Unlocking new functionalities and services such as IndRob's connected services

The remanufacturing process begins with an audit to evaluate the condition of the robot. A decision is made if remanufacturing is possible or not. If yes, a second inspection is made where parts are disassembled. In total, there are 152 checking points. A remanufacturing plan is made. The product is cleaned and replacements and repairs are executed. Worn parts that don't pass inspection are recycled. Each part is cleaned and reassembled. Tests and calibrations are made, a running test of minimum 16 hours. The robot is painted and final configurations are made. The robot is delivered with a 12-month warranty. See Figure 1.

IndRob distinguished between three different remanufacturing processes: remanufactured robots, remanufactured customer robot property and remanufactured arm exchange. Remanufactured robots are buy backs from customers that either are stored as used robots in stock or are remanufactured on demand for a customer. A few robots are remanufactured and stored. IndRob has a large stock of remanufactured and used robots. In comparison, remanufactured customer robot property is when IndRob refurbishes a customer's robot and thus prolongs the robot's life time. The robot then has the same owner before and after the remanufacturing. Remanufactured arm exchange is when IndRob exchanges a mechanical arm with an identical remanufactured arm. By doing this, the controller can be kept with little reprogramming. The remanufacturing process follows a strict systematic process for disassembly, cleaning, examination and testing. IndRob only uses certified staff for the remanufacturing process.

At the remanufacturing centre in the US is located in the same building as the new robot manufacturing. There are 12 employees working with remanufacturing. These employees have extensive skills in robotics and make decisions on whether the robot is suitable for remanufacturing or not. They also decide upon the remanufacturing plan and which parts that needs to be replaced and which can be remanufactured. Usually, there are about 30 robots undergoing work in the remanufacturing area simultaneously. On average, each robot needs 40 hours of work in the remanufacturing process. In comparison, the manufacturing of a new robot in the same factory takes on average 15 man-hours. The remanufacturing process demands many man-hours and skilled personnel. However, it uses little energy and mostly use spare parts from other buy back robots.

4.6. Buying back robots for remanufacturing

IndRob buys back used robots for remanufacturing. Most of these robots are found on the internet. IndRob continuously conducts searches online for used robots. In addition, many robots are found through word of mouth, through IndRob's sales force. *"When they find a robot for us, then we give them a finder's fee if they find a good robot."* Also, IndRob often use the buyback of robots as an incentive for the customer to buy a new robot. By selling a used robot to IndRob, the customer can get a better price for the new robot. Some of these buy backs are not useful for remanufacturing and these robots are then given to junk dealers. In some instances, there is a set fee for a used robot and sometimes IndRob negotiates with the customers. For some customers, there is a pre-defined buy back price.

How used robots are evaluated before buy back depends on the size of the buy back. If it's just one or two robots, then IndRob get pictures and information about hours in use. But if there are many robots, for example 100 robots, then IndRob will go and inspect the robots on-site. A normal buy back would be about four robots.

As an example, a buy back from a large automotive manufacturer will start when that company will replace their shop floor. They will then release a bunch of robots to the used robots market. They will reach out globally and ask how many robots each company is interested in. IndRob will then give them a price and try to buy these robots. One of the things with the buyback is that for a company like IndRob it is very difficult. The difficulty with IndRob is who they compete with. Competitors for buy backs such as junk dealers will usually walk around and have money in their pocket. They can buy robots by writing a check on the spot. IndRob has more administration to manage. IndRob has to set up the customer in their system, which takes time. Also, internally within IndRob, accounting and auditors don't always understand why a particular robot has a particular price. Often the remanufacturing business needs to answer many questions internally regarding buy backs of robots.

4.7. The sustainable future of remanufactured robots

The future for used and remanufactured robots will be challenging as the prices for new robots continue to drop. In addition, there is the fact that robots are much more reliable today than in the earlier days. *"I could argue to you that buying a robot from a junk dealer or a used robot dealer is risky. But with the reliability being up its much easier to take a used robot and put it in the market without any reconditioning. The odds are pretty good that it will continue to run."* Hence, there is a challenge with the technology as it gets better. There is less and less to remanufacture. *"We have run this business since 1990 and they continually say that they don't see a future for this*

business in ten years. That it will go away. It doesn't." However, the content on the remanufacturing is changing. IndRob used to do complete remanufacturing but that business continually changes. There is not as much mechanical content that can be remanufactured as robots contain more and more electronics.

Today, IndRob has a **very green process** that is used to recycle robots. Historically, IndRob used to take scrap robots to a dumpster or to a landfill. Now IndRob disassembles and separate materials and toxic materials. Some materials are bought by other firms, for example some cables are bought by one customer. Other materials are recycled. Remanufacturing involves a lot of hazardous environments with dirty robots and oil leakages. By having a clean and environmental process, IndRob is creating a better place, by handling toxic materials and recycling.

The remanufacturing business actually makes more money per robot than the new robot business, it's a good business. *"I could say that our intention is to be green and to recycle, but our intention is to make money. You know, and lots of it. That's that."*

There are a number of environmental benefits of remanufactured robots, such as:

- Saving material and energy
- Reduced scrap, 60% of the raw material is reused
- Reduced waste and less raw material needed
- Smaller carbon footprint and less greenhouse gases

Despite these environmental benefits, selling remanufactured robots with the selling-point of being sustainable and green is difficult. *"I think in the industrial area it is tough to say that we are green. I think that for IndRob, the green message would be that we use less power and the way we manage things. But I don't think that we are going to say that we remanufacture these robots for sustainability. That is a tough one to pitch."*

5. Discussions and Conclusions

The paper has pointed to a number of benefits from remanufactured industrial robots. First there are customer benefits from remanufacturing industrial robots, such as lower cost, harmonization with existing robot fleet, fast delivery and possibilities to unlock new functionalities. Even though a remanufactured robot requires skilled personnel and more than double the amount of man hours than the manufacturing of a new robot, the cost is lower than for new robots. This is largely due to reuse of the core and that the process takes place using the same manufacturing line as for new robots. Hence, it is a personnel intensive process that is sustainable from a material and energy point of view.

This way of integrated manufacturing and remanufacturing processes is seen as an effective way of reducing cost for the equipment used, using product knowledge and thereby improving the quality of the remanufactured products [15]. Second, there are a number of sustainability benefits from the remanufacturing business, such as material savings, reduced waste and smaller carbon footprint. This is in line with previous research, showing sustainable benefits from remanufacturing [1, 6, 20].

The remanufacturing business is changing, as there is a **faster technology development**. Robots have shorter life cycles due to faster technological development. This is partly due to that there is more electronics in robots, which have shorter life cycles and faster become obsolete. There are fewer mechanical parts to remanufacture as more parts include more electronics. Hence, we see shorter technology cycles due to faster technology development. This in turn leads to that new robots become "old" faster than previously. With faster technological development comes the problem of compatibility for remanufactured robots. Old spare parts that are not available, this is a concern particularly for electronics which have fast technological developments. With limited access to spare parts, the remanufacturing process is threatened. This is similar to the concerns on the availability of suitable cores [10, 21], and the need for introducing flexibility to the remanufacturing process to be able to cope with the variations on old cores [15]. We argue that fast technology development can be a threat to remanufacturing. However, it can also provide a possibility to firms that have well developed remanufacturing processes and modular products where exchange of old technology with new technology is possible. Hence, fast technological development can be both a threat and a possibility for the remanufacturing business of industrial robots.

Another threat to the remanufacturing business is that robots become ever more reliable, limiting the need for remanufacturing. In addition, the fast rate of technology development also makes technology cheaper, which is a threat to remanufacturing, as new robots become cheaper. In addition, new products that include new technology may be preferable also on an environmental perspective [6].

For future developments, modularization becomes ever more important, and needs to be considered in the development phase. In the design phase, firms need to include the possibility to exchange technology that fast becomes "old". Mechanical parts may work well but electronics and software may need to be exchanged at a faster rate. Hence, cross-functional collaboration is needed for firms to succeed in developing more sustainable products, something which has been highlighted in the literature [22-24].

Previous studies have identified important information flows for the remanufacturing process. The information flow from the products in use can greatly benefit the remanufacturing process and closing the material loop and the information loop are intertwined [25]. Design information reaching the manufacturing and remanufacturing can improve these processes, especially for complex products [15]. In the robot case, skilled personnel are needed in the remanufacturing process. Today, however, our studied firm does not have any **collaboration between remanufacturing and R&D** in the design phase of new robots. In fact, competitors are hindering remanufacturing of their own robots by increasing the price on spare parts. This issue is not limited to the industrial robot market, in fact, the majority of remanufactured products have not been designed for remanufacturing [3].

The last threat identified can be found at the customer market. It seems that there is limited acceptance for remanufactured industrial robots from customers as well as

within the robot manufacturing company. This is in line with other studies where customer recognition has been identified as a barrier for remanufacturing [26] and internal struggles within the firm [11].

5.1. Conclusion and further research

The future development of the remanufacturing of industrial robots seems to remain uncertain. The company does not have a reliable inflow of used cores for the remanufacturing process, which creates an uncertainty. The process is highly dependent on skilled personnel but information from the products-in-use is not captured and used to improve the knowledge and thereby the quality of the remanufactured robots. On the other hand, the manufacturing and remanufacturing processes are performed in the same factory and using the same machines providing a knowledge sharing in between them. Also, the customers are not easily convinced a remanufactured robot is as good as a new one, creating another uncertainty for the remanufacturing. However, the remanufactured robots have a lower production cost and most likely a lower environmental impact since used cores are utilized. Improvements in technology are causing problems for remanufacturing by making spare parts obsolete and the remanufactured robots outdated. On the other hand, by using modularity in product design and manufacturing as well as to continuously improve the process by increasing knowledge from e.g. the use phase, the company can adopt a more flexible remanufacturing process and decrease some of the uncertainties in the current process.

Our study has a number of limitations. Only one firm was studied in one market, the US. However, it is a leading firm that is well established in the remanufacturing business. Also, the US market is one of the largest for industrial robots. Future studies could investigate the customers' point of view on remanufacturing to better understand how to improve the process and thereby the business case for the manufacturer. Furthermore, the future points to an increased sustainability focus among customers and the impact of this trend on remanufacturing is another interesting topic for future research.

References

[1] Sundin E, Bras B, Making functional sales environmentally and economically beneficial through product remanufacturing, Journal of Cleaner Production, 2005, 13:913-925.
[2] Chaowanapong J, Jongwanich J, Ijomah W, The determinants of remanufacturing practices in developing countries: Evidence from Thai industries, Journal of Cleaner Production, 2018, 170:369-378.
[3] Prendeville S, Bocken N, Design for remanufacturing and circular business models, in, Sustainability Through Innovation in Product Life Cycle Design, Springer, 2017, pp. 269-283.
[4] Junior M L, Filho M G, Production planning and control for remanufacturing: literature review and analysis, Production Planning & Control, 2012, 23:419-435.
[5] Clark-Derby G, Prolonging a robot's life expectancy, Industrial Robot: An International Journal, 1995, 22:16-17.
[6] Lindahl M, Sundin E, Östlin J, Environmental issues with the remanufacturing industry, in: 13th CIRP international conference on Life Cycle Engineering: held at the Katholieke Universiteit Leuven, Belguim, May 31st-June 2nd 2006, Katholieke Universiteit Leuven, 2006, pp. 447-452.
[7] Zhang T, Chu J, Wang X, Liu X, Cui P, Development pattern and enhancing system of automotive components remanufacturing industry in China, Resources, Conservation and Recycling, 2011, 55:613-622.
[8] Subramoniam R, Huisingh D, Chinnam R B, Remanufacturing for the automotive aftermarket-strategic factors: literature review and future research needs, Journal of Cleaner Production, 2009, 17:1163-1174.
[9] Östlin J, Sundin E, Björkman M, Importance of closed-loop supply chain relationships for product remanufacturing, International Journal of Production Economics, 2008, 115:336-348.
[10] Östlin J, Sundin E, Björkman M, Product life-cycle implications for remanufacturing strategies, Journal of cleaner production, 2009, 17:999-1009.
[11] Matsumoto M, Umeda Y, An analysis of remanufacturing practices in Japan, Journal of Remanufacturing, 2011, 1:2.
[12] Sinha A, Mondal S, Boone T, Ganeshan R, Analysis of issues controlling the feasibility of automobile remanufacturing business in India, International Journal of Services and Operations Management, 2017, 26:459-475.
[13] Mont O, Dalhammar C, Jacobsson N, A new business model for baby prams based on leasing and product remanufacturing, Journal of Cleaner Production, 2006, 14:1509-1518.
[14] Kamigaki K, Matsumoto M, Fatimah Y A, Remanufacturing and Refurbishing in Developed and Developing Countries in Asia–A Case Study in Photocopiers, Procedia CIRP, 2017, 61:645-650.
[15] Tolio T, Bernard A, Colledani M, Kara S, Seliger G, Duflou J, Battaia O, Takata S, Design, management and control of demanufacturing and remanufacturing systems, CIRP Annals, 2017, 66:585-609.
[16] Kapetanopoulou P, Tagaras G, Drivers and obstacles of product recovery activities in the Greek industry, International Journal of Operations & Production Management, 2011, 31:148-166.
[17] Dyer W G, Wilkins A L, Better stories, not better constructs, to generate better theory: A rejoinder to Eisenhardt, Academy of management review, 1991, 16:613-619.
[18] Eisenhardt K, Building theories from case study research, Academy of management review, 1989, 14:532-550.
[19] Miles M, Huberman A, Qualitative data analysis: A sourcebook of new methods, Sage Publ.inc, Beverly Hills, CA, 1984.
[20] Sundin E, Lee H M, In what way is remanufacturing good for the environment?, in, design for innovative value towards a sustainable society, Springer, 2012, pp. 552-557.
[21] Lundmark P, Sundin E, Björkman M, Industrial challenges within the remanufacturing system, in: 3rd Swedish Production Symposium 2009, Göteborg, 2009, pp. 132-138.
[22] Song X M, Montoya-Weiss M M, Schmidt J B, Antecedents and consequences of cross-functional cooperation: a comparison of R&D, manufacturing, and marketing perspectives, Journal of Product Innovation Management, 1997, 14:35-47.
[23] Melander L, Customer and Supplier Collaboration in Green Product Innovation: External and Internal Capabilities, Business Strategy and the Environment, 2018, Early view.
[24] Melander L, Achieving Sustainable Development by Collaborating in Green Product Innovation, Business Strategy and the Environment, 2017, 26:1095-1109.
[25] Lindkvist L, Sundin E, The role of Product-Service Systems regarding information feedback transfer in the product life-cycle including remanufacturing, Procedia Cirp, 2016, 47:311-316.
[26] Wei S, Cheng D, Sundin E, Tang O, Motives and barriers of the remanufacturing industry in China, Journal of Cleaner Production, 2015, 94:340-351.