A report by the partners of:

D3.3 – D3.4 Map of Remanufacturing Processes Landscape

For Horizon 2020, grant agreement No 645984, 2016

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1 Introduction

Remanufacturing is an important component of a resource efficient manufacturing industry. By keeping components and their embodied material in use for longer, significant energy use and emissions to air and water can be avoided. In addition to environmental benefits, remanufacturing provides opportunities for the creation of highly skilled jobs and economic growth.

According to Steinhilper (1999), remanufacturing is the industrial process to restore used products (cores) at the end of their life or use cycle, into products of the same or better quality as new products.

In order to encourage greater remanufacturing activities, the European Commission has funded a project to form, coordinate and support a European Remanufacturing Network (ERN). This Horizon2020 project takes place over a period of two years, with the ambition to:

- encourage new businesses to take up remanufacturing
- help existing remanufacturers improve their operations
- improve competitiveness of remanufacturers domestically and internationally
- create greater awareness of remanufacturing to increase demand and address barriers.

Work Package 3 (WP3) aims to map *best practices* and *challenges* with respect to business models for remanufacturing, design for remanufacturing and remanufacturing processes.

This report focuses on the outputs of Work Package 3.3 (WP 3.3) including Task 3.3 and Task 3.4.

The report summarises the current status of remanufacturing processes in different industries across Europe.

2 Objectives & Methodology

The aim of WP 3.3 is to generate an overview of remanufacturing processes as they are carried out in different industries across Europe.

This report will summarise the work done as following:

1. Description of remanufacturing processes
2. Survey of industry sector specific remanufacturing processes
3. Map of remanufacturing processes
4. Remanufacturing processes case studies
5. Remanufacturing of new and advanced materials
6. Remanufacturing networking event and processes workshop

To gather the information in the first step, 105 companies were identified and their remanufacturing processes were analysed. The results of the analysis are the generic industry sector specific remanufacturing processes as well as typical products and sector specific features.

In the second step, the remanufacturing processes of eight companies were analysed by visiting the companies' facilities. The results of the analysis are the mapping of remanufacturing processes.

In the next step, eleven companies were asked to provide information about their company, their remanufacturing operations, their processes and their business situation. The information collected are summarised as one pagers for remanufacturing processes.

A special report on remanufacturing of new and advanced materials was created based on internet research.

Lastly, a remanufacturing networking event, including a remanufacturing processes workshop, was hosted in Bayreuth (Germany) to discuss the information gathered and to discuss today's and tomorrow's perspectives and challenges in remanufacturing.

The WP involved close collaboration with the industrial partners in order to:

- use their knowledge to unveil best practices among or known to them
- define challenges and opportunities close to the industrial praxis
- map remanufacturing processes in a way that is suitable for and usable by the industry.

3 Remanufacturing Processes

The number and sequence of the remanufacturing steps depend on the type and functionality of the product. According to Steinhilper (1999), mechanical and electromechanical systems have to be separated from mechatronic systems. For mechanical products, five main steps have to be undertaken.

According to Freiberger (2007), for mechatronic and electronical products it is useful to add a sixth step, which is the entrance diagnosis of the product. Thus, failures which are not based on mechanical wear can be identified and separated.

Figure 1 gives an overview of the five respectively six steps of remanufacturing.

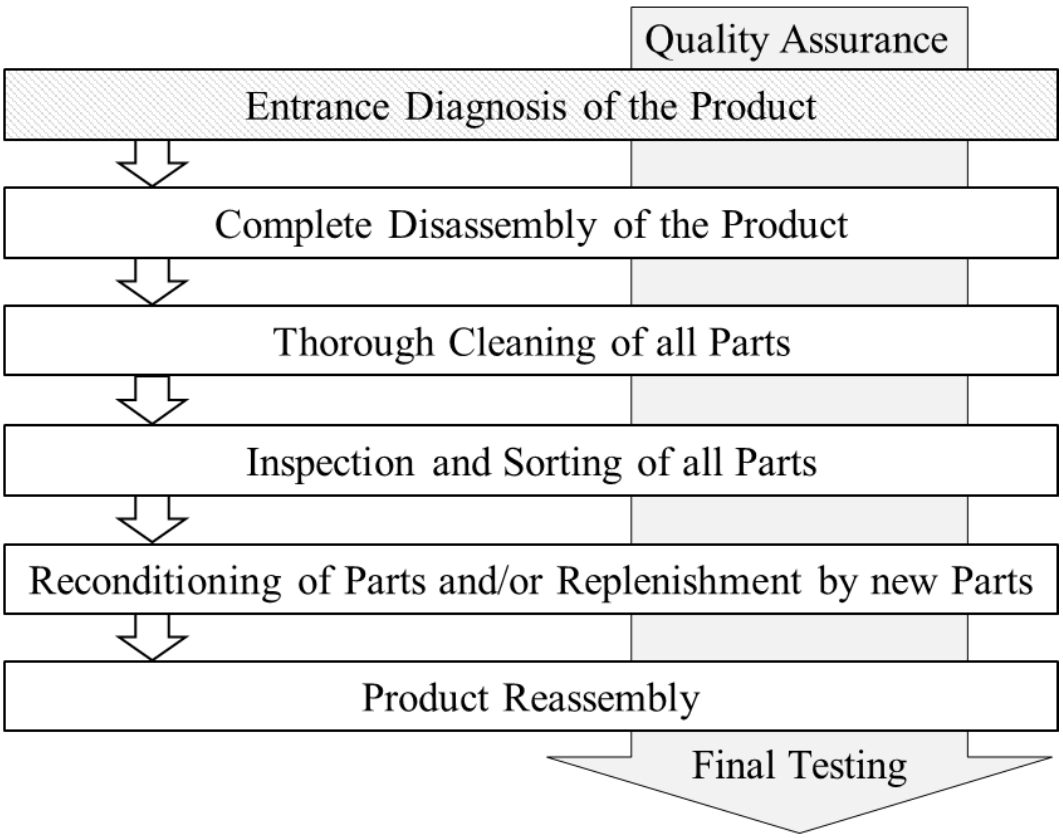


Figure 1 The five respectively six steps of remanufacturing.

In the following the five steps for mechanical systems, according to Steinhilper (1999), are described in more detail.

In the first step, the old products, called cores, are disassembled completely into their single parts. Parts which cannot be reused or remanufactured are sorted out. The disassembly is mainly done manually due to different contaminants and degrees of corrosion.

The second step includes the cleaning, degreasing, deoiling and derusting of all parts as required due to the level and type of contaminants and corrosion. Different cleaning technologies and processes are deployed in sequence or in parallel.

In the third step the parts are classified according to their ability to be remanufactured or reconditioned, respectively. The parts are classified as following:

- Reusable without reconditioning
- Reusable after reconditioning
- Not reusable / to be exchanged

Unlike in the new production of parts and products, within remanufacturing, all parts are inspected to guarantee the required quality.

Within the next step, worn out parts are reconditioned by using metal treatment processes such as drilling, milling, turning, grinding and honing. Parts which cannot be reconditioned will be exchanged with new spare parts.

The fifth step is the reassembly of the parts into a product. The reassembly is done on assembly lines for small batches with the same tools and equipment as in the new production. After the reassembly a functional test is done of all parts to guarantee 100% quality.

Remanufactured products have the same, or even better, quality than new products. To be able to ensure this, the same quality assurance and testing procedures as in the new production are used within remanufacturing operations.

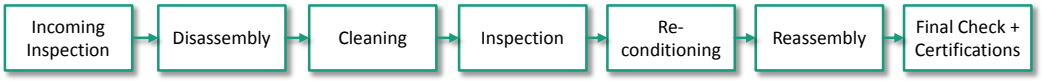
4 Sector Specific Remanufacturing Processes

To provide an overview of remanufacturing processes performed across Europe, 105 companies and their processes were identified and analysed. The results of the analysis are generic industry sector specific remanufacturing processes as well as typical products and sector specific features.

The summarised results of the analysis can be seen below.

Aerospace

Generic Remanufacturing Process



Typical Products:

- Turbines
- Aircraft Seats
- Engines
- Propellers

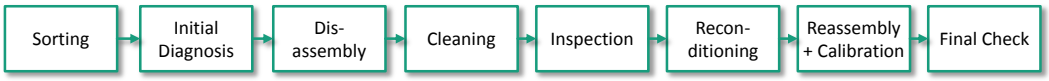
Sector specific features (regarding the Remanufacturing Processes):

- High quality standards must be met in order to achieve the necessary certifications
- Availability of spare parts can be problematic
- To avoid damage, the product as well as its single parts must be handled with great care
- Single parts can be made of advanced materials (e.g. PEEK, Carbon fibre)

Figure 2 Aerospace sector specific remanufacturing process.

Automotive

Generic Remanufacturing Process



Typical Products:

- Turbochargers
- Steering Systems
- Alternators
- Gearboxes
- Engines

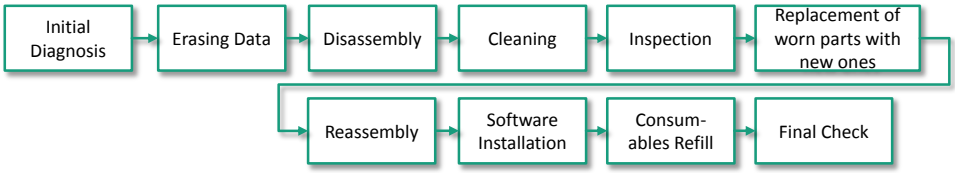
Sector specific features (regarding the Remanufacturing Processes):

- An initial diagnosis at the beginning helps to indentify failures of electronic parts
- Calibration of the product and/or subassemblies within the reassembly might be necessary

Figure 3 Automotive sector specific remanufacturing process.

Consumer goods and electronic products

Generic Remanufacturing Process



Typical Products:

- Ink and Toner Cartridges
- Cell Phones
- White Goods
- Notebooks and Tablets
- Printers

Sector specific features (regarding the Remanufacturing Processes):

- In order to achieve data safety, sensitive data must be completely erased from existing data storage devices
- After the reassembly, required software must be installed and consumables (e.g. ink) must be refilled (if necessary)
- Normally, worn parts are replaced with new ones instead of being reconditioned
- An initial diagnosis at the beginning helps to indentify failures of electronic parts

Figure 4 Consumer goods and electronic products sector specific remanufacturing process.

Furniture/office furniture

Generic Remanufacturing Process

Typical Products:

- Desks
- Tables
- Chairs
- Cupboards

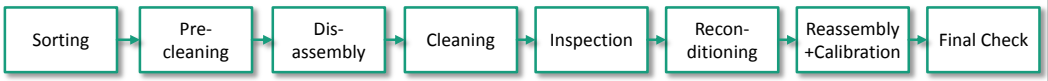
Sector specific features (regarding the Remanufacturing Processes):

- Normally, for large furniture the reassembly is done by the customer
- Broad range of materials (e.g. wood, metal, plastics)
- Often, in this sector, the process is also called "Refurbishing"

Figure 5 Furniture / office furniture sector specific remanufacturing process.

Heavy duty and off road equipment

Generic Remanufacturing Process



Typical Products:

- Gearboxes
- Brake Systems
- Hydraulic Systems
- Engines

Sector specific features (regarding the Remanufacturing Processes):

- In many cases, precleaning of the cores is necessary due to the high contamination levels
- Calibration of the product and/or subassemblies within the reassembly might be necessary

Figure 6 Heavy duty and off road equipment sector specific remanufacturing process.

Machinery

Generic Remanufacturing Process

Typical Products:

- Pumps
- Compressors
- Machine tools
- Robots

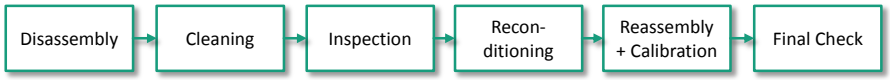
Sector specific features (regarding the Remanufacturing Processes):

- Final check can be very comprehensive (checking function, geometry, performance)
- An initial diagnosis at the beginning helps to indentify failures of electronic parts

Figure 7 Machinery sector specific remanufacturing process.

Marine industry

Generic Remanufacturing Process



Typical Products:

- Engines
- Alternators
- Sea water pumps
- Gear boxes

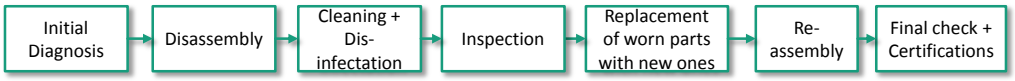
Sector specific features (regarding the Remanufacturing Processes):

- Cores can be highly corroded
- Single parts can be made of advanced materials (e.g Carbon fibre)
- Calibration of the product and/or subassemblies within the reassembly might be necessary

Figure 8 Marine industry sector specific remanufacturing process.

Medical equipment

Generic Remanufacturing Process



Typical Products:

- Computed Tomography (CT) Systems
- Magnetic Resonance Imaging (MRI) Systems
- X-Ray Systems

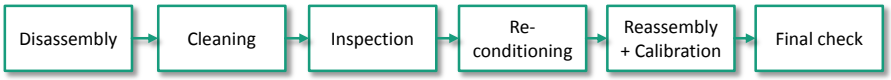
Sector specific features (regarding the Remanufacturing Processes):

- High quality standards must be met in order to achieve the necessary certifications
- Normally, worn parts are replaced with new ones instead of being reconditioned
- Within cleaning, the parts must be disinfected
- Often, in this sector, the process is also called "Refurbishing"

Figure 9 Medical equipment sector specific remanufacturing process.

Rail industry

Generic Remanufacturing Process



Typical Products:

- Engines
- Wagons
- Running Gears

Sector specific features (regarding the Remanufacturing Processes):

- Final check can be very comprehensive due to test drives etc.
- Calibration of the product and/or subassemblies within the reassembly might be necessary

Figure 10 Rail industry sector specific remanufacturing process.

5 Map of Remanufacturing Processes

In the second step of the work package the processes of eight companies were analysed in more detail. The companies' facilities were visited for one to two days. After visiting the remanufacturing operations, the information about the remanufacturing processes were gathered using a standardised questionnaire.

Four of the participating companies are independent remanufacturers and the other four companies are Original Equipment Manufacturers or Suppliers.

Enduring the remainder of the project, more companies will be visited and the updated results will be published in a scientific paper.

The results of the analysis are a detailed map of remanufacturing processes. The summarised results of the survey can be seen below.

Question 1: What criteria do you use for the sorting process?

- Core Classification, Quality
- Criteria „exploit", „recycling", „waste"
- Comprehensive reporting catalogue
- Preselection at the service provider by part number level, selection at the facility by specification of technical nature (technical specification through development department)
- Mechanical information, thermal stress, visually and measured with technical equipment

Question 2: What batch sizes do you typically use in (internal) production orders?

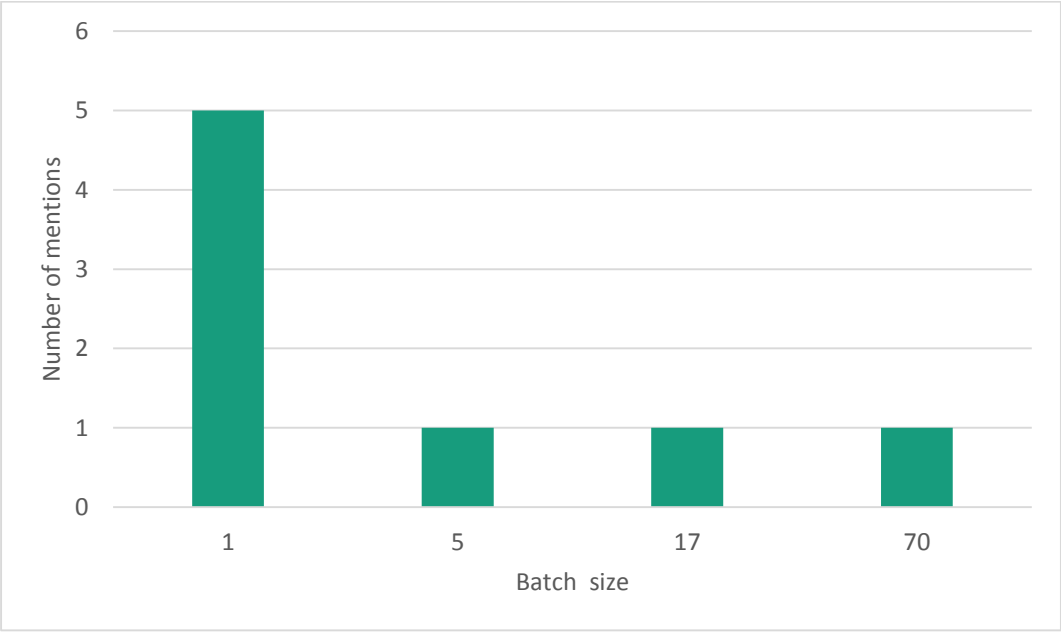


Figure 11 Batch sizes in remanufacturing.

Question 3: What size do your customer orders on average have?

Figure 12 Customer order size in remanufacturing.

Question 4: Which production concept is used?

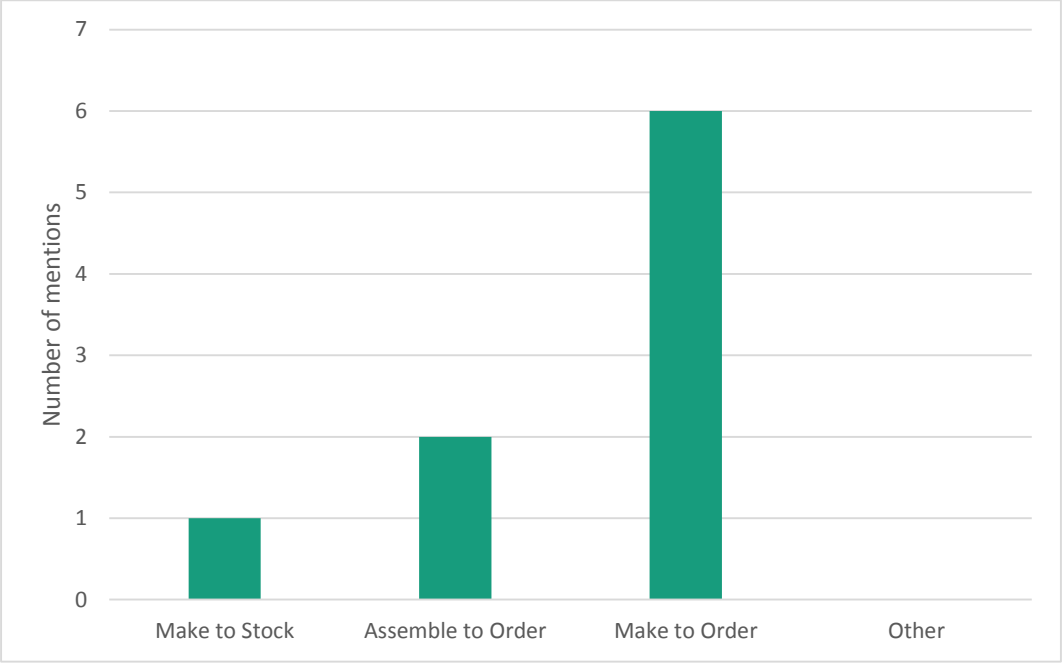


Figure 13 Production concepts in remanufacturing.

Question 5: What methods do you use to generate production orders?

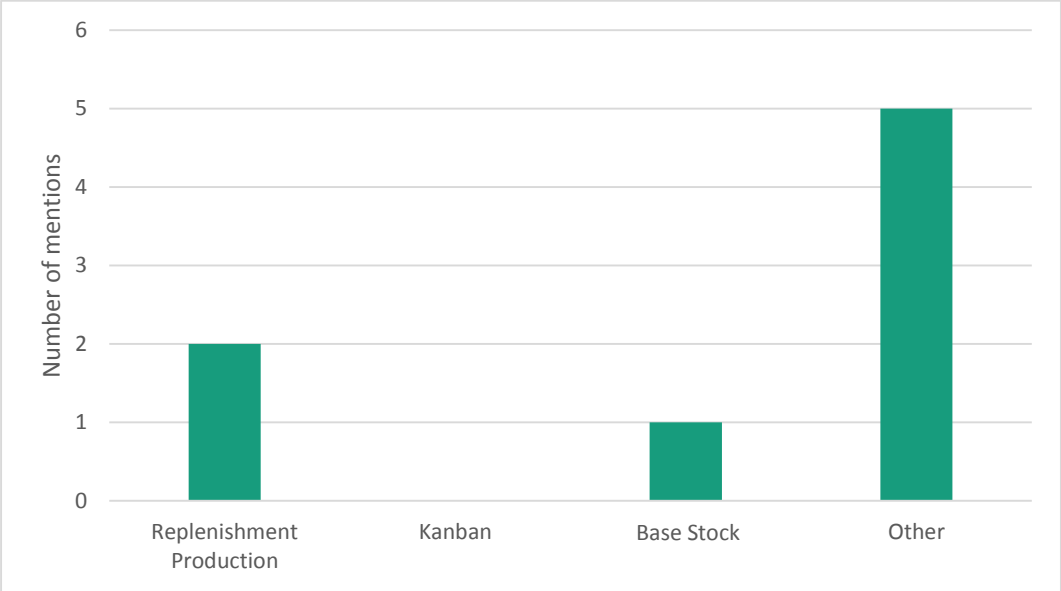


Figure 14 Methods to generate production orders in remanufacturing.

Question 6: Which trigger do you use to release an order?

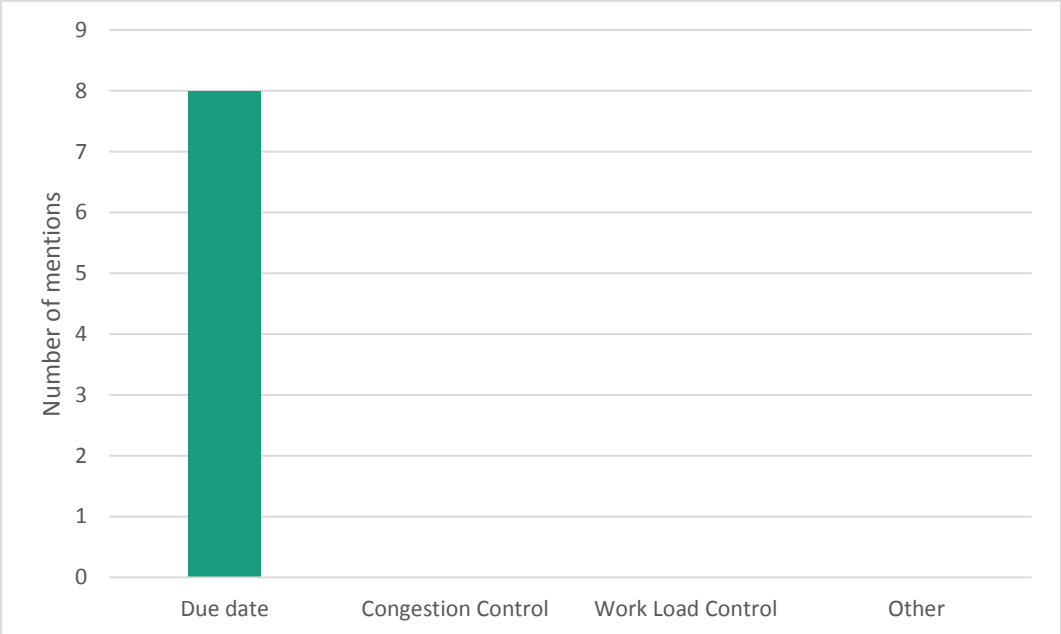


Figure 15 Trigger to release order in remanufacturing.

Question 7: How do you determine the order of production orders?

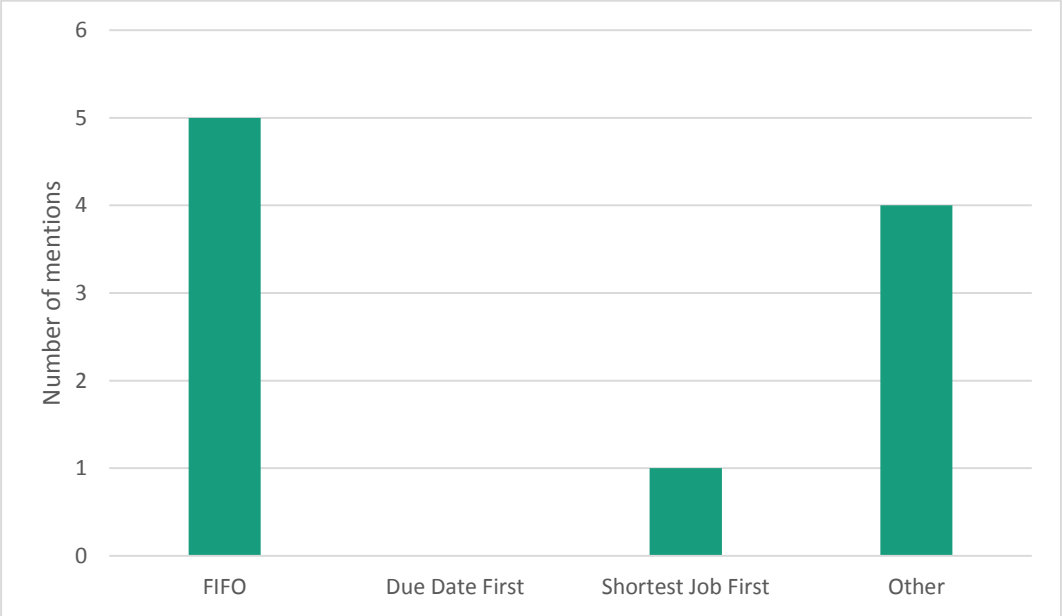


Figure 16 Determinations of production orders in remanufacturing.

Question 8: Which principle do you use to organise your production?

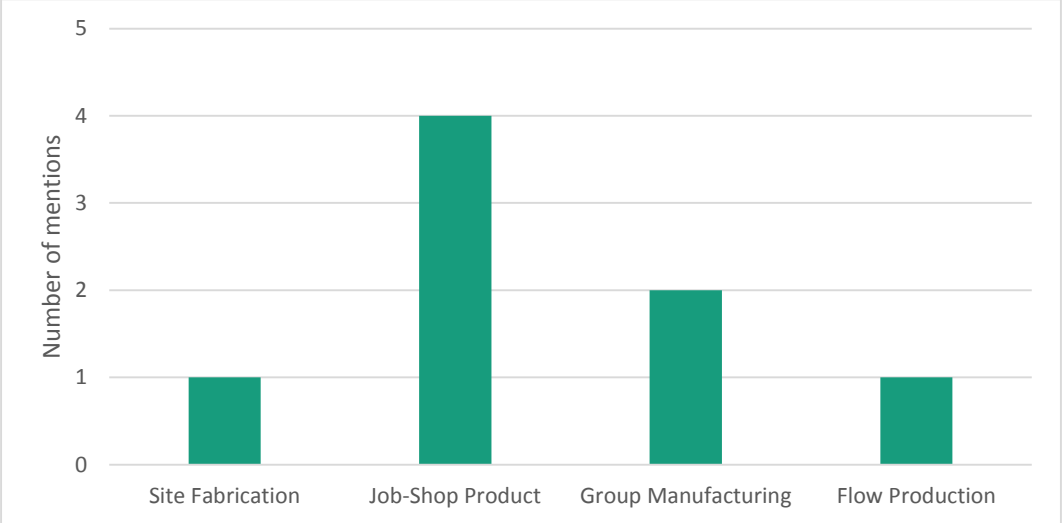


Figure 17 Production organisation in remanufacturing.

Question 9: Which principle do you use to produce goods?

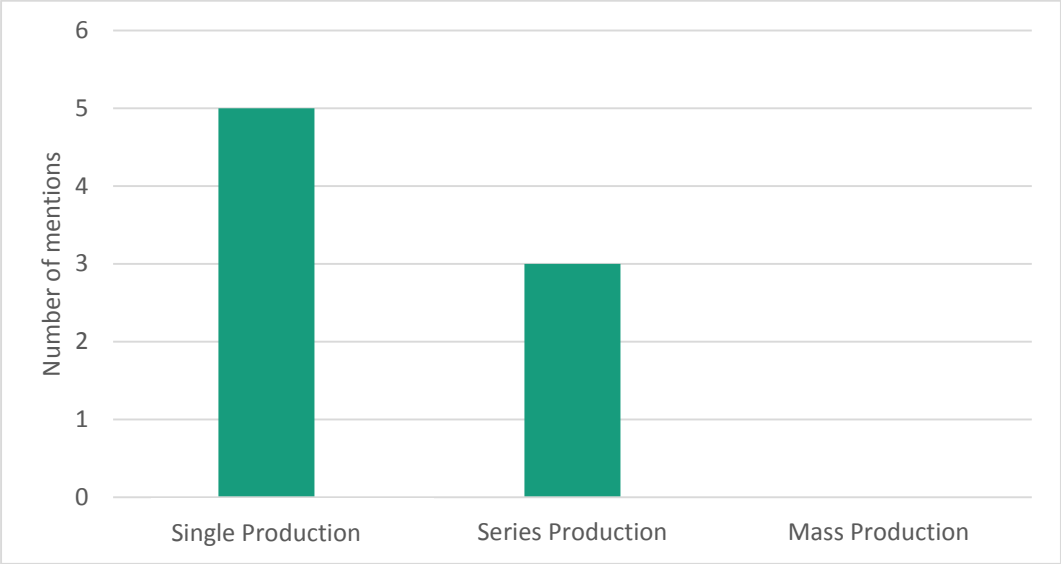


Figure 18 Production principle in remanufacturing.

Question 10: Which lot size concept do you use?

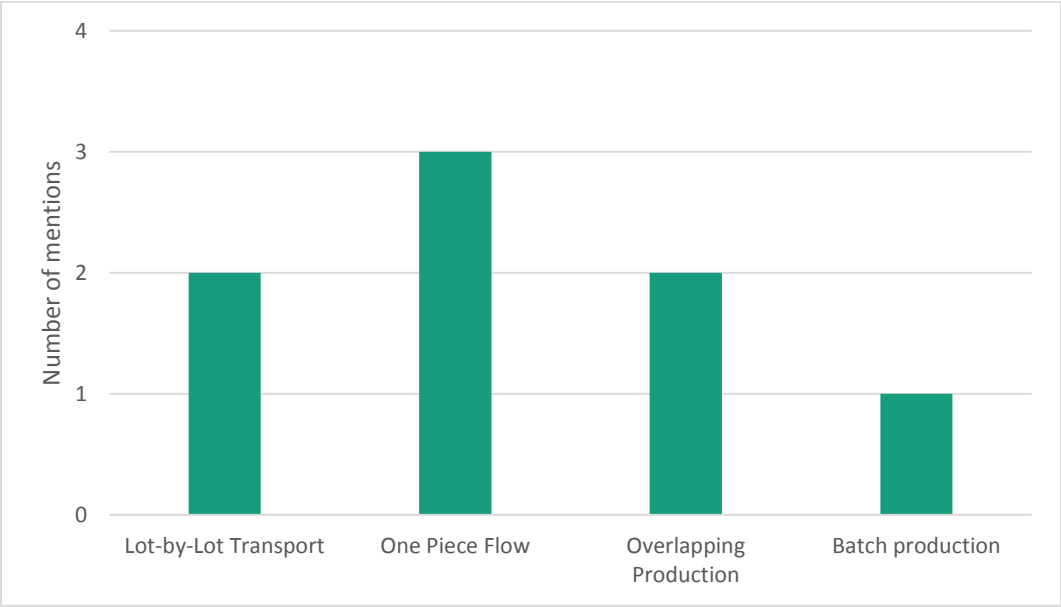


Figure 19 Production lot size concept in remanufacturing.

Question 11: Do you know the bottleneck within your production?

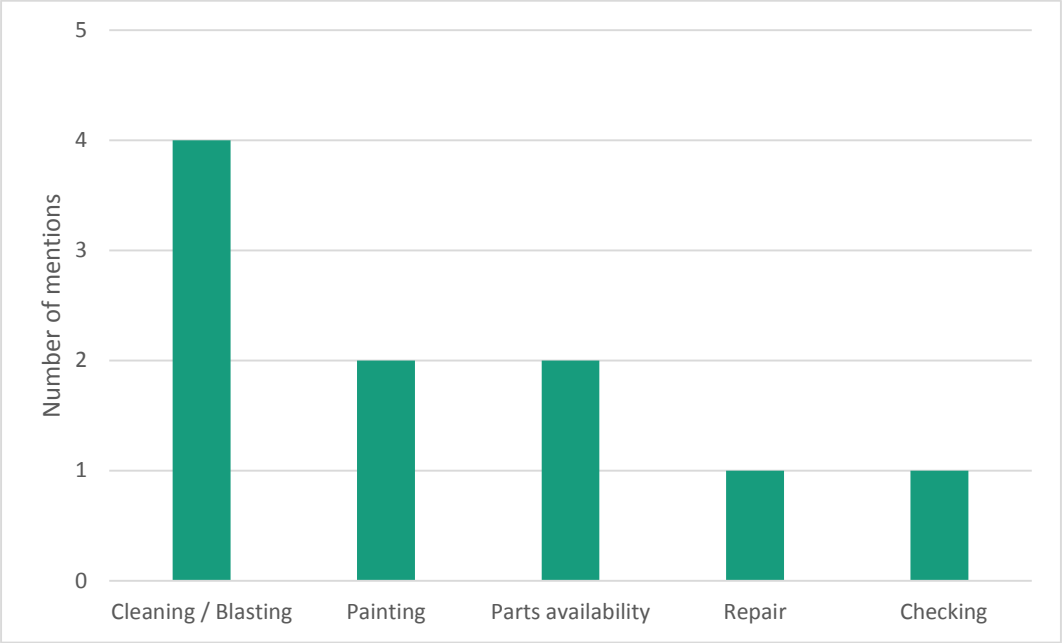


Figure 20 Bottlenecks in remanufacturing.

Question 12: Is there something special in your production scheduling that you would call characteristic for your company?

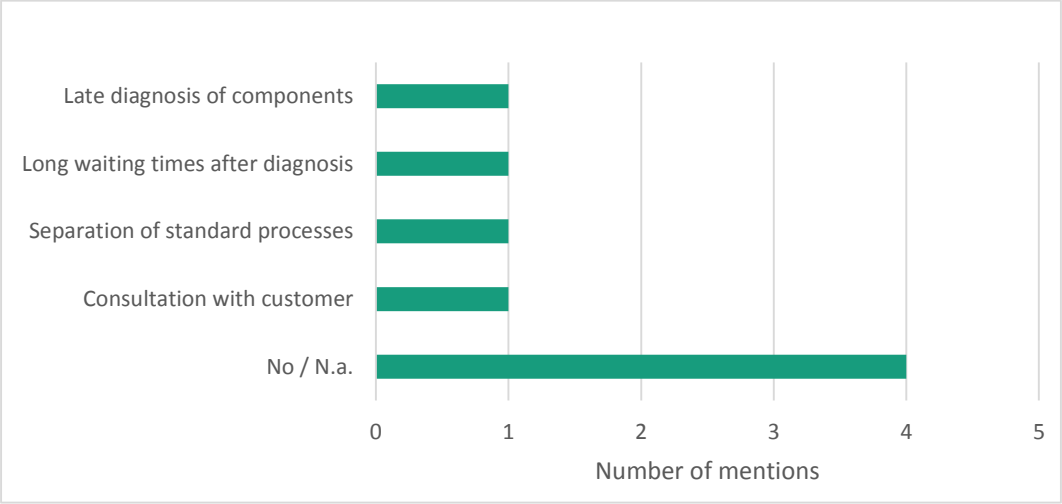


Figure 21 Specifics in production scheduling in remanufacturing.

Question 13: Based on what criteria (e.g. KPIs) do you assess the success of your production?

Figure 22 Key Performance Indicators used in remanufacturing.

Question 14: How do you rate the availability of spare parts and cores for your production?

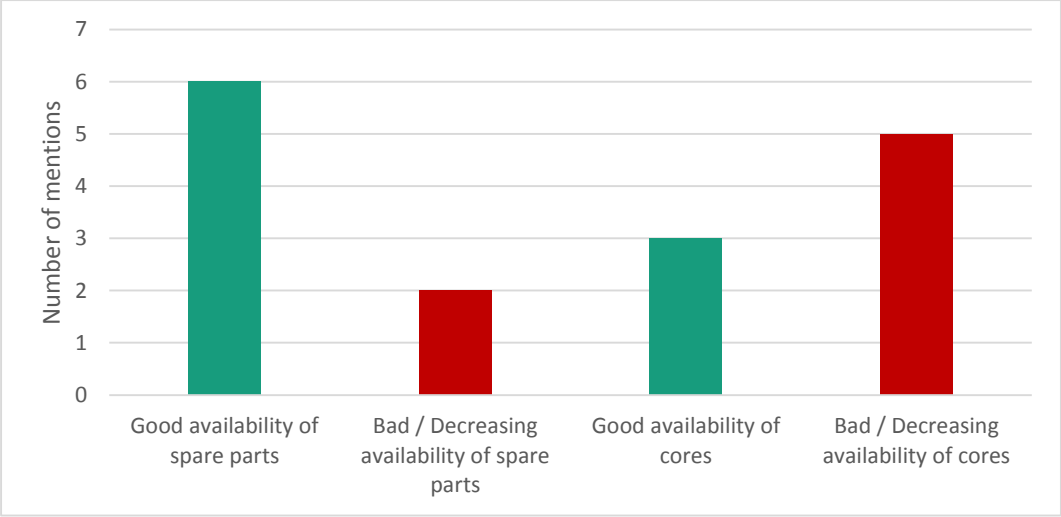


Figure 23 Availability of spare parts and cores in remanufacturing.

Question 15: Have you already conducted measures to increase resource efficiency? If so, please specify what you did.

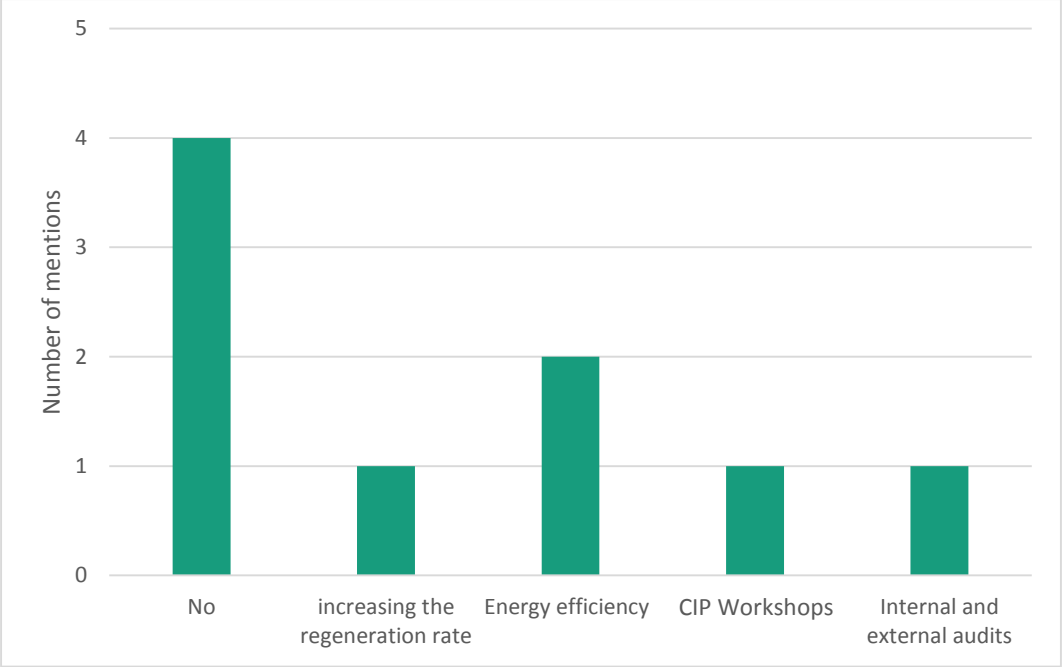


Figure 24 Measures for resource efficiency in remanufacturing.

Question 16: Were those measures successful in increasing resource efficiency significantly in your company?

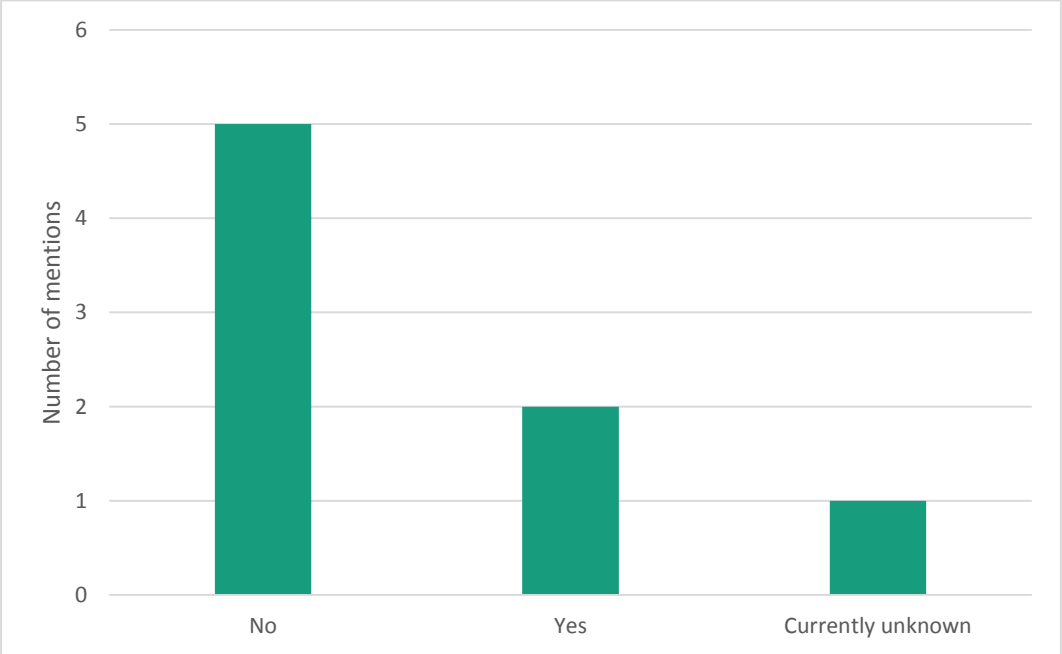


Figure 25 Successfully implemented measures regarding resource efficiency in remanufacturing.

Question 17: How do you conduct quality control?

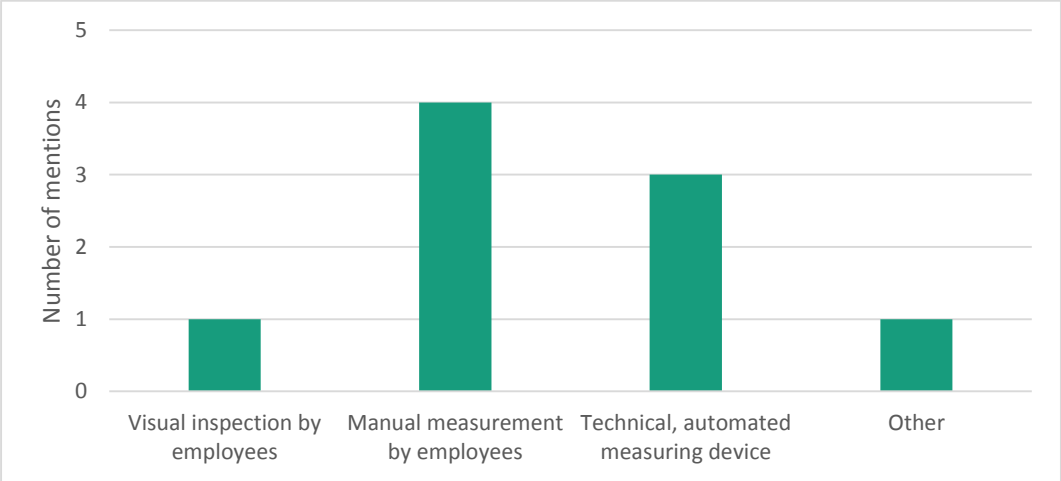


Figure 26 Quality control in remanufacturing.

Question 18: What trends do you see in the remanufacturing industry?

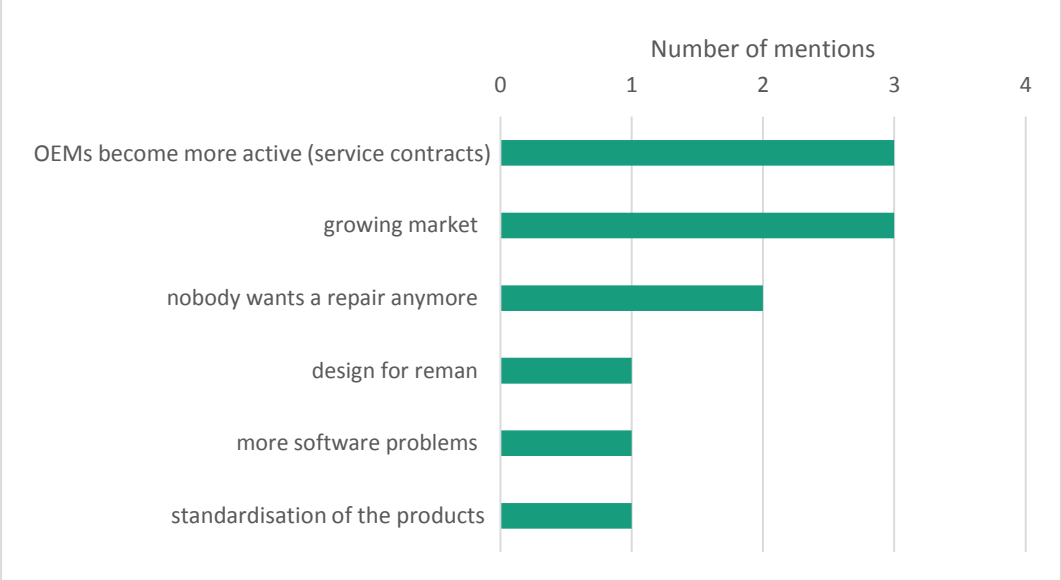


Figure 27 Trends in remanufacturing.

Question 19: Which of the following materials do you remanufacture?

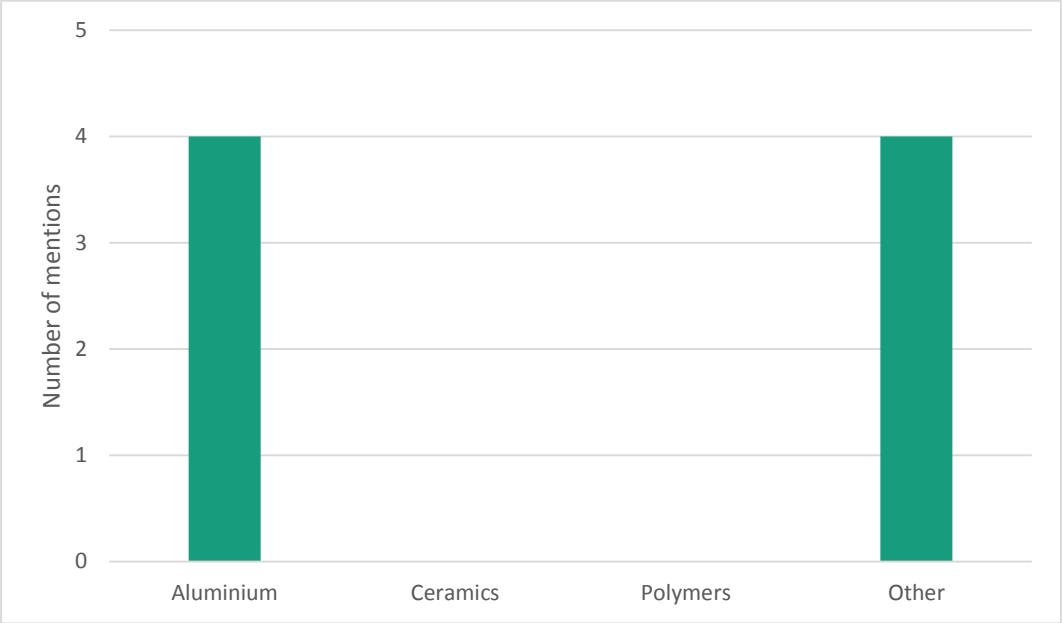


Figure 28 New and advanced materials recovered in remanufacturing.

Question 20: In what area / concerning what questions in remanufacturing do you wish for more extensive research in academia?

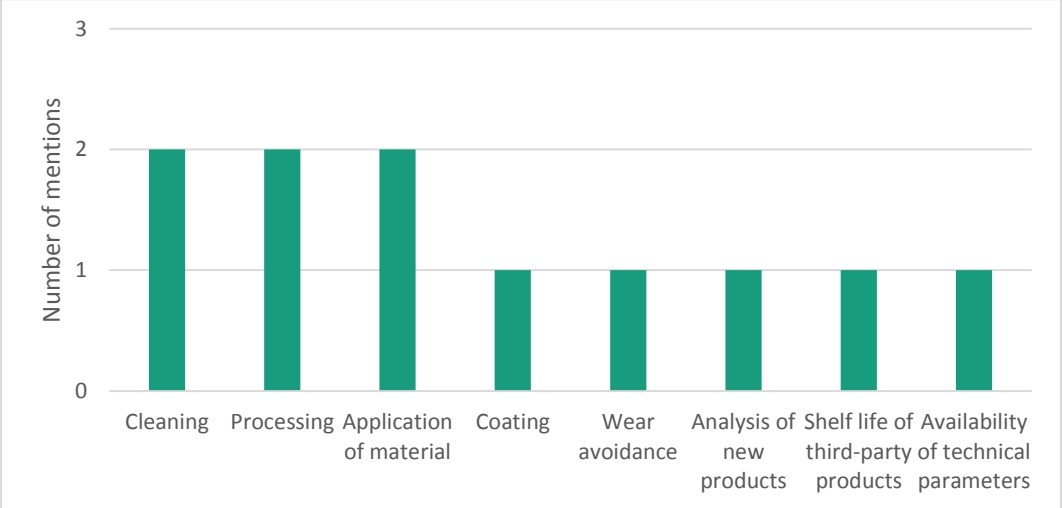


Figure 29 Research needs in remanufacturing.

6 Remanufacturing Processes Case Studies

In this chapter the results of the remanufacturing processes analysis is shown.

Eleven companies were asked to provide information about their company, their remanufacturing operations, their processes, their business situation, as well as their unique characteristics.

The information collected are summarised as one pagers for remanufacturing processes which are also part of the remanufacturing processes toolkit which is available at the project homepage www.remanufacturing.eu.

The aim of the remanufacturing processes one pagers is to provide accessible information to companies and interested people who are not active in remanufacturing yet as well as for remanufacturing companies and other stakeholders of the project to get an impression of remanufacturing companies and their remanufacturing processes in different industry sectors across Europe.

During the remainder of the project more one pagers will be created and integrated into the remanufacturing processes toolkit.

Case Study:

BORG Automotive

With more than 1,000 employees, BORG Automotive is one of the largest independent remanufacturing companies.

Company and Business Model

As one of Denmark's largest automotive companies and one of the largest independent remanufacturing companies, BORG Automotive has more than 40 years experience in remanufacturing. With a workforce of more than 1,000 employees, the company continuously strives for excellence. In 2015, BORG Automotive was awarded as „Remanufacturer of the Year". BORG Automotive's three brands (Elstock, DRI and Lucas) are launching the remanufactured products.

Products

With the wide and diverse range of brands, BORG Automotive can meet the customers demands for commercial vehicles and passenger cars as well as marine, construction, agricultural and industrial applications. Examples for the company's remanufactured products are EGR valves, A/C compressors, alternators, starters, electric & hydraulic steering racks/columns, electric & mechanic servo pumps and calipers.

Remanufacturing Process

The remanufacturing process at BORG Automotive is subdivided into six process steps: Disassembly, cleaning, inspection & sorting, reconditioning & replacement, reassembly and final testing. Within the first step, the cores undergo a complete disassembly into individual components. Components which cannot be reconditioned are disposed of. The next step is the cleaning of the components which is followed by an intensive inspection & sorting. This is done visually and with test equipment.

Within the next step, the reconditioning & replacement, re-usable components are reconditioned and non-reusable components are replaced with new quality components. Afterwards, the remanufactured products are reassembled and each remanufactured product undergoes a 100% performance test.

Unique Characteristic

The company has developed a produced-to-order concept which is supported by the unique core division. This ensures a high level of delivery with high quality and outstanding finish of the products.

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Funded by the Horizon 2020 Framework Programme of the European Union

Case Study:

MBS Motoreninstandsetzung und Baumaschinenservice GmbH

The MBS refurbishes diesel engines predominantly from agricultural and construction machines.

Company and Business Model

The company operates with its 15 employees as an independent remanufacturer for predominantly diesel engines on the market. Due to the 86 years of company history, MBS has a wide experience in remanufacturing of diesel engines. Additionally, acting as contract dealer for four large engine manufacturers, the company can provide a wide range of spare parts and special product know-how. The catchment area for customers is greater Bautzen.

Products

The range of products are predominantly diesel engines form agricultural and construction machines, in almost all sizes including older series. To generate further growth of sales and to develop new strategic business units, the company also focuses on engines from classic cars, private boats and biogas power plants.

Remanufacturing Process

After delivering the engines, the refurbishment process starts with an incoming analysis to create an estimation of costs (common to private customers). After the customer releases the order, the disassembly, cleaning process and detailed analysis of the engine starts. Following, the customer can receive a second estimation of costs including a list of spare parts.

The next step is to change the damaged-, and to refurbish the worn parts of the engine. At this point, MBS profits from the product know-how of the employees. They are able to analyze the engines and to find the right parameters for the milling and drilling machines, especially for older engines, where no data sheets exists. After reassembly, MBS uses a test bench to check the performance parameters. Finally, the engine is painted and ready for delivery.

Unique Characteristic

Due to the long existence of the company and the extensive experience of the employees, the company is able to refurbish a wide range of diesel engines unproblematic.

This advantage allows MBS to accept a wide range of different orders and generate growth of sales. Additionally, they have a workshop truck to repair engines and change spare parts in the field.

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Case Study:

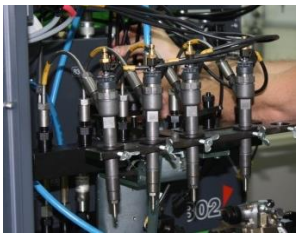
Bosch Service Lehner

The company is a franchisee of the Bosch GmbH with a own car repair shop and a smaller remanufacturing division for diesel fuel feed components.

Company and Business Model

Bosch Service Lehner is a franchisee from the Bosch GmbH with only one branch office, located in Bautzen. The company has two business units, the "Bosch Service" as a car repair shop and the "Bosch Diesel Center" with focus on remanufacturing of diesel fuel feed components.

For the remanufacturing process, they receive the cores preliminary from their own car repair shop and partial from other regional car repair shops. A special procurement management system for cores is not part of the business model.



Products

The products for the remanufacturing process are components from the diesel engine fuel feed like injectors, fuel pumps and injection nozzles.

Remanufacturing Process

After delivering the cores to the remanufacturing workshop, they are checked on a test bench to verify, if the engine´s problem is caused by the tested component or from other parts of the engine.

Following, the customer receives a simplified estimation of costs. After he releases the order, the disassembly and the cleaning of the components begin. The next step is the analyses of the components to identify damaged or worn parts. Here, the customer could receive a more detailed estimation of costs again.

After releasing the order, the replacement of damaged parts begins, followed by the reassembly. The reassembling of diesel fuel feed components demand a very high technical cleanness. Because of the high pressure of the fuel injection and the low tolerances between the components, they have to be without any particles. Finally, the products are checked on the test bench to verify the function and performance parameters. Now they are ready to reuse in the engine.

Unique Characteristic

An advantageous aspect of the company is the franchisee from the Bosch GmbH. First, they got the special know-how, the test benches and spare parts directly from the manufacturer of the products.

Secondly, they receive the trust of customers in the remanufactured products, because they see the well known brand Bosch as serious distributor with its high image in Germany.

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Case Study:

Continental AG

The Continental AG is an international producer for car components, it has also a remanufacturing division for instrument clusters.

Company and Business Model

Continental is an international technology company with more than 208,000 employees in 55 countries and five divisions: Chassis & Safety, Interior, Powertrain, Tire, and ContiTech. In Babenhausen in Germany, the Continental AG has a plant to produce and remanufacture instrument clusters for cars. To provide the remanufacturing process with cores, the company can use its well developed network to automotive manufacturers and its service stations.

The collecting of cores and the selling of remanufactured products is managed by the central logistic center of the car manufacturer. The customer comes to the service station of his car manufacturer with a damaged instrument cluster. After changing the instruments, the damaged cluster is sent back to the car manufacturer´s central logistic center. From there, a few deliveries per month with huge unit numbers are delivered back to Continental. Due to that, Continental is getting defined types of instrument clusters back for their own remanufacturing process.

By using this business model, the circular economy has no connecting points for independent remanufacturing companies.

Remanufacturing Process

The most important part of the remanufacturing process in this case is the connection between the remanufacturing and the development division. If the remanufacturing division identifies statistical anomalies or typical defaults at the cores, they forward this information to the development division to adjust the design parameters of new products. In return, the development division offers a data base with information about important software and hardware updates or technical spare part which should be changed in remanufacturing process. This information is available for every series and type of Continental instrument cluster.

By using the database in the remanufacturing process the remanufacturing division knows, what hard- and software updates should be done for each model, directly from the development experts.

The first step in the remanufacturing process is to scan all the incoming instrument clusters via barcode. After that they make a selection, based on the model and the proposed rectifications from the the division responsible for product development. For the appropriate instruments, the next steps are the software reset and update and the disassembling. After that, the remanufacturing of worn parts the manufacturing of pointers and the reassembly follows. The last steps are the final test and packaging.

Unique Characteristic

Continental´s unique characteristic is the co-operation between remanufacturing, development and quality department.

Additionally, after end-of-production of a product series, Continental can use the original technical systems for remanufacturing processes.

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Case Study:

Air France Industries KLM Engineering & Maintenance

As a part of the AIR FRANCE KLM Group the company maintains, repairs and overhauls airframes, aircraft components and engines.

Company and Business Model

Air France Industries KLM Engineering & Maintenance is one of the three businesses of AIR FRANCE KLM Group. With a workforce of approx. 14,000 employees the Air France Industries KLM Engineering & Maintenance operates at different leading-edge engineering facilities at different locations such as Amsterdam-Schiphol, Paris Orly or Toulouse. In order to take up the technological challenges of the future, the employees are put through demanding apprenticeship and training cycles. To stay a flagship player in the global marketplace and bolstering the competitive advantage, the company has a large-scale of technical and human resources.

Products

The range of products for the companies business reaches from airframes to engines of Airbus, Boeing as well as regional Aircraft (e.g. Bombardier, Embraer)

Remanufacturing Process

In this case, the remanufacturing process is termed as "Overhaul".

The process steps are ranging from the disassembly to the repair of components and the reassembly which is followed by various validation tests.

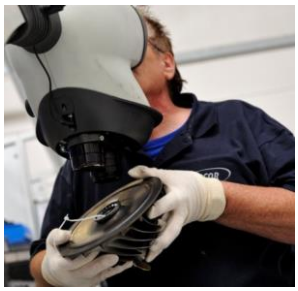
The single process steps are carried out by experts in accordance with proven processes.

Air France Industries KLM Engineering & Maintenance is able to provide individual modules repairs alongside the full overhaul services.

Unique Characteristic

Air France Industries KLM Engineering & Maintenance has gained a combined experience due to approx. 11,000 completed engine shop visits as well as continuous technological development on all aircraft maintenance segments. Due to the rely on privilege relations with the manufacturers, the company constantly develops new, more efficient and cost-effective processes. Customers can benefit from price optimized top-quality services.

Furthermore, the company covers a high number of various approval and certifications such as ISO 9001, EN 9100, FAR 145 and much more.



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Source: http://www.afiklmem.com; 05.02.2016

Case Study:

Liebherr-Ettlingen GmbH

The Liebherr Ettlingen GmbH as part of the Liebherr Group is specialized in remanufacturing of drive components from Liebherr products.

Company and Business Model

The Liebherr Group is an OEM for among other products, excavators, wheel loaders and cranes for construction and mining industries. The Location in Ettlingen, called Liebherr Ettlingen GmbH, is specialized predominantly in remanufacturing of Liebherr drive components like diesel engines, hydraulic pumps and gear boxes.

Liebherr designed the business model for remanufacturing in the spirit of the circular economy. If one of the above mentioned parts is damaged, the customer contacts his nearby Liebherr contract service center. Here, the customer has four options – to buy a new component, to repair the old one, to exchange to an other remanufactured one or he can release an overhaul order for his own used component. In case of a component exchange, Liebherr offers a credit for the old part.

This business model keeps the market closed for independent remanufacturing companies and additionally, Liebherr has all the newly produced components and cores for the remanufacturing process under control.

Products

The products in the remanufacturing process have very different sizes, geometries, weights and degrees of contamination. They range from small hydraulic components to large V12 diesel engines.

Remanufacturing Process

Following the remanufacturing process for a diesel engine exchange component is described:

The process starts with the disassembly and the subsequent stream jet. Afterwards, a pre-cleaning, the chemical paint stripping and rust removal is arranged. The next step is the mechanical cleaning of surfaces which are analyzed to quantify the degree of wear. After that, the components are ready to be analyzed and to identify the worn parts. After quantifying the scope of the remanufacturing work and defining the tasks, the mechanical cleaning of the whole components begins.

The last steps in this process are the final cleaning and the painting with rust preventives. After that, the single parts are stored.

If a customer orders a “new” remanufactured engine, Liebherr starts to reassemble the order from the stored parts. In this way, the stored components are mixed to a new engine because they all have the same parameters and quality.

Unique Characteristic

The characteristic of the Liebherr remanufacturing process is the high variance of products. The high degree of capacity utilization of all processes guarantees the profit, while additionally they can adjust their remanufacturing processes optimal to each product group. The circular economy with no connecting points for independent remanufacturing companies is an advantageous strategy for Liebherr, making sure they always have enough cores.

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Case Study:

ax-lightness composites GmbH & Co.KG

ax-lightness is one of the most innovative manufacturers and remanufacturing companies of CRP-composites in Germany.

Company and Business Model

ax-lightness was founded in 2001 and has 30 employees. The company started as a manufacturer for CRP-components (carbon fibre reinforced plastics) in bicycles, later on in motor sports and medicine industries.

The products and its components are predominantly designed for high performance usage and partially custom made. The high product price, the performance expectations form the customer and the small number of CRP-companies on this level in Germany are reasons why customers buy the products from ax-lightness. Due to this, the customers also bring their products or components back to ax when they are broken or worn, so the remanufacturing process becomes more and more important for the company.

Products

The products and the components for bicycles are manufactured in smaller and mid size batches, for medicine and motor sports they are predominant custom made.

Remanufacturing Process

The remanufacturing process starts with the disassembly and the analysis of the product to decide whether the product is repairable.

Due to the products ax-lightness produce, most of the repair operations focus on repairing tubes or surfaces, made from CRP. They usually separate the damaged CRP-component from the product and replace it with a new one. The critical process step is the integration of the new CRP-element in the existing structure of the old product. First, the replaced element has to fit perfectly in the cut area. The second challenge is to create a strong connection between the changed component and the connecting points of the product. This requires a lot of know-how and experience concerning CRP material.

Additional to the permanent quality tests conducted by the employees while remanufacturing, the products are tested finally on a test bench to verify the function and the performance parameters.

Unique Characteristic

The unique characteristic of ax-lightness is the expertise in CRP-material characteristics and the interaction between its two complex components, the carbon fiber mesh and the resin. The strength of the connection points between the product and the changed element depends on the experience of the employee and the orientation of the CRP-meshes at the connecting areas. Ax-lightness can transfer the know-how from the manufacturing to the remanufacturing processes.

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Case Study:

Knorr-Bremse Commercial Vehicle Systems

Within a remanufacturing facility in Liberec (Czech Republic), the company remanufactures various products for commercial vehicles

Company and Business Model

The company with the headquarter in Munich (Germany) has more than 110 years experience in the development, production, distribution and service of modern brake systems. In 2014, Knorr-Bremse Commercial Vehicle Systems had a turnover of approximately 5.2 billion Euros and more than 23,000 employees. The original equipment manufacturer remanufactures a wide range of different products in the company's plant in Liberec (Czech Republic). The remanufacturing activities take place in a remanufacturing facility with 9,000 square meters.

Products

The range of remanufactured products includes spring brakes, one-cylinder as well as two-cylinder compressors, electronic clutch actuator, electronic air control and modules of the electronic braking systems. These products are for commercial vehicles like trucks and trailers.

Remanufacturing Process

The remanufacturing process starts with a comprehensive sorting of the incoming cores. Within the sorting, the cores are graded according to different criteria (e.g. core class, quality). In the next step, the cores are disassembled into their single parts. After the disassembly, the single parts are cleaned and reconditioned. Within the reconditioning, comprehensive quality checks of the single parts take place. In the last step, the products are reassembled based on criteria which are applied to the production of new products. Moreover, some of the products are reassembled on the assembly line of the new products. This takes place in production plants that are also part of the Knorr-Bremse CVS Remanufacturing Production Network. This ensures a high quality of the remanufactured products.

Besides the comprehensive quality check of the incoming cores as well as of the single parts within the reconditioning, a visual quality check is performed by the workers within each remanufacturing process step.

Unique Characteristic

Within the remanufacturing, know how as well as data and information regarding the technical and qualitative specifications based on the manufacturing of new products are accessible and rigorous applied.

Last but not least, to ensure a high efficient remanufacturing, Knorr-Bremse Commercial Vehicle Systems implemented strictly the company's own production system.

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Case Study:

Herrenknecht AG

The Herrenknecht AG is the world wide market leader for the production of tunnel boring systems.

Company and Business Model

The Herrenknecht AG is an international operating company for the production of tunnel boring machines (TBM). The business model is to develop and manufacture tunnel boring machines according to specific project requirements.

After a tunnelling project is finished, the machine typically did not reached its technical life time. Therefore, Herrenknecht conducts a machine analysis, rebuys the complete TBM or the reusable components and takes them back to the Herrenknecht Rebuilt Services in Kehl (Germany). The fact, that all tunnel boring machines are custom made for the individual geological requirements and generally designed for several project life cycles, makes the buyback economically and the reuse reduce the consumption of resources.

Products

The products in the remanufacturing process are originally produced by Herrenknecht. Due to individual project requirements such as the tunnel diameter, most of the machine components are individual designed. For bought-in components like hydraulic pumps or electronic motors, Herrenknecht reduces the number of variants.

Remanufacturing Process

In this case, the remanufacturing process differ from other industries caused by the extraordinary product size and the business model.

After the delivery of the TBM or reusable components to Kehl, the identification, disassembly, initial analysis on component level and the preservation for storage starts. Then they are stored at the open storage area or weather protected in the warehouse.

If a customer wants to buy a new tunnel boring machine, Herrenknecht starts a calculation in order to define the selling price. In this way, they try to integrate reman components from the current stock in the new TBM to reduce the offered price to the customer. They start to analyze which of the available components match to the TBM technical specifications and requirements and could be remanufactured for the offered tunnel boring machine.

After the customer releases the order, the designing of the TBM including the integration of the reman parts starts. Here, they define the remanufacturing orders for the workshop and suppliers. If the remanufacturing process with its further disassembling, cleaning, remanufacturing, sandblasting, painting and reassembling with new spare parts is finished, the components are delivered to the Herrenknecht headquarter in Schwanau in Germany. At these location, the company starts with the final workshop assembly, testing and certification of the TBM. Caused by the different types and sizes of the components, the remanufacturing process has different loops of cleaning, disassembling and product analyzing steps.

Unique Characteristic

The unique characteristic for Herrenknecht is the opportunity to design for reman because they use predominantly the similar key components for drilling machines.

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Case Study:

robotif GmbH

robotif is specialized in remanufacturing industrial robots.

Facts and Business Model

The company was founded in 2009 and is focused on repairing Adept, Bosch, Denso and Stäubli robots. With its meanwhile 18 employees, robotif offers repairing, maintenance, modification and remanufacturing of industrial robots and their components. The market of remanufacturing robots is very small, actually only a few companies world wide are able to offer remanufactured robots. Due to this, robotif is the first stop for customers, who want these robots to be repaired or maintained.

Products

The product range concentrates on 6-axis and scara robots produced by the manufacturers mentioned above.

Additional to the "standard remanufacturing", robotif increasingly tries to improve spare parts in their remanufacturing process.

As an example, the wiring harnesses in robots are often worn and the available OEM spare parts have the same weak points. Due to that, robotif designed improved wiring harnesses with its supplier to deliver the best quality to their customers. The usage of spare parts developed by robotif becomes increasingly important for the company.

Remanufacturing Process

The remanufacturing process starts with the disassembling and cleaning of robots. After that, the analysis, the remanufacturing and the reassembly is arranged. The last step is the extensive final test of the robots.

Unique Characteristic

robotif has developed more than one unique characteristic. In the following, a few of them are described.

One key characteristic of robotif is the intense documentation. For every malfunction, worn part or damage, robotif creates a documentation sheet. Due to the high number of product variants, the employees have a central data base where they can find special information for each robot model.

Another unique characteristic is the high know-how of the mechanics. Additional to product analysis or the quality control, the well educated employees can find damaged parts as example by listening or feeling the transmissions – because of their know-how and their experience with the product. A further characteristic is the already mentioned improvement of spare parts. Due to this, the customers can rely on the remanufactured robots from robotif. Even if the OEM does not deliver spare parts any more or these parts are not the quality they are looking for, robotif is an independent of affordable high quality spare parts for this machines.

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Case Study:

MAN Truck & Bus

The OEM with its headquarter in Munich has production facilities around the globe and had an total turnover of 9.0 Billion Euro in 2015.

Company and Business Model

MAN SE is subdivided into two business units: Commercial Vehicles and Power Engineering. The OEM with its headquarter in Munich, Germany has production facilities around the globe like in Germany, Russia, Turkey, China, India, Brazil and Mexico. The total turnover of MAN T&B was approx. 9.0 Billion Euro in 2015. The section "Trucks" has the largest share of the total turnover (56%) followed by "After Sales & Services" with 20% share of the total turnover.

Products

Within the facility in Nuremberg, Germany, the company develops, manufactures, remanufactures and distributes diesel and gas engines for on-road, off-road, power and marine applications with more than 4,000 employees.

MAN T&B provides remanufactured spare parts and subassemblies (e.g. turbochargers, gearboxes), replacement engines, which have a share of remanufactured spare parts and remanufactured subassemblies, totally remanufactured engines and customized remanufactured engines, which have a greater share of remanufactured spare parts and subassemblies than the replacement engines.

Remanufacturing Process

The remanufacturing process at MAN T&B is subdivided into nine process steps. First of all, the core is disassembled into its single parts. After this, the single parts are diagnosed. The next process step is the cleaning of the single parts followed by the reconditioning of the single parts. After this, the reconditioned single parts are stored in a stock. Before the product is reassembled, the required single parts are commissioned. After the reassembly, each product undergoes a performance test. The last step is the finish of the tested product.

Unique Characteristic

The company assess the success of the manufacturing with an own cost-center. Here, the profitability is assessed frequently.

Moreover, the company has access to specific data and information like technical specifications of the remanufactured products.

Last but not least, MAN T&B applies the company's own production system MNPS ("MAN Nutzfahrzeuge Produktionssystem")

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7 Remanufacturing of New and Advanced Materials

During the mapping of the remanufacturing processes it turned out that not many remanufacturers are active in the field of new and advanced materials. Therefore, the question was turned around and it was asked:

Who is active in the field of remanufacturing of new and advanced materials?

The internet research was mainly conducted by using the online search engine Google.

The following search terms were used as single terms and as combinations:

Carbon remanufacturing / refurbishing / reman / aufbereitung / CFK remanufacturing / refurbishing / reman / aufbereitung / repair, Composites remanufacturing / refurbishing / vakuuminfusion / carbonbeschichtung

Thus 50 companies who are active in the field of remanufacturing and repairing of new and advanced materials could be identified.

A summary of the results of the internet research can be seen in the following:

Figure 30 shows the industry sectors in which remanufacturing of new and advanced materials is performed. The main sector for remanufacturing of new and advanced materials is the *consumer goods sector*. Especially the bicycle sector has to be mentioned here.

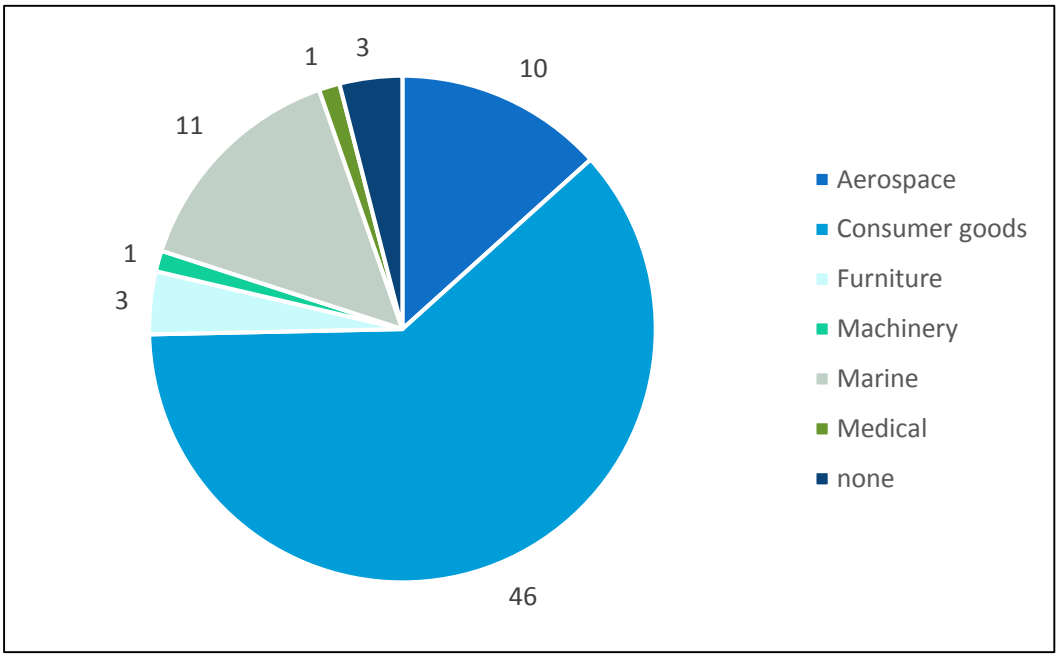

Figure 30 Sectors in which remanufacturing of new and advanced material is performed.

Figure 31 shows the countries in which remanufacturing of new and advanced materials is performed. The country in which remanufacturing of new and advanced materials is performed the most is Germany. The results of the study could be influenced by the location of the research facility in Germany.

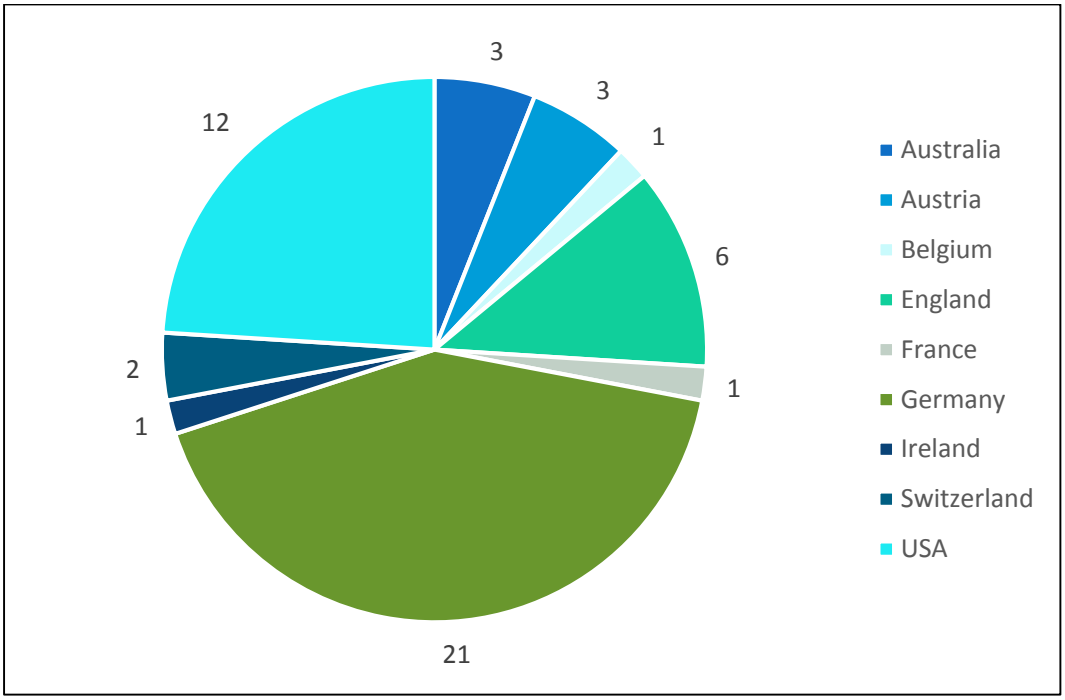

Figure 31 Countries in which remanufacturing of new and advanced material is performed.

Figure 32 shows the products which are remanufactured or repaired. The products which are remanufactured or repaired most frequently are bicycle parts.

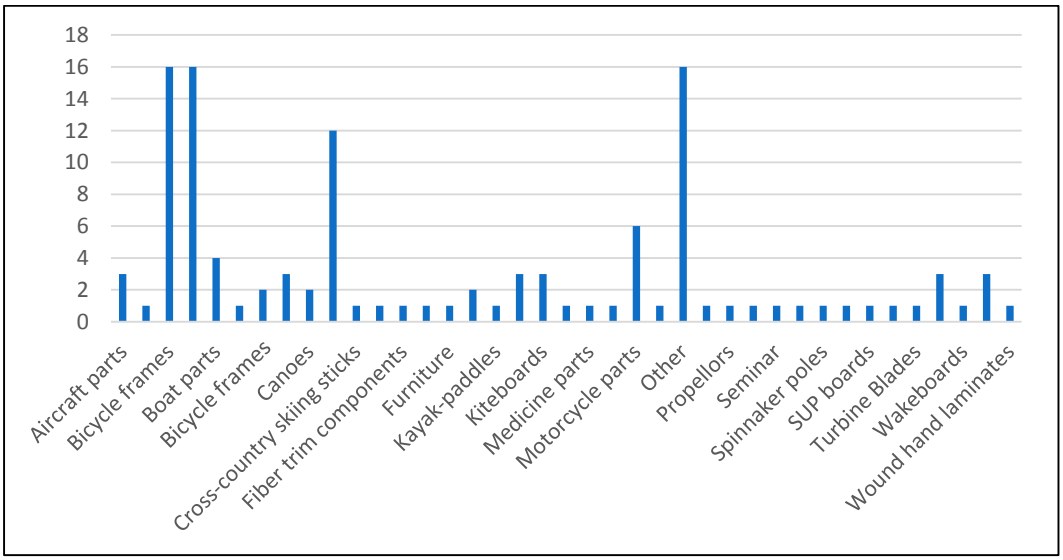

Figure 32 Products which are remanufactured respectively repaired.

8 Remanufacturing Networking Event and Processes Workshop

N.B. The content of this section comprises a report of the activity associated with the deliverable D3.4 – D3.3 Remanufacturing Processes Landscape Draft.

Besides a session at the World Remanufacturing Summit 2015 in Amsterdam a remanufacturing networking event and remanufacturing processes workshop was hosted at the facility of the Fraunhofer Project Group Regenerative Production in Bayreuth at the beginning of 2016. More than 90 representatives from industry and research from around the globe participated at the two-day event. The first day of the event was packed with presentations from leading scientists and industry representatives as well as the processes workshop, a podium discussion and a networking dinner. At the second day the participants were able to visit the robot remanufacturing company robotif GmbH.

In the following some impressions of the event and workshop are illustrated. Furthermore, the summarised results of the workshop are presented.

8.1 Event and Workshop Impressions

8.2 Workshop Results

Within the remanufacturing processes workshop 42 representatives from industry and research were asked to discuss the following topics:

1. Challenges regarding remanufacturing processes
2. Today's strengths, weaknesses, opportunities and threats (SWOT)
3. Tomorrow's strengths, weaknesses, opportunities and threats (SWOT)

Information about the participants are illustrated in the following figure:

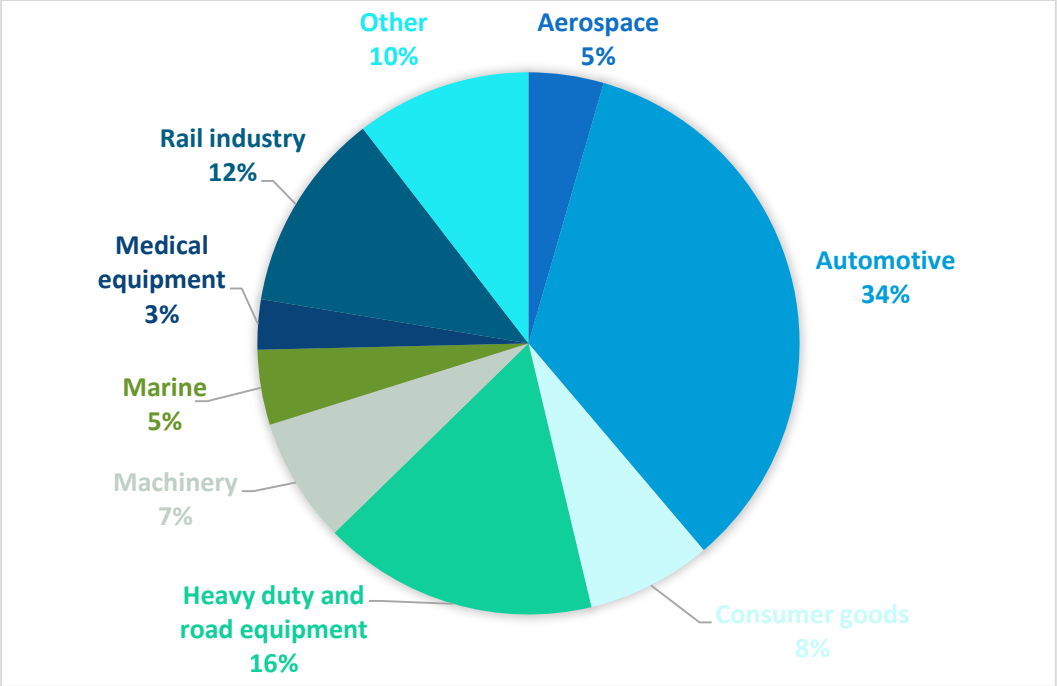

Figure 33 Industry sectors in which the participants are active.

The results of the workshop can be seen in the following.

Due to the participants the following four challenges are the major challenges regarding remanufacturing processes. The most commonly named challenge regarding remanufacturing processes is the increasing electrification of products.

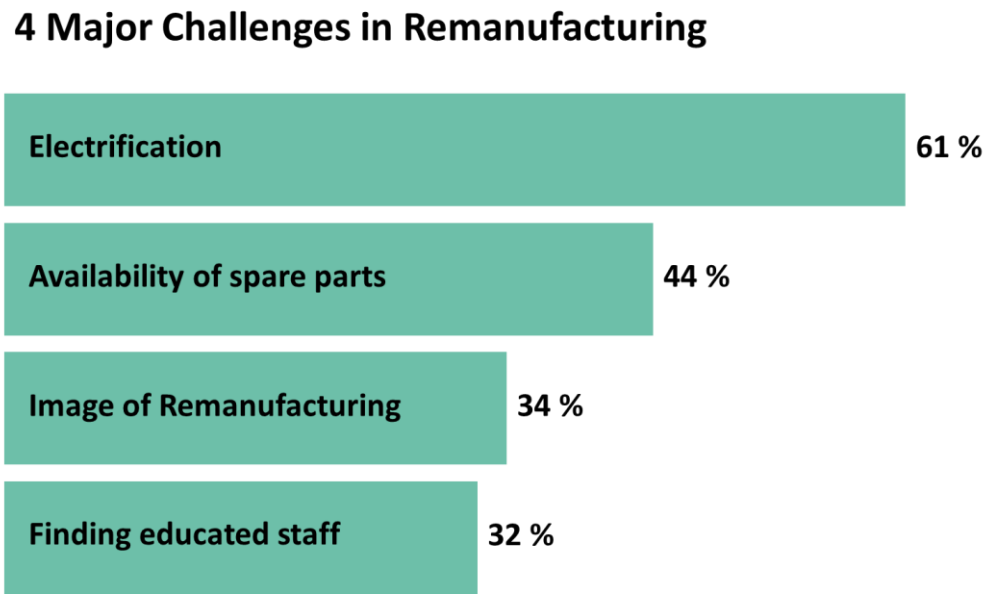

Figure 34 Major challenges regarding remanufacturing processes.

Following are the summarised results of the SWOT analysis of remanufacturing for today and the future.

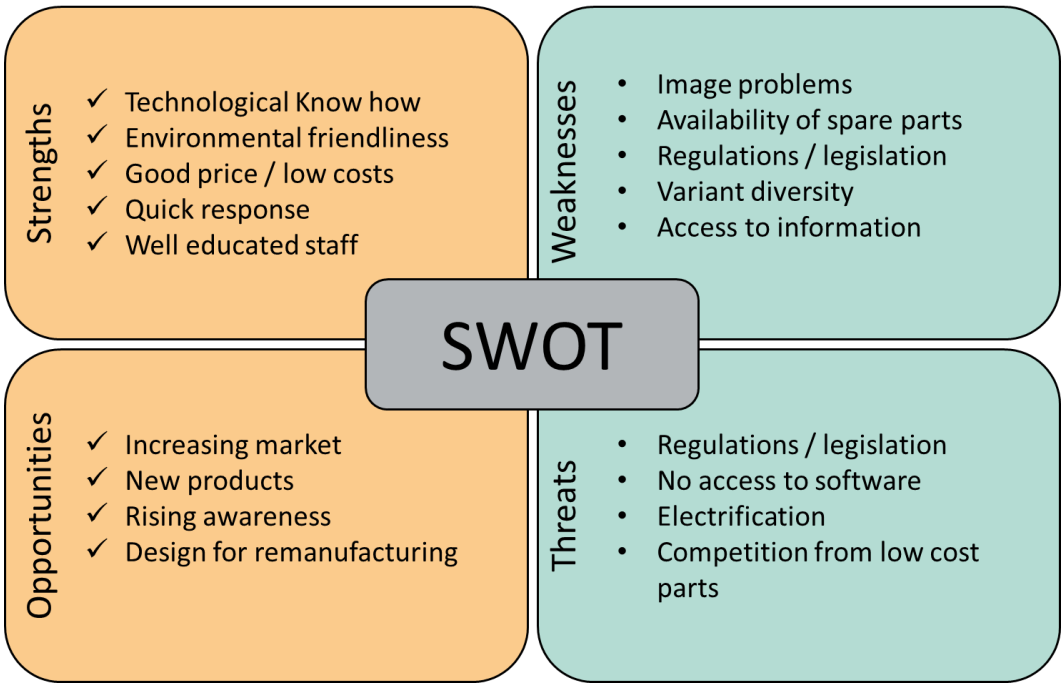

Figure 35 Today's strength, weaknesses, opportunities and threats (SWOT)

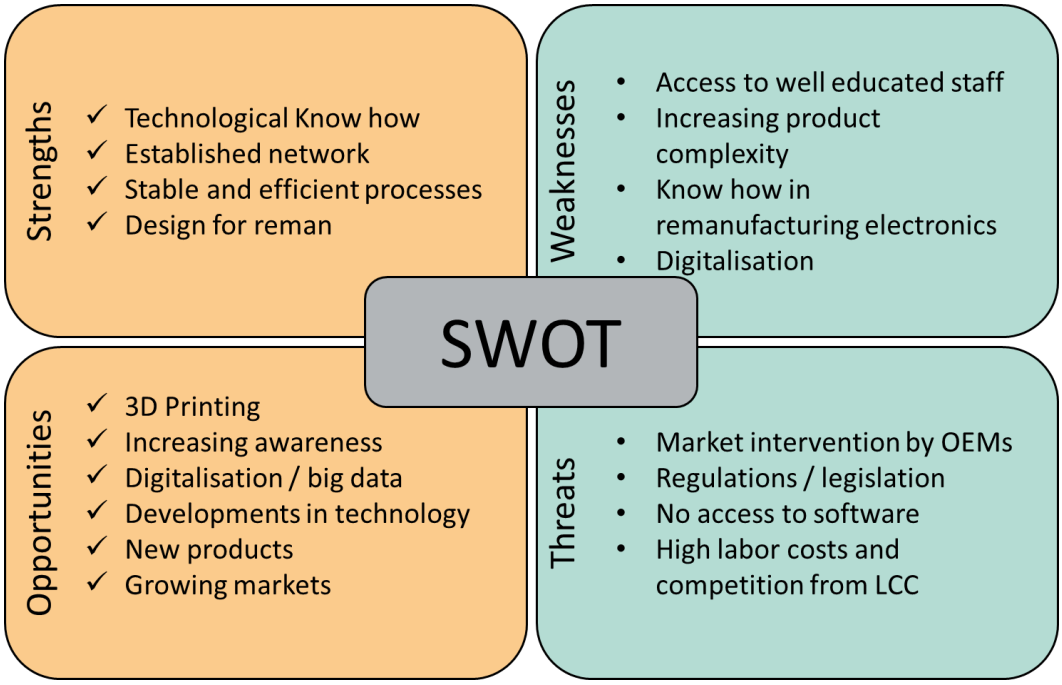

Figure 36 Tomorrow's strength, weaknesses, opportunities and threats (SWOT)

9 Conclusions

The aim of WP 3.3 is to generate an overview on remanufacturing processes as they are carried out in different industries across Europe.

Within this report the work done within WP 3.3 is summarised. The following topics are described within the report:

1. Description of remanufacturing processes
2. Survey of industry sector specific remanufacturing processes
3. Map of remanufacturing processes
4. Remanufacturing processes case studies
5. Remanufacturing of new and advanced materials
6. Remanufacturing networking event and processes workshop

The WP involved close collaboration with the industrial partners in order to:

- use their knowledge to unveil best practices among or known to them
- define challenges and chances close to the industrial praxis
- map remanufacturing processes in a way that is suitable and usable for the industry.

Moreover, it is important to mention the high importance of design and business models for remanufacturing. Detailed information about these topics are available in the respective deliverable reports.

The results of WP 3.3 and the report will be used as base for the future coordination and support activities within the project ERN – European Remanufacturing Network.

The information gathered will be especially used in Work package 4 *Joint actions to address challenges* and Work Package 5 *Create sustainable partnerships* to educate interested representatives of remanufacturing companies and companies which are not active in remanufacturing yet as well as to initialise research projects together with industry and research partners on a European level to face today's and tomorrow's challenges in the field of remanufacturing.

10 References

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Further Information about the Fraunhofer Project Group Regenerative Production can be found on the following website: http://www.regenerative-produktion.fraunhofer.de/

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