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Remanufacturing Process Assessment – A Holistic Approach

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Abstract

Today, remanufacturing is a key industrial discipline at the end of a product's life or use cycle. Unfortunately, there is a lack of knowledge when it comes to the assessment of remanufacturing processes (technical and organizational processes within the production) and the comparability of remanufacturing processes. To close the lack of knowledge, both in industry and science, this paper shows the main aspects of a holistic approach to assess and improve remanufacturing processes. The rudiments of the holistic assessment approach are a maturity model, the value stream methodology and material flow simulations. On the one hand, the holistic approach will enable remanufacturing companies to analyze their processes, and on the other hand, the approach will enable them to manage the progress of improvement of their remanufacturing processes. At the end of the day, the holistic approach will support the remanufacturing industry to improve their competitiveness by increasing their cost and resource efficiency.

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Keywords: Remanufacturing; Process Assessment; Production Optimization; Holistic.

1. Introduction

The corporate landscape has changed in the recent years, due to increasing competitive constraints [1]. An option, manufacturing companies have chosen to satisfy their customers is, increasing product variants. Increasing product variants and thus increasing product complexity leads to increasing complexity in the production and logistics as well [2].

In addition to increasing competition, increasing resource scarcity and increasing commodity prices endanger the profitability of enterprises [3]. An innovative approach to increase the resource efficiency in (manufacturing) companies is the *Circular Economy*. The idea of a circular economy is described by the Ellen MacArther Foundation (EMF) in their Circular Economy System Diagram [4]. One key element of the Circular Economy is remanufacturing.

Today, remanufacturing is a key industrial discipline at the end of a product's life or use cycle. According to Hauser and Lund, remanufacturing is the process to restore nonfunctioning, discarded or traded-in products to condition like new [5]. Nasr and Thurston described the condition of remanufactured products "as-new" [6]. Typical Products, which are remanufactured, are automotive components such as starters, alternators and water pumps [6]. Remanufacturing is performed due to economic, ecological and/or policy reasons [7].

In terms of the economic potential, remanufacturing facilitates multiple use of the value-added from new production by several life cycles. For preserving work, material and energy, effort costs of new production can be avoided. Ecologically, this leads to corresponding resource savings, avoiding of emissions and waste. The ecological performance of remanufacturing has been shown in many scientific studies. Sundin and Lee have gathered these studies in 2012 [8].

Nevertheless, remanufacturing companies face similar challenges as manufacturing companies. In terms of product and thus process complexity, remanufacturing companies must be able to manage the broad spectrum of OEMs / OESs, product groups, product generations as well as quality and contamination levels of the cores, etc. [9]. Unlike manufacturing companies, remanufacturing companies can only react on the increasing product complexity [10, 11].

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Due to the before mentioned reasons, it is important to analyze and to improve remanufacturing operations.

2. State of the Scientific Knowledge and Need for Action

In this chapter, the state of the scientific knowledge relating to remanufacturing processes and remanufacturing process assessments is described.

2.1. Remanufacturing Processes

According to Steinhilper, the remanufacturing process depends on the type and functionality of the products. Mechanical and electromechanical systems have to be separated from mechatronic systems. Mechanical products have to be processed in five main steps. [12]

According to Freiberger, it is useful to add the *entrance diagnosis* as a first process step, for mechatronic and electronical products. Thus, products with electronical failures can be separated, directly. [13]

Figure 1 shows the five respectively six steps of remanufacturing.

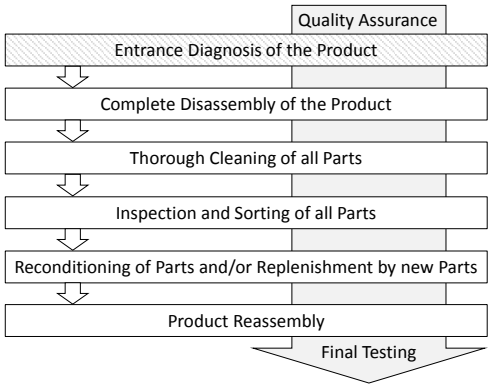

Fig. 1 Steps of remanufacturing according to [12] and [13].

To ensure the same product quality as new products, quality assurance steps are performed during and between the remanufacturing steps. Moreover, a comprehensive final testing is conducted after the reassembly.

2.2. Challenges and Approaches for Remanufacturing Processes

Several studies described the differences between manufacturing and remanufacturing processes [14, 15, 16, 17].

In terms of challenges, especially the planning and control activities of remanufacturing operations are mentioned [15, 16, 18].

According to Guide, seven characteristics complicate the production planning and control activities in remanufacturing [15]:

- Uncertainty in timing and quantity of returns
- Uncertainty in quality of returns
- Balancing returns with demand
- Product disassembly
- Requirement of a return collection system
- Return of an identical product (if applicable)
- Stochastic routings for materials within remanufacturing processes and highly variable process times

Kurilova-Palisaitiene and Sundin identified three major constraints in terms of remanufacturing, which are product quality, process lead time and the inventory level [16, 19].

The most promising approach to face the challenges of remanufacturing operations, in terms of planning and control, is *Lean Remanufacturing* [16, 19, 20].

2.3. Need for Action

Already in 2000 and 2003, Guide as well as Ferrer and Guide pointed out, that most of the approaches to improve the planning and control processes for remanufacturing are limited to narrow aspects [15, 21].

Unfortunately, there is still a lack of knowledge when it comes to the assessment of remanufacturing processes (technical and organizational processes within the production), the comparability of remanufacturing processes, as well as the targeted improvement of remanufacturing processes. To close the lack of knowledge, both in industry and science, this paper shows the main aspects of a holistic approach to assess and improve remanufacturing processes.

3. Development of a Holistic Approach

The rudiments of the holistic approach are a maturity model, the value stream methodology and material flow simulations. The methodologies as well as the related tools are described in this chapter.

3.1. Maturity Models

Humphrey described the *assessment* as an important topic to evaluate the own position: “If you don’t know where you are, a map won’t help” [22]. Thus, the first module of the holistic approach is a maturity model.

Maturity models enable the evaluation of operations and processes. The rudiment of each maturity model is a stage model which characterizes the levels of ability. To archive a higher level of ability, defined criteria must be fulfilled. [1]

Scientists from Bayreuth developed a maturity model, especially for remanufacturing operations. Following are the criteria respectively topics, which are assessed by using the maturity model for remanufacturing operations [23].

- Parts management (cores, spare parts and finished products)
- Technology know how
- Costs
- Information flow
- Material flow

- Quality management and assurance
- Technical cleanliness
- Resource efficiency (sustainability)

For gathering the data and to present the results, an Excel based questionnaire and calculation tool was developed. On the one hand, the maturity model and the tool enable remanufacturing companies to benchmark their processes against the processes of other remanufacturing companies. Thus, it is possible to define the own level of ability, e.g. compared to remanufacturing companies from the same industry sector or compared to all companies, which data are available within the tool. On the other hand, it is possible for the remanufacturing companies to measure their progress of improvement, by comparing their actual results with the results of previous assessments.

Exemplified results of the maturity level analysis are illustrated in figure 2.

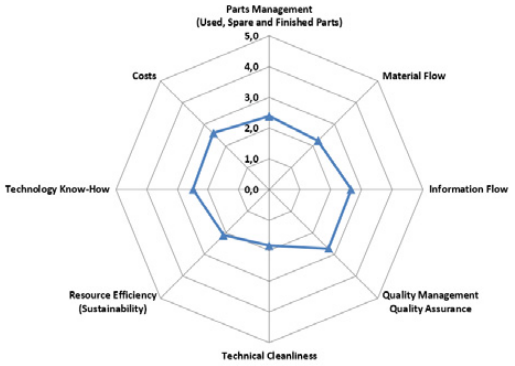

Fig. 2 Structure of the holistic approach.

Within the holistic approach, the maturity model is used to get an impression of the potentials of improvement and thus helps to use the following two modules targeted.

3.2. Value Stream Methodology

The second module of the holistic approach is the value stream methodology. A *value stream* describes all operations, which are performed to process a product, to the needs of a customer. Operations can be either value adding or non-value adding. Non-value adding operations can be separated into necessary operations and wastages. [24]

The value stream methodology is a common approach in science as well as in industry, and described in several books, for example by the authors Rother and Shook [24] as well as by Erlach [25] and Klevers [26].

The focus of the value stream methodology is to identify and to eliminate waste within productions. Following are the seven types of waste which should be eliminated, according to Ohno [27]:

- Overproduction
- Stockpilling
- Conveyance
- Rejections
- Motion
- Processing
- Waiting time

In figure 3, a value stream of a turbo charger remanufacturing factory is illustrated.

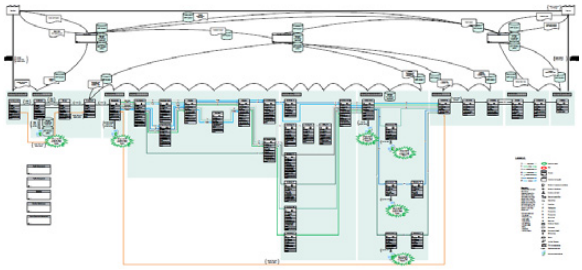

Fig. 3 Value stream of a turbo charger remanufacturing factory.

Within the holistic approach, the value stream methodology is used to create an overview of the remanufacturing operations as well as to identify potentials for improvement and optimization methods based on the principles of the value stream methodology.

3.3. Material Flow Simulation

The third module of the holistic approach are material flow simulations. Material flow simulations are a common method to plan new productions and to optimize already running productions [28]. It is possible to assess and compare certain optimization methods or approaches, before implementing them in real productions [29].

Especially for remanufacturing operations it is useful to execute material flow simulations for validating optimization methods or approaches, due to the various challenges, control variables and disturbance variables, within remanufacturing operations. Unfortunately, the effort for material flow simulations is quite high. Therefore, scientists from Bayreuth developed a modular simulation model for remanufacturing operations [30]. Thus, it is possible to reduce the time needed for material flow simulation studies, enormously.

The user interface of the simulation model is illustrated in figure 4.

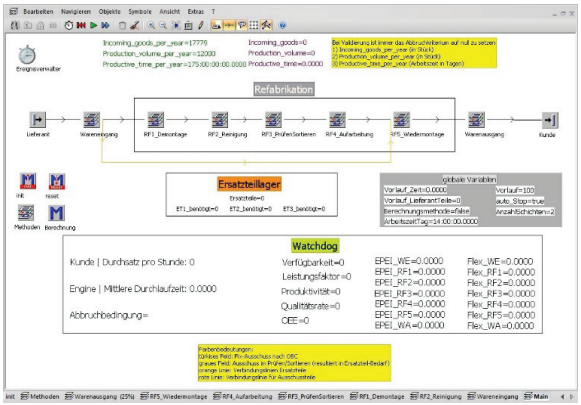

Fig. 4 User interface of the modular simulation model for remanufacturing operations.

Within the holistic approach, the material flow simulations are used to assess certain optimization scenarios and thus to find the best solution.

3.4. Holistic Approach

Based on the methods described before, a holistic approach to assess and to improve remanufacturing processes was developed. The approach combines the three methods, maturity models, the value stream methodology and material flow simulations. Thus, the disadvantages of the methods can be eliminated and the advantages can be strengthened. Figure 5 shows the structure of the approach.

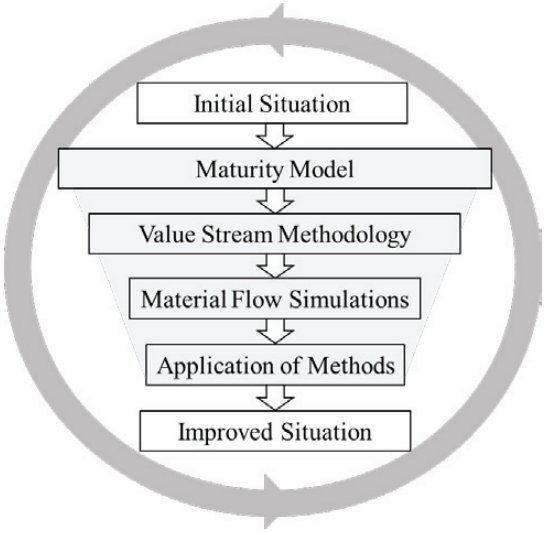

Fig. 5. Structure of the holistic approach.

Starting with the initial situation at a company, the remanufacturing processes are assessed by using the maturity model for remanufacturing operations. The companies' processes are benchmarked against processes from other remanufacturing companies. Thus, it is possible to identify the potentials of improvement on a generic level - according to the eight indicators described before.

In the next step, a value stream analysis is performed. The focus of the analysis are the potentials of improvements, identified in the first step. The value stream analysis is used to substantiate and to concrete the potentials of improvement. Furthermore, it is possible to identify the key processes for the potentials instead of directly optimizing allegedly wrong processes. After the analysis of the value stream, the value stream is improved by using e.g. lean methods, according to the principles of the value stream methodology. The result of this step is a target value stream of the remanufacturing operations.

In the third step, the potential solutions, to overcome the challenges, are assessed by targeted material flow simulations. Due to the limitation of potential solutions and the usage of the generic remanufacturing simulation model developed, the effort for the simulation studies can be reduced enormously. Furthermore, the data gathered during the value stream analysis can be used as base for the material flow simulations, which reduces the time needed as well. The results of the material flow simulations are dynamically assessed solutions to improve remanufacturing processes.

In the last step, the solutions to close the potentials of improvement are implemented. The result are improved remanufacturing processes.

According to the Continuous Improvement Process (CIP), it is fundamental, to not stop improving processes at this stage and instead use the improved situation as initial situation for the next round of improvement.

4. Conclusion and Outlook

In this paper, the development of a holistic approach to assess and improve remanufacturing processes is described. The rudiments of the approach are a maturity model, the value stream methodology and material flow simulations. For each of the three methodologies, a customized tool for remanufacturing operations was developed.

In further research, the theoretical approach will be implemented and tested in industry. That will allow to improve the single modules as well as the intersections of the holistic approach.

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