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Reusing used components in new product generations - a systematic literature review on challenges and future research

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ABSTRACT: This paper presents a systematic literature review to figure out challenges of integration of used components into new product generations. Reuse of components is an essential strategy of circularity and is becoming highly relevant as resources are limited and sustainability requirements have to be meet across industries. The reuse process was examined from a constructive perspective. It was found that the reuse process is not uniformly defined and that there is a divergent understanding of it. This divergent understanding continues through the Reuse process steps and the added value of using Reuse. Various technical challenges of reuse were identified. These challenges were translated into requirements that are intended to enable reuse for used components. An initial concept for solving the design problem of integrating used components is proposed with the help of these requirements.

KEYWORDS: circular economy, sustainability, design theory

1. R-Strategies and problem definition

Limited resources and increasing pollution require effective resource management strategies. The guiding principle of a circular economy is to provide various approaches to reuse materials, components or products that can be categorized into three main core strategies: narrowing, slowing and closing loops. (Bocken & Ritala, 2022) There are numerous approaches to increase sustainability of technical products. Kirchherr et al. (2017) has summarized the nine most common approaches, the so-called R-Strategies. The existence of the other R-Strategies considered, according to Kirchherr et al. (2017), shows that more can be recovered with a recirculated product (Kirchherr et al., 2017). However, comprehensively established is the recycling of materials. This R-strategy is associated with limited resource efficiency. Also, it can be observed that a high portion of products which are replaced include components that are fully functional. A large proportion of waste containing defective household appliances, ends up in landfill sites or recycling centers (Jeschke & Heupel, 2022). Considering for instance an electric motor, which contains valuable resources, a long and complex chain must be started here in order to produce a new electric motor from recycled materials. Since in many appliances only some of the components are defective, some components like electric motors, can be reused. Reuse is characterized by the fact that a still functioning, returned or used product is directly reused for the same purpose or functionality in another product. This is also possible for individual components (Kirchherr et al., 2017). In remanufacturing components or assemblies can also be reused. As reuse is not standard practice in the industry, the question arises which challenges have to be tackled. In order to develop a design support approach for the reuse of components in new product generations, this research analyses the challenges and proposes an initial concept based on a systematic literature review.
In order to tackle the problem described, reuse has to be considered in more detail and differentiated from Design for X approaches. The term Design for X summarizes a number of design approaches that focus on single lifecycle phases or product properties (Ehrlenspiel & Meerkamm, 2013), like design for reuse.

Existing literature provides a number of design guidelines that focus on enabling easy reuse of components, e.g. by following principles of modularity. (Mesa et al., 2020) However, these approaches focus on forward-looking design and do not consider the reuse of used components in new product generations. In our research we focus on the design with used components that return from the market. After the components of the recirculated product have been extracted, they are reintegrated into a new product. To enable integration, the products must first refurbished, e.g. by cleaning or carrying out minor repairs (Bernard, 2011). It should be noted that no uniform definition of the reuse process can be found in the literature. However, a process was defined based on various literature, which is to be considered a reuse process of used components in the context of this work, see Figure 1. (Mangun & Thurston, 2002; Wang et al., 2017b)

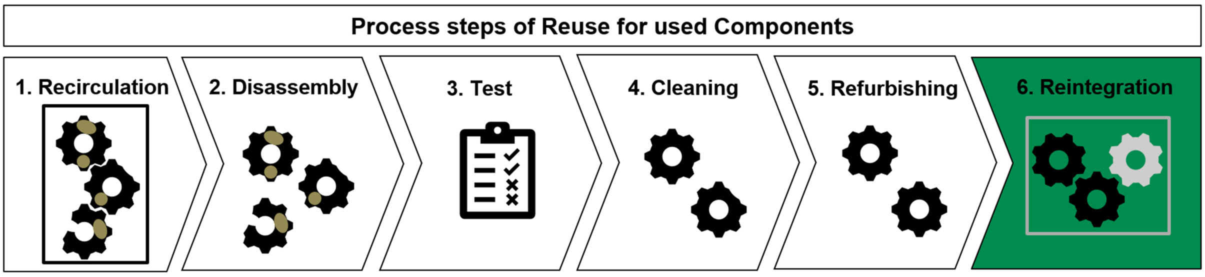

Figure 1. Process steps of reuse

The phase of recirculation describes the return of an end-of-life used product from the market. (Wang et al., 2017b) The product is then dismantled in order to extract intact components. (Mangun & Thurston, 2002) A subsequent functional test allows a selection to be made regarding possible reuse. (Wang et al., 2017b) The used component is then cleaned to remove dirt. (Wang et al., 2017b) The component parts are then refurbished to restore them as far as possible to their original condition. (Mangun & Thurston, 2002) In the final phase of reintegration, the component can be reintegrated into a new planned product. (Wang et al., 2017b) The last phase of the reuse process is colored green, as it is addressed again later in this work.

2. Objective and methodology

The objective of this research is to identify challenges arising during the process of reusing components in new product generations. A systematic literature review (SLR) is conduced to identify and classify challenges and existing solutions focusing on technological aspects. The results serve as a basis to derive requirements for a method to consider used components with the design of new product generations. According to the Design Research Methodology (DRM) (Chakrabarti, 2002), the research is focusing on the research clarification (RC) and descriptive study 1 (DS I). Referring to existing research this work extends the state of the art by the following contributions:

- A systematic classification of existing challenges allocated to the different activities in the reuse process.
- An initial concept to support the reuse of components in new product generations based on design automation.

Existing research already examines the approaches of reuse and remanufacturing in a literature review and points out gaps in knowledge regarding social and economic aspects (Santos et al., 2023). Albers et al. (2024) proposed a framework to include circularity and the reuse of components across product generations on a conceptual level. Interrelationships between individual product generations were examined with regard to value retention strategies and value creation tiers. This was done using an example of a recirculated electric grinder. (Albers et al., 2024). However, these works do not provide an overview of requirements for integrating used components into new products on a concrete level. The objective of this research is formulated according to the *Goal Question Metric Approach* (Van Solingen et al., 2002) in Table 1.

Table 1. Main research objectives according to the Goal and Question Metric Approach

Purpose	Implementation of a systematic literature review focusing on the
Issue	identification of design challenges and solution concepts to reuse components in
Object	the engineering of new product generations
Viewpoint	from the perspective of research and practical product development.

The guiding research question is formulated as follows: *What are the challenges from a product development perspective to reuse used components within engineering of new product generations?* In performing the SLR this main research question is decomposed into three questions:

- What is the meaning of the term reuse and which activities have to be considered in the process of reuse?
- Which value and opportunities are associated with the reuse of used components?
- What challenges arise in the engineering of new product generations based of used components?

These study questions are answered using a SLR explained in the following chapter. The SLR follows the process proposed by PRISMA. (Moher et al., 2009) To identify relevant publications, the following search string was used:

"used part" OR "used component" OR "used element"
AND "reuse" OR "integration"
AND "circular economy" OR "circular design"
AND "requirement" OR "challenge" OR "method" OR "condition" OR "need" OR "specification"
AND "product generation" OR "product line" OR "product platform" OR "platform"

The search was performed on November 14, 2024, using Google Scholar which returned 183 references in total. Inclusion and exclusion criteria were defined to filter the identified publications, see Table 2.

Table 2. Inclusion and exclusion criteria for the systematic literature review

Type	No.	Criteria
Inclusion criteria	1	Only papers that involve the reuse/recycling of used mechanical components or assemblies are considered.
	2	Only papers that contain the word "reuse" and refer to a methodological context are considered.
	3	Only papers that address the individual process steps/phases of the reuse process from chapter 1.1 are considered.
Exclusion criteria	1	Non-specialist topics related to reuse, e.g. from medicine, construction or similar, are not considered.
	2	Duplicates are excluded.
	3	Non-English language papers are excluded.
	4	Non-peer-reviewed papers from a conference or a publisher's book are excluded from the search.

All 183 papers were subjected to a screening. 11 papers were excluded according to exclusion criteria 2. Another 11 papers were excluded according to exclusion criteria 3. Exclusion criteria 4 further excluded 64 results and further 91 papers were excluded using exclusion criteria 1. After filtering with the inclusion and exclusion criteria, 6 results remain. By snowballing using the software ResearchRabbit, 4 further papers were included in the full-text analysis.

3. Results and findings of the literature review

In this section the results of the literature review are presented. Based on the gathered data, the study questions are answered.

3.1. Data analysis

The 10 publications focusing on the reuse of used components were analyzed in detail. In Table 3 an overview of the publications is given. In general, it was found that the reuse process is not clearly defined and remanufacturing is considered as part of reuse by some authors. This finding explains the low number of publications identified and will be considered in further work. The research questions from Section 2 are examined below.

3.1.1. Findings for RQ1: What is the meaning of the term reuse and which activities have to be considered in the process of reuse?

There is no uniform understanding of the term *reuse* in literature. Kalverkamp and Raabe (2018) consider remanufacturing as a form of reuse. Reuse involves strategies that extend the service life of products and components. The example of the direct reuse of car parts as spare parts or as a resource for remanufacturing is classified as a type of reuse here (Kalverkamp & Raabe, 2018). According to Hegedűs and Longauer (2023), there are several reuse options: Repair, Refurbish, Remanufacture, Cannibalization and Recycling (Hegedűs & Longauer, 2023). Mesa et al. (2020) defines reuse as the reintegration of used components into the lifecycle of newly developed or existing products, which allows the original purpose of use to continue. Further the authors define reuse in the context of sustainability as a process that describes economic, environmental and social challenges related to the reuse of used components (Mesa et al., 2020). Bettinelli et al. (2020) distinguishes reuse from recycling based on the distinction that used components are reused and not converted into raw material as in recycling. They also define remanufacturing as a form of reuse by which used components can be integrated into new products (Bettinelli et al., 2020). Conti and Orcioni (2019) generally associate the term reuse to whole products. Following this understanding there can be a reuse of entire products that are sufficiently returned in monetary and functional terms. However, individual used components can also be reused in new products if entire products are no longer functional and therefore are dismantled and cannibalized. (Conti & Orcioni, 2019). Cooper and Gutowski (2017) classifies reuse as one of the 3Rs: Reduce, Reuse, Recycle. There are several subtypes of reuse: Relocation, Remanufacturing with Re-fill, Remanufacturing with Remediation of Component properties, Remanufacturing with Module reuse/ replacement with or without upgrade, Adaptive reuse, Cascade and Reform. They argue that reuse is a non-destructive process that enables the reuse of solid goods, e.g. products or components, after their actual intended use. The areas of reuse and resale of products overlap to some extent. Reuse is often only understood in the context of the reuse of entire products. In contrast, the reuse of components is often only present in small-scale activities. The industrial reuse of individual components is often referred to as remanufacturing. For Cooper and Gutowski (2017) however, reuse is understood as a positive strategy associated with assumed, but the actual overall effects remains unclear. (Cooper & Gutowski, 2017) Kimura et al. (2017) explain the understanding of reuse with the example of a camera, in which components can be reused over several product generations. (Kimura et al., 2001) Wang et al. (2017) explains that components are reused as part of remanufacturing. (Wang et al., 2017a)

It can be summarized that there is an unclear understanding of the concept of reuse. On the one hand, this is evident as the process of reuse is only defined as the reuse of an entire product. In contrast to this, other literature refutes this by mentioning individual components of the reuse process. Furthermore, different R-strategies such as remanufacturing, repair or refurbishing are referred to as reuse strategies. However, there are also mentions of a reciprocal inclusion, e.g. of remanufacturing as a step of reuse. While others refer to reuse as the literal reuse of a used product or individual used components, other works define reuse as the transformation of a non-destroyed object into new products.

Due to these contradictions, it is decided at this point that the reuse process is understood as the reuse of individual used components, in which the individual process steps above are to be carried out to varying degrees depending on the condition and purpose of the returned product. The unclear understanding of the individual sources as to which process steps are to be carried out shows that it is necessary to compare the literature with the process steps in Figure 1. Therefore, the six process steps of recirculation, disassembly, testing, cleaning, refurbishing and reintegration of the reuse are located in the 10 papers under consideration in Table 3. More in detail, Table 3 indicates how the single process steps are addressed in the analyzed publications. Now it seems interesting to verify this by examining the basic naming and location as well as the frequency of occurrence.

Two different perspectives from the literature are listed here in Table 3 to aid understanding. Kalverkamp and Raabe (2018) focus on reuse in the form of spare parts. Therefore, the necessary process steps, market return, testing of the used component with regard to the application of an R-strategy, e.g., direct reuse, repair or remanufacturing, are mentioned here. This is followed by direct reintegration. (Kalverkamp & Raabe, 2018) Wang et al. (2017) argues from the perspective of the reuse of components in different product generations. A precise process is specified: Component is returned, disassembled, cleaned, undergoes refurbishing, component is tested, then component is repaired and finally market demand is met again. (Wang et al., 2017a)

Table 3. Frequency and categorization of the process steps in the literature review

		Process steps of reuse, see Figure 1					
Reference	Title	1	2	3	4	5	6
(Kalverkamp & Raabe, 2018)	Automotive Remanufacturing in the Circular Economy in Europe: Marketing System Challenges	x		x		x	x
(Kalverkamp, 2018)	Hidden potentials in open-loop supply chains for remanufacturing						
(Hegedűs & Longauer, 2023)	Implementation of a circular supply chain model using reusable components in multiple product generations	x	x	x		x	x
(Mesa et al., 2020)	Modular architecture principles – MAPs: a key factor in the development of sustainable open architecture products						
(Bettinelli et al., 2020)	A decision support framework for remanufacturing of highly variable products using a collective intelligence approach						
(Conti & Orcioni, 2019)	Cloud-based sustainable management of electrical and electronic equipment from production to end-of-life		x	x		x	x
(Cooper & Gutowski, 2017)	The Environmental Impacts of Reuse		x		x	x	x
(Kimura et al., 2001)	Product Modularization for Parts Reuse in Inverse Manufacturing			x			x
(Kondoh et al., 2005)	A Closed-loop Manufacturing System focusing on Reuse of Components		x	x	x		x
(Wang et al., 2017a)	Component reuse in remanufacturing across multiple product generations	x	x	x	x	x	x
	Sum	3	5	6	3	5	7

This comparison shows that there is a different understanding of the reuse process steps. On the one hand, this results from the different understanding of reuse in the literature from RQ1. On the other hand, the result is due to the different ways of looking at the reuse of components. For example, if an entire product is reused, it does not necessarily have to be dismantled and cleaned after a successful test. It can be returned directly to the market. As described above, this is not the case with a defect product where all six process steps may have to be run through. In any case, it can be noted that the disassembly, testing, refurbishing and remanufacturing steps were mentioned most frequently in the majority of the results analyzed. In each case, all were mentioned at least three times and testify to the relevance of the reuse process as a whole. As the restriction of reusing used components applies here this idea is reinforced, as all further steps are necessary to implement this project. The only exceptions are steps 4 and 5, which seem rather optional. Consequently, the question arises as to what added value arises from reuse and thus from the individual steps.

3.1.2. Findings for RQ2: Which value and opportunities are associated with the reuse of used components?

In contrast to the diverse understanding of the concept of reuse, value and opportunities of reuse can be divided into three main categories, namely *ecological*, *social*, *technical and economic* value. The basic principle of ecological value is that sustainability is increased (Kalverkamp, 2018; Kimura et al., 2001; Kondoh et al., 2005). Reuse reduces the need for raw materials, as the reuse of products or components does not require no new raw materials need to be mined (Cooper & Gutowski, 2017; Kimura et al., 2001; Mesa et al., 2020). Moreover, reuse reduces the processing energy required for new products (Mesa et al., 2020). As a result, fewer materials are sent to the landfill, which reduces the environmental impact on soil and groundwater (Conti & Orcioni, 2019; Cooper & Gutowski, 2017). Focusing on the social value, inexpensive products that have been reused, can be purchased by consumers who would otherwise not have been able to buy these products (Cooper & Gutowski, 2017). Moreover, the useful lifetime of products is extended (Mesa et al., 2020). Technological value of reuse include that used components do not have to be broken down into raw materials first, but can be reused directly shortening the manufacturing process (Bettinelli et al., 2020). Used components have less faults or need for optimization, as these have already been identified through experience in product operation. (Conti & Orcioni, 2019) Standardized and electricity-free products and components are less energy-intensive to reuse than new production (Cooper & Gutowski, 2017). The reuse of components reduces or eliminates the manufacturing time need for them (Mesa et al., 2020). The economic value is associated with a lower average price of remanufactured products, which is between 45% and 65% of the cost of a new product (Cooper & Gutowski, 2017) as well as reduced manufacturing costs (Kondoh et al., 2005; Mesa et al., 2020). In the end, it is beneficial for companies to introduce less new product families and therefore focus more on product generations. This can improve reverse logistics. (Wang et al., 2017a)

It can be seen that the added value and opportunities of reuse result from various areas. Some of these are mentioned several times. Listed above are 4 ecological, 2 social, 4 technical and 3 economic key added values and opportunities of reuse. In terms of relevance to the argument, the ecological added values predominate. This is a logical conclusion of the original idea of reducing environmental pollution and overproduction through reuse. These findings strengthens the pursuit of the reuse process from these 13 stated added values. The next step is therefore to identify the challenges that stand in the way of reusing used components.

3.1.3. Findings for RQ 3: What challenges arise in the engineering of new product generations based of used components?

In literature there are five main categories used to classify challenges associated with reuse, namely *economic*, *ecological*, *social*, *logistical*, and *technical* challenges. A total number of 44 challenges were identified, covering 9 economic, 4 environmental, 6 social, 8 logistical and 17 technological challenges. As technical related challenges are in focus of the research, these are listed explicitly in Table 4. The most frequently mentioned economic challenge is the identification of monetarily worthwhile components of a used product. (Hegedűs & Longauer, 2023; Kalverkamp, 2018) The situation is more divergent in the ecological area. However, it should be noted that reuse is not a fundamental guarantee of environmental benefits. (Cooper & Gutowski, 2017) One social challenge that has been mentioned several times is that customer preferences and associated fashions change over time. (Cooper & Gutowski, 2017; Wang et al., 2017a) One logistical challenge that has been mentioned several times is that information about the past and a classification of the used component should be available and up-to-date for an optimal reuse cycle. (Bettinelli et al., 2020; Conti & Orcioni, 2019; Mesa et al., 2020; Wang et al., 2017a)

The technological challenges from Table 4 were classified (CL) in order to differentiate the challenges of the sixth process step of reintegration and thus also design challenges. A distinction was made between design-related (D), process-related (P), quality- and performance-related (QP) challenges.

Table 4. Technological challenges in the product development process

CL	C.-No.	Description of the technological challenges	Literature
D	C.1	In order to enable the integration of used components into new product generations, a design connection is required.	(Conti & Orcioni, 2019; Hegedűs & Longauer, 2023)
D	C.2	Design openness of the system, allows replacement of used components in the new product, as used components can fail spontaneously.	(Bettinelli et al., 2020; Kimura et al., 2001; Mesa et al., 2020)
D	C.3	Each used component has hundreds of technological properties that should be assigned to an application.	(Bettinelli et al., 2020)
D	C.4	Design guidelines are needed to simplify design in the reuse process in the future.	(Cooper & Gutowski, 2017)
D	C.5	Functional upgrade options for new product generations.	(Kimura et al., 2001)
D	C.6	Efficient reuse of components in remanufacturing requires systematic planning in the product design phase.	(Wang et al., 2017a)

(*Continued*)

Table 4. Continued.

CL	C.-No.	Description of the technological challenges	Literature
P	C.7	Components with software are difficult to reuse due to changing system interfaces and operating systems.	(Kalverkamp, 2018)
P	C.8	The large number of variants and growing diversity of manufacturers of some components is problematic.	(Kalverkamp, 2018)
P	C.9	Test methods must be developed to determine the specifications of the original components.	(Cooper & Gutowski, 2017)
P	C.10	Because of different shapes of the used components, it is difficult to clean and repair them.	(Kimura et al., 2001)
P	C.11	Obsolete technologies or technology incompatibilities and technological stability of used components.	(Cooper & Gutowski, 2017; Kimura et al., 2001)
QP	C.12	The quality of a reused product will not match the quality of a new product.	(Hegedűs & Longauer, 2023)
QP	C.13	The fluctuation of quality and easy quality control of used components.	(Kimura et al., 2001; Kondoh et al., 2005)
QP	C.14	The reuse of components becomes partially inefficient due to degradation.	(Cooper & Gutowski, 2017; Wang et al., 2017a)
QP	C.15	The performance (e.g. efficiency) of the used components is relevant for deciding whether integration into new product generations is worthwhile.	(Hegedűs & Longauer, 2023)
QP	C.16	The energy efficiency of used components can fluctuate in different phases of use and is usually inferior to that of newer components.	(Conti & Orcioni, 2019; Cooper & Gutowski, 2017; Kimura et al., 2001)
QP	C.17	Satisfying customer demand with the same performance and the guarantee of old components in a new product.	(Wang et al., 2017a)

It can be summarized, that the total of 17 technological challenges can be divided into 6 design-related, 5 process-related and 6 quality- and performance-related challenges. It can be seen from the literature that some technological challenges are mentioned several times. In particular C.1, the need for a geometric connection of used components to the new product, C.2 modularity with regard to disassembly for reuse, C.12 sorting out obsolete technologies and C.17 paying attention to the energy efficiency of newer components compared to the used older components, were mentioned particularly frequently. With these findings, requirements for the sixth step of the reuse process can now be defined in the next step.

3.2. Requirements and solutions in the Reuse-Process

In this section, basic requirements for a design support of reusing components in new product generations are determined. The objective is to focus on *design with used components* rather than *design for reuse*. A total of 11 requirements, see Table 5, were defined on the basis of challenges C.1 to C.7 from Table 4. It

Table 5. Technological requirements

C.-No.	R.-No.	Description of the technological requirements
C.1	R.1	The design approach must support a geometric connection for used components during creation.
	R.2	The design approach must fulfill the geometric connection from the intended functional purpose.
C.2	R.3	Flexibility should provide modularity through the design approach for future disassembly and replacement of spare parts.
C.3	R.4	All parameters of a used component must be considered in the design approach.
	R.5	The parameters of the used component must be subjected to a decision logic regarding the relevance for the individual design case.
	R.6	The decision-making logic must be automated in order to be able to handle the large number of necessary parameters resulting from the diversity of variants.
	R.7	Highly differentiated, non-existent or partially inaccurate input data of the component parameters must not lead to uncertainties in the design approach.

(*Continued*)

Table 5. Continued.

C.-No.	R.-No.	Description of the technological requirements
C.4	R.8	The design approach must be uncomplicated and easy for the user to understand and modify.
	R.9	The design process must be flexible in itself.
C.5	R.10	Functional upgrades of used components must be able to be integrated into the design approach for new product generations.
C.6	R.11	The information on the component condition must provide a decision logic for the design steps to be carried out or for damage compensation, which enable the damage to be repaired.
C.8	R.12	The design approach must be fully automatable so that the variety of variants and manufacturers can generally be managed.

should be pointed out that the requirements can be formulated even more specifically, but a certain level of generality must be present in order not to predetermine a solution approach.

With these developed requirements, a design approach can now be sought. It should be noted that the design approach is supported in particular with regard to the diversity of variants of the returned used components. This is essentially the problem described in the introduction, namely that a designer cannot design an integration for such a variety of geometric connections in terms of time and money. Further requirements, such as dealing with the parameters of the components and decision logics about the individual necessity of these and dealing with damage, lead back to a workable individual design for each used component. However, it is not humanly workable. Accordingly, an automated design is required here.

4. Initial concept to support reintegration of used components

An initial concept is needed to support the reintegration of used components into new product generations. The requirements identified in Table 5 focus on the reintegration and product development phase. No requirement from Table 5 is secondary. However, R.1 to R.4 are more important, as the integration of a geometrically and functionally suitable environment is more fundamental than R.5 to R.12. In order to be able to process this large amount of functional and geometric data, an automated reintegration or design is required. Design automation deals with the concept of targeted computer-aided adjustment of product parameters with the aim of eliminating the need for manual processing of certain design tasks and thus increasing the efficiency of the design process. (Rigger et al., 2016) Automated design is often restricted to certain design objectives (Tarkian, 2012). The main opportunities of design automation lie in the processing of a volume of tasks with an associated variety that a designer cannot manage manually. In contrast to humans, a computer-aided system is unbeatable when it comes to the speed with which a specific task with defined limits can be solved. (Rigger et al., 2016) However, there are also restrictions, e.g. in relation to the objective with the associated programming effort, which initially play no role in the type of problem solution (Gorski et al., 2016). Figure 2 shows an initial concept for processing geometric and functional parameters in consecutive steps.

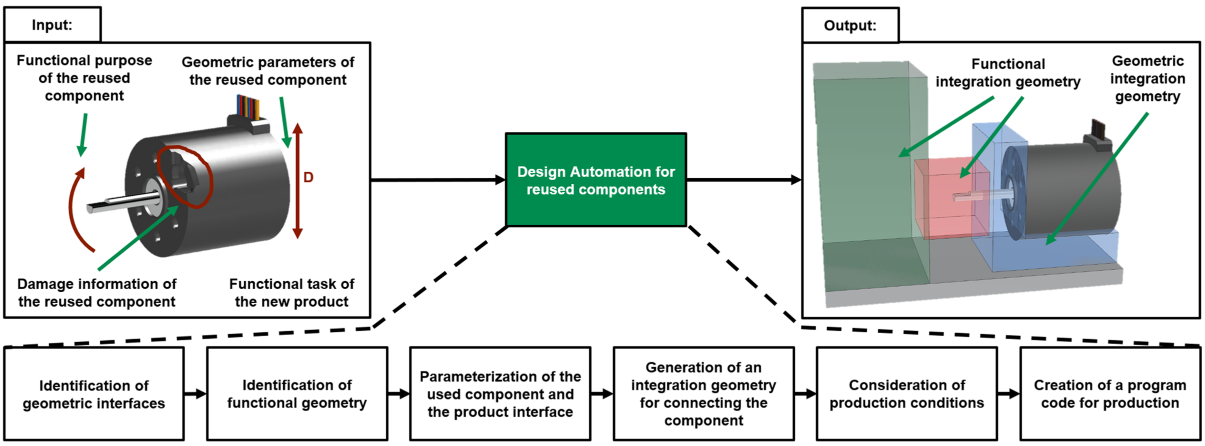

Figure 2. Design automation of reused components

Since there are not enough case studies, as shown by the literature research, an electric motor was introduced in Figure 2 as an initial idea for a future case study. This electric motor seems to be an interesting example due to the materials it contains and the widespread functional application of generating rotation through electricity. Figure 2 shows information such as geometry, function and purpose are processed one after the other and intermediate results are transformed until a designed result is generated in order to reintegrate used components into new products. It should be emphasized that the approach in Figure 2 is a very first principle that needs to be further specified, elaborated and validated. However, with reference to the next chapter, a case study will be carried out in future work.

5. Discussion and limitations

After conducting the systematic literature review, all three research questions were answered. RQ1 provided an unclear understanding of the definition of the reuse process from literature. The process steps of reuse were also mentioned differently several times. However, there is an accumulation of the process steps test and reintegration. Based on these findings, reuse of used components is understood as shown in Figure 1. The search for the added value of reuse in RQ2 is also more divergent resulting in a conclusion based on different understandings of reuse, but also produced an overlap of significant ecological added value. These approaches were reflected in RQ3 and thus in the identification of the challenge of reuse. Here, 44 challenges from various areas were identified and 17 were presented from a technological perspective.

Two comments should be made with regard to the limitation. The requirements were derived from the challenges identified and not from other practical examples. It can be noted here that the literature review revealed that there is a lack of case studies for the reuse process of used components for reintegration into new product generations. It can be assumed that further challenges could be identified if such a case study were to be carried out. Due to the divergent understanding of reuse more technical terms related to reuse such as Cannibilization were found. It was also found that remanufacturing is understood as part of reuse. These terms were not used in the search string of the literature review, but should be considered in future work.

6. Summary and further research

The problem that used components come back from the market in a large number of variants and cannot be manually integrated into new products due to the amount of work involved, raises the question of how this problem can be solved. Due to the initially established fact, that there is a diverse understanding of the R-strategy of reuse used components and the associated process, a literature review was carried out. With this literature review, it was identified that only a small amount of literature exists on this explicit issue. Also, the general understanding of the reuse process of used components could be established with this literature review. Process steps, added value and challenges of reuse were also identified. Design requirements were derived from these challenges. These requirements were used to develop an initial proposal to solve the initial problem using a specially tailored design automation.

In the next step, the limitation of the missing terms described in the previous chapter, e.g. Cannibilization, should be included in further work in order to expand and consolidate the results. Further elaboration should also focus on the final process step of reintegration. These two boundary conditions should be used for a further literature review on design automation. The proposed design automation concept will then be further elaborated. Furthermore, an initial case study of a used and technically valuable component should also be carried out. To this end, a case study must be defined that reflects the identified challenges, poses new challenges to the design automation process of reusing used components for reintegration into new product generations and is scientifically and economically relevant.

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