Elaboration of an Operational Methodology for the Development of a Collaboration Platform for the Reuse of Tools and Tool Components

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Abstract. Environmental sustainability is becoming increasingly important for tool and die making companies. Tools and tool components are often discarded because they are no longer needed for their original application, although they are often still good to use. Despite the need for environmental sustainability, the concept of circular economy, especially reuse, is not applied. This paper deals with the elaboration of an operational methodology for the development of a collaboration platform for the reuse of tools and tool components.

The analysis of existing methodologies for the development of collaboration platforms that incorporate environmental sustainability and reuse, shows the need for the development of a specific methodology for tooling. In addition, the market demand for tooling and tool components, the environmental impact of tooling reuse, and potential revenue streams for the platform demonstrate the industry need. The methodology includes a specific approach in each phase and includes determined methods and standards to implement it. Overall, the results of each phase of the developed methodology enable the user to develop a platform with a circular economic and waste reduction orientation. Further research is needed for validation as well as practical implementation and further improvement of the methodology for developing collaborative platforms.

Keywords: reuse platform · tool components · platform economy

1 Introduction

The continuous pursuit of cost optimization, timesaving and quality improvements defines the near-perfect industrialization of the past. In combination with globalization, productivity increased even further. This resulted in continuous economic growth, which increased resource consumption and carbon emissions [1]. The efficient use of resources generally appears to be desirable. This is based on the approach that resources are scarce and their careful use is becoming increasingly important in times of high consumption by society [2]. This is the reason for the necessity of a circular economy, in other words the return of used primary resources to the energy and material cycle as secondary raw materials [3].

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As a result of these developments, the guiding principle of sustainability becomes increasingly important, both socially and economically. In this context, resources can be considered as a strategic dimension [4]. The change in strategy translates in an immediate pressure for transformation on manufacturing companies and SMEs in particular. Sustainability is increasingly becoming the all-important competitive factor [1]. Tool and die making industry is one of the most relevant representatives of single and small batch production (SME) [5]. The tool and die making industry is the enabler of series production and can therefore have a significant influence on the sustainability of series production. Due to this pressure for change affects these SMEs in particular.

Tool and die making industry is caught in the middle and has to face these challenges. That consist of providing the series production with economical and at the same time sustainable tools and dies without sacrificing quality. Therefore, this paper deals with the development of a reuse concept including a collaboration platform for the exchange of tools and tool parts that could be one solution to the challenge.

2 State of the Art

2.1 Tool and Die Making and Its Value Chain

Tool and die making as part of the manufacturing industry and in a key position within the industrial value chain is located at the interface between product development and series production. It is characterized by the pursue of the five goals of cost, time-to-market, quality, innovation and productivity [6]. The typical value chain in tool and die making consists of five process steps and starts with acquisition, which includes costing, sales and distribution. The second process step, tool development, is divided into process planning and design. The third step, production planning, is divided into the steps of fine planning and NC programming. Fourth, in tool manufacturing, the steps are mechanical manufacturing, assembly and testing. Finally, fifthly, after the tool has been handed over to the customer, comes the series support, which is provided by the after-sales service [7].

2.2 Circular Economy and Reuse in Tooling

The goal of the circular economy is to save resources and avoid waste to maintain a closed material cycle [8]. Circular processes are possible on different levels. One level is the reuse of products [9]. Reuse is the re-purposing of non-waste materials for their original function, with no structural changes. This method may necessitate collection but little or no conversion. Reused products are typically sold on a peer-to-peer basis, with no repairs or testing [10]. The circular economy in manufacturing must combine three key aspects to be successful as an overall concept: Waste and the environment to avoid and minimize environmental impacts, resource scarcity as a motivation to use resources in a regenerative way, economic benefits for industrial companies to maintain and increase profitability [11]. In the tooling industry, the latest results of the Excellence in Production 2021 competition for the tooling of the year show that the reuse rate of tools and tooling components is below 9%, which means there is still a lot of potential [12].

2.3 Collaboration Platforms

"Collaboration platforms" is used as a fluid term for interactions among distributed groups of people supported by digital platforms. They enable them to exchange, share, and collaborate in the consumption and production of activities that use capital and goods [13]. There are four types of participants in the platform economy: Digital infrastructure, digital platforms, digital entrepreneurs and digital users [14]. Collaboration platforms can be used for a variety of topics, including sustainability. Platforms with a sustainability focus must take care in their design to facilitate knowledge sharing among diverse stakeholders [15].

2.4 Digital Shadow

For Industry 4.0, a suitable database is highly relevant that is available in near-real time and does not require any manual effort for creation or cleansing [16]. The data from various existing collection systems must be extracted and aggregated centrally, both as raw data and in refined form through data analysis [17]. The digital shadow creates an accurate picture of processes in production, development and adjacent areas that can be accessed in real time to address challenges [18].

The application of the data shadow in collecting tool usage information consists mainly in the following six points: real-time monitoring, data aggregation, integration with other systems, predictive maintenance, optimization of processes and decision making.

3 Objectives and Requirements

Based on the state of the art, the objective for the platform "facilitate sustainability by making it economical and easy" combines the three dimensions of collaboration, reuse, and tool and die making. Then, 12 tool and die making companies were surveyed to determine the requirements for the development of the tool and die making collaboration platform through interviews and workshops. The core requirements for the reuse platform are identified as follows: 1. Data quality and completeness—essential for the evaluation of the degradation on tool components, 2. Data security—to create a trustworthy environment for sharing sensitive data between companies, 3. Information transparency—to create trust in the shared data, 4. Intuitiveness of the user interface—for the ease of use and for a maximum of data given by the seller, 5.Economic efficiency—besides sustainability the price is still the deciding factor.

4 Results

The presentation of results begins with a review and evaluation of existing platform development approaches. Based on this, a new approach for the development of a collaborative platform is derived. Finally, the developed methodology for platform design is provided with supporting methods and tools to implement the individual phases.

4.1 Analysis of Existing Methods

We consider a sequential platform development approach by Vaishnavi & Keuchler and Grams et al. The method consists of 4 phases (1) Data Collection, (2) Data Analysis, (3) Development and (4) Syntheses & Evaluation [19].

The platform development method is not suitable in its current form without an initial strategic orientation. Without prior consideration of strategic goals and requirements, the method cannot produce a platform that considers uncertain future customer needs, technological changes, and competitor responses. Furthermore, the long-term perspective is neglected without an initial strategic orientation, which may cause the platform to be unsustainable in the future [20]. As a result, integrating a strategy formulation phase can provide internal and external data to enhance the success of such a platform [21].

In the following, the spiral model according to Boehm will be explained. This is an iterative platform development process. The methodology consists of 4 phases and is used to develop and improve a platform. In each iteration, objectives, alternatives, and constraints are first determined [22].

In its current form, Boehm's spiral model is not a suitable solution for a collaboration platform development methodology. Compared to the sequential methodology, this method lacks focus on data collection and analysis. In addition, the iterative approach increases the complexity of the application.

4.2 Methodology for the Collaboration Platform Development

Both previously explained methods for platform development can be used in their current form, but according to the given reasoning, they are not optimal in their current form. Therefore, the combination of the two methods is beneficial. The method of Grams et al. is extended by the first phase of the spiral model of Boehm. This solves the problem of the lack of strategic orientation. The method then looks as follows (Fig. 1).

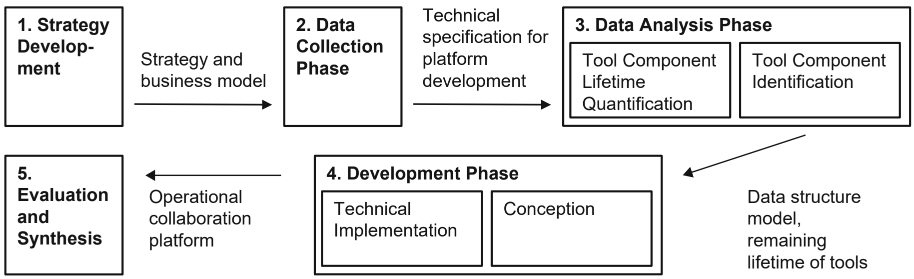

Fig. 1. Connectivity and dependencies diagram of the methodology for the development of a collaboration platform

Now that a suitable methodology for the development of a collaboration platform has been derived, the individual phases will be expanded to include the required input as well as tools and methods. This serves to make the methodology practically applicable for the reuse in tool and die making.

The business model canvas (BMC) is used to develop the **strategy** and a corresponding business model in the first phase. The BMC is particularly suitable because it provides a holistic perspective on the business model and at the same time allows flexible adaptation to change in strategy. The method supports a comprehensive analysis based on the systematic evaluation of nine key factors. Based on the results, business models can be critically evaluated, potentials identified and well-founded strategic decisions made. To obtain the necessary information for the BMC, specific questionnaires can be used to conduct surveys at toolmaking companies. Based on the results of the survey, the development and definition of an application-oriented service system consisting of platform-based reuse services can be carried out.

In the second phase, data collection, tool data is gathered. This phase is crucial to create a comprehensive database that ensures the smooth functionality of the platform and that the tools offered meet the needs of the customers. Data collection takes place along the life cycle of the tools and the tool components. In terms of the circular economy and the associated focus on sustainability, this covers the tool and die making including raw material extraction and production as well as the utilization phase of the tools and recycling or remanufacturing at the end of the life cycle. These results are compiled in a technical specification for the platform, which later serves as the basis for programming the platform.

In the data analysis phase, the results from the previous development steps are used to develop a use case-specific data structure model. On this basis, the necessary information is determined that must be contained in a digital twin over the life cycle of the tool along the value chain and beyond when the tool is reused. This process divides the data analysis phase into two sub phases and is illustrated in Fig. 2.

Fig. 2. Two-step approach in the data analysis phase

In the first sub phase, tool component identification, components of injection molding and sheet metal forming tools are classified. This serves to identify platform-relevant tools. This procedure is based on requirements that were identified in interviews with toolmaking companies and validated in workshops with interview partners.

In the tool component lifetime quantification phase, a formula is developed to determine the remaining lifetime of the tools identified in the previous phase. The extensive data in the digital shadow is used, as shown in the formula below, to realistically adjust the remaining lifetime (R) of the tool components.

First, the formula subtracts the already elapsed operating time (O) from the expected lifetime (E) of a particular tool. However, this only gives a very inaccurate evaluation of the actual remaining lifetime of the tool, as this still depends on many other factors. In order to take these factors into account and thus achieve a more accurate lifetime determination, the last term is required. The factors temperature (T), pressure (p), hardness (h) and resistance (r) are particularly relevant in this context [23].

$$R = E - O - f(T, p, h, r)$$

Because of this, the formula is extended by a function that takes these factors into account. This is the function f(T, p, h, r), which obtains the related data for the factors just listed from the digital shadow and needs to be specified with further research.

The development phase includes the conception as well as the technical implementation of the platform. First, a suitable system architecture for the collaboration platform to be developed is conceptualized. The portal will be designed in a micro-service architecture, on the one hand to implement data protection and data security in the best possible way, and on the other hand to support the broadest possible utilization. In particular, the design of a tamper-proof data transfer to ensure the corresponding data security must be considered. Second, the platform needs to have a user experience which leads to the objective with its requirements. To achieve the best possible user experience, the process of human-centered design according to ISO 9241-210 should be used [24].

Finally, the evaluation and synthesis phase is used to test the developed collaboration platform with users and fill it with tools for exchange. It is a long-term step to continuously improve the platform and extend the digital shadow along the technical capabilities of the tooling companies.

5 Discussion

With the help of a digital shadow, it is possible to track the entire life cycle of a tool using the associated data. This ensures data quality and enables a transparent information situation to simplify the collaboration process. Nevertheless, most tool and die making companies still collect their data manually. Therefore, the methodology with all its cutting-edge features can only be used if the tool and die making industry successfully manages the digital transformation to be able to collect data automatically to maintain a digital shadow for every tool during its life cycle.

The reuse idea can only prevail in tool and die making if the previous classic production factors of time, manufacturing costs and quality are not negatively affected. This is challenging because the tools are very specific, as they are a product of single and small batch production. The results focus on the development of the platform, but for practical use it is crucial to provide a comprehensive set of tools in addition to the associated data quality and transparency. Moreover, the platform must be designed so that users can easily find the tool they are looking for based on its specifications.

6 Conclusion

The methodology developed in this study shows a structured approach for the development of a collaboration platform in tool and die making for the exchange of used tools. The five-phase process shows how the requirements for combining the three dimensions of collaboration, reuse and tooling can be met. It uses methods and standards applicable in practice and is optimized for the tool and die making industry but requires progress in digital transformation.

Further research could focus on developing concepts for digital transformation in the tool and die making industry. With the help of automated data acquisition and processing, not only the digital shadow is made possible, but also further optimization potential arises, such as sustainability accounting and cost optimization. Another area of research could be the concept of promoting sustainability in the tool and die making industry as a whole, and in particular reuse and the collaboration platform. By showing not only the environmental potentials but also the economic benefits, it could be much easier to move the tool and die making industry towards more sustainability.

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