Towards an Integrated Knowledge Management System for Small and Medium-sized Enterprises in the Field of Assembly System Engineering

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***Abstract*—The development of assembly systems requires deep knowledge about assembly processes and process technologies as well as profound knowledge about the product to be assembled. A method supporting communication and knowledge management during assembly system development and manufacturing will be described in this paper. The method is designed to meet the needs of small and medium-sized enterprises (SME) and consists of several modules. One of the modules visualizes the product and the assembly line in order to gain a common understanding of the system. By adding metadata to files, the assembly line manufacturer's staff can quickly access data from completed projects using semantic searches. The communication module ensures an information exchange without changes between different media formats amongst all parties during assembly line development. All modules will be put together in a web-based software application to enable multiuser access and collaborative work. The interaction of the modules allows transparent communication, as well as the linking of data and elements of knowledge throughout the entire assembly system development process.**

Keywords-assembly system; collaborative engineering; knowledge management; information sharing.

I. INTRODUCTION

The demand of consumers for individual and innovative products has been continuously increasing. New, more complex products and new model generations are demanded by market in ever-shorter intervals [1]. This leads to an increased number of variants and higher complexity along the entire value chain and its components, like special machinery and assembly systems (see Figure 1), as a subcategory of special machinery.

Figure 1. Assembly system with manual and human robot collaboration workstations.

The development of special machinery requires high planning efforts, as each machine is designed individually for the product and the task to be performed. Therefore, assembly systems are often built only once. These small lot sizes are complicating a standardization of design and construction [2].

Assembly system development poses a challenge to knowledge management. Persons involved in the process of assembly system development require a deep knowledge on the product to be produced as well as on the assembly system and its production processes and production resources. Given restrictions like structural conditions, the legal framework and others have also to be taken into account. Changing one element in the system is potentially affecting other system elements. For that reason, assembly system design is a recursive process, integrating the product, the production processes, the production resources and given restrictions (see Figure 2).

Almost each assembly system is a new project for the manufacturer. Correspondingly, project folders for each project are created on the servers. If many assembly systems already have been built in a company, then the number of folders and data is difficult to survey for an individual person. Particularly new employees spend a lot of time searching for design data of already created concepts. If a previously created concept or a drawn part could be used in another project, the employee has to know in which project folder the required file is stored or he/she searches extensively for it. New employees do not have detailed knowledge about past projects, the challenges, built in parts, and so on. Therefore, these employees do not have the opportunity to search for specific concepts. Especially since file names are not always meaningful. However, due to their lack of experience, new employees need more and structured information about completed projects, to prevent a re-development of already existing concepts.

Although the number of features of an assembly system increased over the last years, customers of special machinery are demanding ever shorter delivery times [3] because the

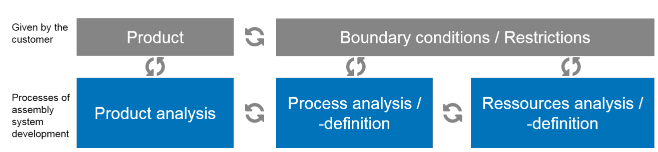

Figure 2. Process elements of assembly system design.

time-to-market for products with short product life cycles is decisive for the market success of the product. In order to keep the time-to-market as short as possible, special machinery is ordered at an early stage of product development. With completion of the product development, the machine shall be available for production [4].

On the one hand, simultaneous development of the product and the special machinery offers potential for improving quality, reducing costs and reducing the time to market [5][6]; on the other hand, there are also disadvantages associated with simultaneous development. In the course of product development, there is a large number of changes in product design. Some of these design changes necessitate a design change of the special machinery. Another disadvantage is the increased coordination effort for the communication of product design changes and the resulting impact on the system, on costs and on the schedule [4].

To guarantee a uniform level of knowledge amongst all team members, all relevant changes to the product have be communicated quickly and comprehensibly. This requires a frequent exchange of data and knowledge between the project partners. As schematically shown in Figure 3, there is a multitude of information flows amongst the project partners. The provision of the latest product data from the customer to the system manufacturer is often not immediately carried out after a change was made.

After receiving information about product changes, the product manager coordinates the incoming requests and assigns tasks to persons concerned. This procedure leads to long information transfer times and binds personnel capacity.

For a successful simultaneous product and assembly system development process, a common understanding of the product as well as of the assembly system, concerted actions and sharing of information between the right people at the right time is crucial [7]. In direct communication at meetings or telephone conferences, communication is hampered by a lack of common understanding of the

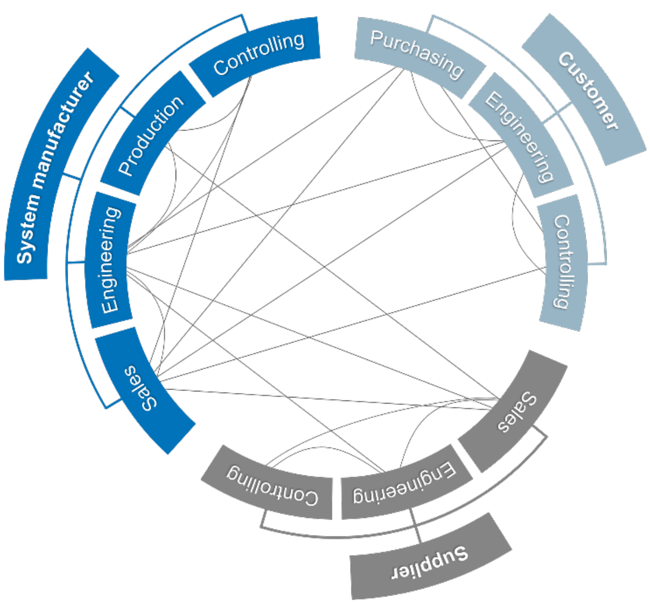

Figure 3. Information flows between the involved parties.

product, the processes and resources and their interdependencies. Especially people without profound technical knowledge have difficulties understanding the structure and relationships of the interconnected system elements. Even for experts, communication is susceptible to errors since terms for the same component differ from company to company.

Inefficient communication between the project partners and suboptimal knowledge management within the company leads to unnecessary work. For companies, efficient communication and processing of information is vital, as the available personnel capacity is scarce and expensive due to a shortage of skilled workers [8][9]. Another reason for the need of an efficient knowledge management is the competition between the companies. Thus, efficient order processing and a shorter delivery time compared to the competitors can generate a competitive advantage. Because of this, a concept that allows simple, transparent and media-break-free communication amongst all parties as well as an efficient knowledge management for small and medium-sized companies is presented.

The key contributions of this work are the following: (i) schematic visualization of the assembly system to support better understanding; (ii) semantic description of assembly system elements and associated files beneficial to ease the reuse of available knowledge; (iii) improved collaboration through communication and annotation tools.

The paper is structured as follows: In Section II the state of the art of the key subjects is shown. Section III introduces the methodology and its elements. Section IV concludes the paper and gives a prospect on future works.

II. STATE OF THE ART

Design and construction of assembly systems involve a holistic consideration of several research areas. The analysis of the literature focuses on the three main topics: assembly system design, simultaneous/collaborative engineering and knowledge management. Due to the wide scope of each subject area, the state of the art is presented separately for each subject area.

A. *Assembly System Design*

There are different models, procedures and methodologies of the assembly system design process. The product is the starting point for the planning method proposed by Müller [10]. A process chain is derived from structure of the product, the geometric characteristics of its parts and their type of connection. With knowledge about the product and the necessary processes for product assembly, suitable production resources will be determined. The dependencies between product, process and production resources are also taken into account in the process of assembly system design [10]. This concept is taken up by Eilers [11] and extended by a methodology for designing multi-variant production lines. Kluge [12] focuses on the capabilities of production resources, the consideration of different quantity scenarios and their influence on the assembly system. Konold and Reger [13] divide the process of assembly system design into the five phases: problem definition, rough design, detailed design, realization and production start-up. A review of the outcomes at the end of each phase should protect against misplanning and malinvestments. In literature, further methods for assembly system design can be found, differing in procedure and focus [14]-[17]. The examined methods focusing on assembly system design, the topics cooperation and knowledge management are only considered marginally.

B. *Simultaneous, concurrent and collaborative Engineering*

Product development as well as assembly system development takes place in teams with people from different disciplines. This collaboration has been explored for several decades, over time this research has been dubbed differently. Therefore, the terms simultaneous engineering and concurrent engineering are synonyms. The term collaborative engineering is intended to clarify the integration of different subject areas and engineering disciplines [18]. A clear demarcation of the terms is not possible because each author has another focus. Thus, there are many overlaps, since the basic elements of concurrent engineering, parallel workflows, development teams, early integration of all parties [19], for collaborative engineering also applies [20][21]. In the following, for simplification and due to its broader scope, only the term collaborative engineering is used.

In literature, a multitude of methods and concepts for collaborative engineering is presented [5][21]-[24]. Kamrani [21] introduces seven principles for a collaborative development of a product and names the faculties of a collaborative team. He also emphasizes the importance of knowledge management and communication in a collaborative engineering team. The presented communication tool allows the exchange of files, direct communication between the involved parties is not intended. Mas et al. [25][26] addresses the importance of communication, he notes that even in big companies, over the wall communication is practiced. In order to solve this problem, he proposes to expand the digital mockup of a product by production equipment so that a common visualization of the product and production equipment is possible. Several tools are available on the market, supporting collaborative engineering and teamwork [27]. Wognum [18] notes that despite the variety of tools and methods that promise to support collaborative engineering, these systems are not sufficiently developed to cover all the needs. In particular, classical product lifecycle management systems (PLM) do not meet the requirements of collaborative engineering [25].

C. *Knowledge Management*

The term knowledge management summarizes the ability to identify, store and retrieve knowledge. For a successful knowledge management system in companies there has to be understood which information and knowledge is important for the company, which goals are pursued and which challenges have to be solved [28]. Amongst others, the most important challenges for SME is the rapid integration of new employees, the use of existing knowledge, the transfer of knowledge across projects, as well as a consistent documentation over the whole product lifecycle [29]. Anderl [30] identifies documents that are relevant to each phase of the product lifecycle and highlights the need for cross-disciplinary knowledge sharing. Another important success factor for companies is to empower the employees to access the existing knowledge of the company [31]. Different knowledge management systems are established in companies. Products like Wikis, document management tools, blogs, groupware systems, forums, etc. are used for knowledge management [32]-[34]. Depending on the used system, the access to certain information is difficult because of missing possibilities to cross-link information stored in different systems [3]. In particular, systems, tools and methodologies for knowledge management, fitting to the needs of SME are poorly understood [35].

III. METHOD

The deep process analysis showed the major issues during assembly system development. Based on these results, a method was developed, which meets the special requirements for a simultaneous development process of a product and an assembly system. The focus of the developed method is to support the design of assembly systems, to improve information exchange and communication as well as knowledge management. The functions and modules resulting from the defined focus are shown in Figure 4.

The developed method has to be transferred in a software application that supports all parties in the structured development of assembly systems. The software application has a modular structure, so the functional scope can be expanded with new modules. Due to the special demands of assembly system manufactures, the software will be customized to their needs.

In-house developments and Open Source software modules offer comprehensive possibilities for adapting

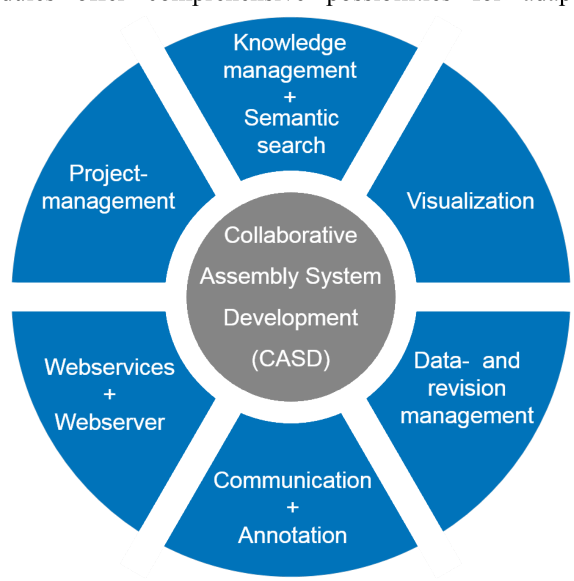

Figure 4. Modules and functions of the methodology for assisted assembly system development.

functions to the given requirements. The use of software without license costs helps to make the software attractive for SME also from a financial point of view. In the following the most important functions and modules of the Collaborative Assembly System Development (CASD) tool are described.

A. *Knowledge Management and Semantic Search*

The knowledge management module offers different tools. The most basic tool is the possibility to search file contents and to have the search results displayed. However, this method cannot be applied to files with content that is not textually searchable (e.g., images, CAD data, sketches, etc.). Therefore, metadata can be attached to describe the content. This metadata can be interpreted and searched by a computer as well as a human. Further information about the file can be written to this metadata. For example, there could be a link to the operating instructions or to the supplier's homepage in case of purchased parts.

A tag is a special variant of metadata, which describes the file content with keywords [36]. Semantic searches can be performed since metadata is attached to the files. The result of a semantic search shows not only results, containing the search term but also a context sensitive results are displayed [37]. For example, one wants to grab round rods with a diameter of 40 mm, one can search for files which are marked with the tags gripper jaw, round, rod, 40 mm. This allows easy access to files and knowledge that has been developed in previous projects.

Furthermore, existing knowledge can be enhanced by deploying queries analyzing the data, metadata, semantics and links. With this method, also new employees are able to get access to knowledge, which is already available on the servers. The description of the file contents with metadata enables the computer to find files with similar content. If the user searches for a concept or a drawing in order to adopt it to the current project, this function can be used to show files with similar metadata to the user. This helps to accelerate the process of familiarization as well as to increase the reuse rate of already available concepts and design data.

B. *Visualization*

In order to create a common understanding of the product, the processes, the resources and their interdependencies and dependencies, the assembly system is represented schematically by means of symbols (see Figure 5). Each part and subassembly of the product is represented by a symbol. In the first step, symbols of the product are positioned and connected with edges in accordance to the assembly sequence. In the next step, the assembly processes are defined and drawn into the schema. Processes are connected to the visualization of the assembly sequence, in order to show the match between the parts and the respective assembly processes. Finally, the production resources are defined, drawn in the visualization and connected with the processes. At the end, the whole system is visualized. The graph is showing all connections between the parts of the product, the assembly processes and the

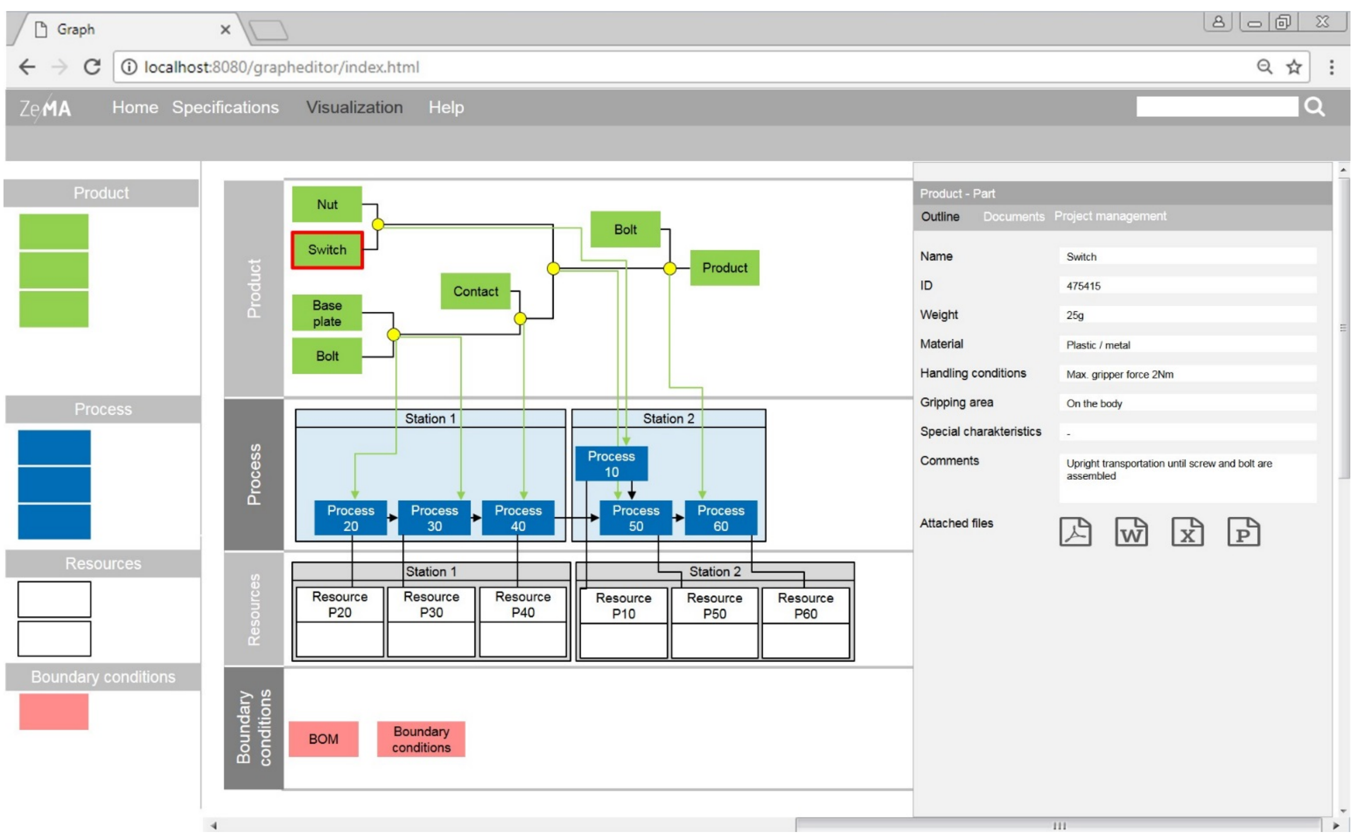

Figure 5. User interface of the visualization tool.

production resources. This graph can be used for further analysis and automatic optimization of the system.

Another result of the visualization is the uniform understanding of the product, processes and resources as well as the constraints for all parties involved. This contributes to an improvement in communication because a scheme of the assembly system is present to all parties and the named symbols allowing a precise communication. Influences on the assembly system design and the parts of the system, resulting from product changes, can be shown quickly and vividly to the customer.

Depending on the real world element, which is represented by a symbol, different input forms are available. For example, the parameters for a bolted connection can be entered in the input form that belongs to the process symbol bolting process. Furthermore, documents (e.g., operating instructions, CAD data, CE declarations of built-in products, etc.), annotations, process characteristics, etc. can be stored and assigned to the symbol using the input forms. The metadata collected in this way can also be used for semantic search.

By collecting all the information belonging to the object in one place, the user has the opportunity to get all important information about a specific object quickly and without any search effort. In addition, data entered in the input forms as well as the graph with its connections between the symbols is a further input to the knowledge management system. The knowledge about the connections of the symbols combined with the knowledge from the input forms can be used to check the validity of the system automatically.

C. Communication and Annotation

Assembly system development requires numerous documents. Among these documents, the specification sheet takes on a prominent role, since the system requirements and specifications are described from the customer's point of view with this individual document. The specification sheet is the basis for the creation of an assembly system, the assembly system manufacturer has to work on it intense. Different departments are working on the specification sheet simultaneously. Thus, at the assembly system manufacturer's site several copies of the specifications are edited. This means that ideas, solution concepts and knowledge are not transferred to other departments.

The annotation module provides the framework for working together on one single specification. Comments and information can be added to the digital version of the specification and are therefore visible to all authorized users. Annotations are individual-related, depending on the group a person belongs to, reading and writing of annotations is possible or not. Internal annotations are for example only visible for employees of the system manufacturer.

These annotations are connected to the correlating symbols in the visualization of the assembly system. Therefore, a quick switch between the specification and the visualization is possible. This helps during process definition as well as in the case of changes in the specifications.

The method allows the integration of several persons with different tasks in the project as well as non-project experts to solve problems even if they work with a time shift. In addition, forums offer the opportunity for transparent and open communication. Persons in charge kept up to date about the current development and discussions by a RSS feed. The communication module enables an easier more transparent and quick exchange of data and information, leading to a better collaboration of the parties and better project results.

D. Data Management and Revision Management

During assembly system development, many files are created and changed over time. This is especially common with CAD design data. In order to work on the right files, for project participants it is essential to recognize the latest version of a file. In particular, this is important when multiple people are working on one file. The file management is supported by a document management system, which is adapted for the specific requirements of the collaborative assembly system development process. This tool offers the opportunity for revision management and the attachment of metadata to the files. Documents can be identified via a unique identification number. This helps to connect the documents to a symbol in the visualization and supports therefore a speedier access on the document. Data access management is integrated in the document management system. Every user is assigned to one or more user groups. For each folder with all its documents or if necessary for each document the rights (read, write, delete) are defined for each user group. This avoids unauthorized access to sensitive information like cost calculations.

E. Project Management

The visualization offers also a feature for project management tasks. Data that is recorded with the input forms can also be used for project management. For instance start and end dates for the execution of tasks can be defined. After the user confirms the start or completion of a task, the color of the task changes. An automatically generated gant chart can be used to create an overview of the tasks to be performed and used for scheduling. Work orders with a detailed description of the task can be assigned to a person and followed up. The project manager gets an outline of pending, started and completed work orders. With this information he/she can track the time course of the project. The knowledge of how the system elements are connected with each other, enables the project manager to identify persons to be informed about a specific product change. If the company has already installed a project management software, all the recorded information can be exported to JSON file. This file can converted into the data format of the available project management software and imported then.

F. Web Services and Web Server

The backbone of the platform is a web server that manages the users' requests and assembles the individual software modules into one application. A web based software design allows the use of Open Source web tools, which are made for social media and web communication. In order to keep the organizational efforts, for the management of the personalized access to the system, little there will be a user management with predefined user groups. The web-based concept allows to run the system on premise as well as in a cloud, depending on the strategy and the IT infrastructure of the company.

IV. Conclusion

In this article, the need for a holistic treatment of knowledge management and communication during product and assembly system development is shown. From the findings of the deep analysis of processes, communication and knowledge management during assembly system development, the requirements and modules for the method could be derived. Through the visualization of the assembly system by a schematic representation a common understanding of the system is created. The graph which is created in the visualization tool shows the connections of product parts, processes and production resources and allows a direct identification of affected persons, processes and resources in case of product changes.

Easy access to already existing data can be achieved with the knowledge management module and its ability to perform semantic searches. Thereby, the training period for new employees can be reduced. By linking information and files using metadata, contents of files like CAD-drawings or images are getting accessible to the user and the computer.

Transparent communication helps to keep every team member on the same level of knowledge and thus better teamwork is supported. The project manager is able to follow up the progress of the project by using the project management module.

Modules as the visualization tool, the project management tool and the web server have already been implemented. As the project progresses, the graph analyzing software as well as the document management software will be connected to the visualization tool by a bidirectional interface. Since graph analysis as well as document management software is available on the market, we will revert to an already implemented and tested product. Finally, the method and the software will be tested with different user groups.

Overall, a method for communication and knowledge management, which meets the needs of assembly system manufacturers and their clients, was developed and briefly presented.

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References

[1] R. Müller, J. Eilers, L. Hermanns, and R. Gerdes, „Model-supported buildability check during assembly planing, increasing planing accurancy for the integration of variants,“ in „wt Werkstattstechnik online,“ vol. 9, pp. 253-260, May 2017.

[2] S. Poeschl, F. Wirth, and T. Bauernhansl, „Situation-based Methodology for Planning the Commissioning of Special Machinery using Bayesian Networks,” in “Factories of the Future in the digital environment - Proceedings of the 49th CIRP Conference on Manufacturing Systems,” vol. 57, pp. 247-252, ISSN: 2212-8271, 2016.

[3] U. Sendler, „Boundless industry 4.0,“ Springer Vieweg, Berlin Heidelberg, vol. 1, pp. 213, ISBN: 9783662482780, 2016.

[4] R. Müller et al., „Communication during assembly system development, platform to support the communication between costumer and assembly system manufacturer,“ in „wt Werkstattstechnik online,“ vol. 9, pp. 647-651, Okt. 2017.

[5] W. Eversheim, W. Bochtler, and L. Laufenberg, „Simultaneous Engineering – Industry experience for the industry,“ Springer, Berlin, vol. 1, pp. 15, ISBN: 9783642789182, 1995.

[6] M. Weck, W. Eversheim, and W. König, „ Production Engineering: The Competitve Edge,“ Butterworth Heinemann, vol. 1, pp. 65, ISBN: 9781483102122, 1991.

[7] D. Dixius, „Simultaneous project organization: A guideline for project work in simultaneous engineering,“ Springer, Berlin Heidelberg, vol. 1, pp. 177, ISBN: 9783642589768, 1998.

[8] PricewaterhouseCoopers GmbH, „Utilization on the limit: skilled workers in mechanical engineering are becoming scarce,“ Available rom: https://www.pwc.de/de/pressemitteilungen/2017/auslastung-am-limit-fachkraefte-im-maschinenbau-werden-knapp.html, Retrieved: February, 2018.

[9] K. Suder et al., „Competitive factor professionals, Strategies for Germany's companies,“ McKinsey Deutschland, pp. 39, 2011.

[10] J. Feldhusen et al., „Pahl/Beitz Design theory methods and application of successful product development,“ Springer Vieweg, vol. 8, pp. 702-725, ISBN: 9783642295690, 2013.

[11] J. Eilers, „Methodology for planning scalable and reconfigurable assembly systems,“ Apprimus, ISBN: 9783863592950, 2014.

[12] S. Kluge, “ Methodology for the ability-based planning of modular assembly systems,“ Jost-Jetter, ISBN: 9783939890812, 2011.

[13] P. Konold and H. Reger, „Practice of assembly technology Product design, planning, system design,“ Springer-Vieweg, pp. 32-75, ISBN: 9783663016090, 2003.

[14] B. Lotter and H. Wiendahl, „Assembly in industrial production: A manual for the practice,“ Springer-Vieweg, ISBN: 9783642290619, 2012.

[15] H. Bullinger, D. Ammer, K. Dungs, U. Seidel, and B. Weller, „Systematic assembly planning,“ Carl Hanser, ISBN: 3446146067, 1986.

[16] B. Rekiek and A. Delchambre, „Assembly Line Design: The Balancing of Mixed-Model Hybrid Assembly Lines with Genetic Algorithms,” Springer, ISBN: 9781846281143, 2006.

[17] N. Thomopoulos, “Assembly Line Planning and Control,” Springer, ISBN 9783319013992, 2014.

[18] N. Wognum and J. Trienekens, “The System of Concurrent Engineering,” in “Concurrent Engineering in the 21st Century Foundations, Developments and Challenges,” Springer, vol. 1, pp. 21-50, ISBN: 9783319137766, 2015.

[19] X. Koufteros, M. Vonderembse, and W. Doll, „Concurrent engineering and its consequences,” in “Journal of Operations Management,” vol. 19, pp. 97–115, ISSN: 0272-6963, 2001.

[20] S. Willaerta, R. de Graafb, and S. Minderhoudc, „Collaborative engineering: A case study of Concurrent Engineering in a wider context,” in “Journal of Engineering

and Technology Management," Elsevier, vol. 15, pp. 87-109, ISSN: 0923-4748, 1998.

[21] K. Kamrani, "Collaborative Design Approach in Product Design and Development," in "Collaborative Engineering Theory and Practice," Springer, vol. 1, pp. 1-18, ISBN: 9780387473215, 2008.

[22] J. Leimeister, "Collaboration Engineering: Systematically develop and execute IT-supported collaboration processes," Springer Gabler, vol. 1, ISBN: 9783642208911, 2014.

[23] J. Krottmaier, " Simultaneous Engineering Guide: Short Development times Low Costs High Quality," Springer, vol. 1, ISBN: 9783642793813, 1995.

[24] H. Bullinger and J. Warschat, „Concurrent Simultaneous Engineering Systems: The Way to Successful Product Development," Springer Science & Business Media, vol. 1, ISBN: 9781447114772, 1995.

[25] F. Mas, J. Menéndez et al., "Design Within Complex Environments: Collaborative Engineering in the Aerospace Industry," in "Information System Development, Improving Enterprise Communication," Springer, vol. 1, pp. 197 - 205, ISBN: 9783319072159, 2014.

[26] F. Mas, J. Menéndez, and M. Oliva, J. Rios, "Collaborative Engineering: an Airbus case study," at "Procedia Engineering, The Manufacturing Engineering Society International Conference, MESIC 2013" vol. 63, pp. 336 – 345, ISSN: 1877-7058, 2013.

[27] R. Damgrave and D. Lutters, "Multi-user Collaborative Design Tools for Use in Product Development," in "Global Product Development Proceedings of the 20th CIRP Design Conference," Springer vol. 20, pp.227-236, ISBN: 9783642159732, 2011.

[28] D. Olson, "Descriptive Data Mining," Springer, vol.1, pp.1-7, ISBN: 9789811033407, 2017.

[29] R. Orth, S. Voigt, and I. Kohl, " Practice Guide Knowledge Management, Implement Process-Based Knowledge Management Using the ProWis Approach," Fraunhofer, vol. 1, pp. 7, ISBN: 9783839603062, 2011.

[30] R. Anderl and R. Deger, „The role of consistent documentation of mechatronic products as a success factor for quality and customer satisfaction," research study, Technische Universität Darmstadt, pp. 27, 2008.

[31] H. Kohl, K. Mertins, and H. Seidel „Knowledge Management in SMEs: Basics - Solutions - Practical Examples," Springer, vol. 1, pp. 9-18, ISBN: 9783662492208, 2016.

[32] F. Kramer et al., " Computer-Supported Knowledge Management in SME -A Combined Qualitative Analysis-," in "Proceedings of the 50th Hawaii International Conference on System Sciences," pp. 4567-4576, ISBN: 9780998133102, 2017.

[33] P. Hentsch, " Development of assembly systems for varied precision engineering products," pp. 119-122, 2014.

[34] R. Cerchione and E. Esposito, "Using knowledge management systems: A taxonomy of SME strategies," in "International Journal of Information Management," vol. 37, pp. 1551-1562, 2017.

[35] I. Ul Haq et al., "Product to process lifecycle management in assembly automation systems," in "Proceedings of the 7th CIRP International Conference on Digital Enterprise Technology," pp. 1-11, 2011.

[36] H. Tipton, M. Krause, "Information Security Management Handbook," Auerbach Publications, vol. 5, pp. 1094, ISBN: 9780203325438, 2003.

[37] G. Bruno, "Product Knowledge Management in Small Manufacturing Enterprises," in "Knowledge Management Initiatives and Strategies in Small and Medium Enterprises," IGI Global, vol. 1, pp. 157-180, ISBN: 9781522516439, 2016.