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Product Data Management in the Context of Industry 4.0

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ABSTRACT

Industry 4.0, known as the fourth industrial revolution, generates great potential for self-organized, networked products. Industry 4.0 products have the ability to detect the environmental conditions and are enabled to communicate with each other. They collect lifecycle data, verify information and transfer them back to the product development. The information are used to create a new product generation. Product Data Management Systems (PDM) are used conventionally during the product development phase. In this paper the requirements of Industry 4.0 products are analyzed for PDM Systems. An analysis of six PDM Systems with the greatest market share are provided. At the example of a torch it is demonstrated how a PDM Systems is used to develop and manage the data of an Industry 4.0 product.

Index Terms – Product Data Management, Industry 4.0, Technical Inheritance, Smart Products

1. INTRODUCTION

Nowadays, product developers are working in a dynamic and digitized time, where information about technical products and components can be collected and deployed [1]. Industry 4.0 is associated with intelligent products, which provide internet-based services and have the ability to communicate [2]. Therefore physical hardware components are connected with software to achieve a significant additional benefit for the costumers [3]. During the development of such new products the amount of data and information increase significantly, but new developments can be derived on the basis of existing information, designs and solutions [4].
Since the 1980s, Product Data Management systems are used in the product development for saving, managing and providing product models and information are State-of-the-art [5]. These systems focus on the management of product models, product structure, documents and development relevant information [6] [7]. For a targeted and efficient work in the product development, the product information need to be managed, structured, standardized and can be used to develop an adapted next product generation. The concept for a product generation development, based on the feedback of the lifecycle experience and information, is called Technical Inheritance [8] [9].
The challenging estimation of product data management and structuring for Industry 4.0 are rarely describe in literature. This paper examine the question, if a PDM System is suitable for the development of products within Industry 4.0 under the aspect of Technical Inheritance to provide information to create a new product. Initially in section 2 the State-of-the Art for Industry 4.0, Technical Inheritance and PDM Systems is shown. In section 3 the approach for structuring Industry 4.0 product information with PDM Systems is introduced. Section 4 contains a case study that shows an exemplary application. The final section contains the summary of the contribution and shows further research requirements.

2. Products in Context of Industry 4.0

2.1 Industry 4.0

Industry 4.0, known as the fourth revolution, was proclaimed by the German federal government on the Hannover Messe in 2011. As a synonym for Industry 4.0 the term Smart Factory is used [3]. Both define a self-organized, decentralized, networked production with components, which communicate with each other and the machine tools and find their way through the production autonomously. Nowadays Industry 4.0 does not only obtain the production, but also the complete lifecycle and its phases [10]. Industry 4.0 products are not always developed completely new, but existing products are expanded by an "intelligence", e.g. intelligent drill bit in the industrial sector or watches and toothbrushes in the commercial sector [11]. These products can be divided in four different categories [3], depicted in Fig. 1:

- Mechatronic Products (MP)
  Mechatronic Products owns sensors, actuator, which transforms the measured physical value into an electronic signal, and data processing.
- Intelligent Mechatronic Products (IMP)
  The basis is a MP, which is expanded with processors and storage components.
- Cyber-Physical Systems (CPS)
  IMPs expanded with the ability to communicate are Cyber-Physical Systems. CPS are networked and exchange data with each other or the environment.
- Smart Products (SP)
  Additional internet based services, so called Smart Services, are combined with CPS and result in Smart Products. Smart Services are assembled by evaluation, analysis and projection of the production and usage data.

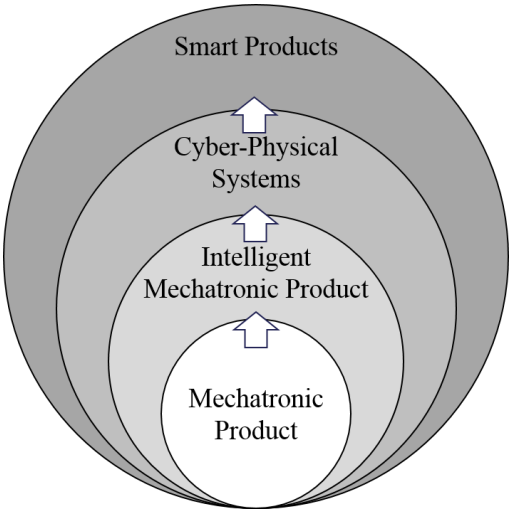

Fig. 1: Categories of Mechatronic Products to Smart Products [3]

2.2 Technical Inheritance

Products are enabled to deliver information about themselves and their environment during their lifecycle with Industry 4.0. These product information are used for the development of a

new product generation through Technical Inheritance. The process for an intergenerational product development with Technical Inheritance is depicted in Fig. 2.

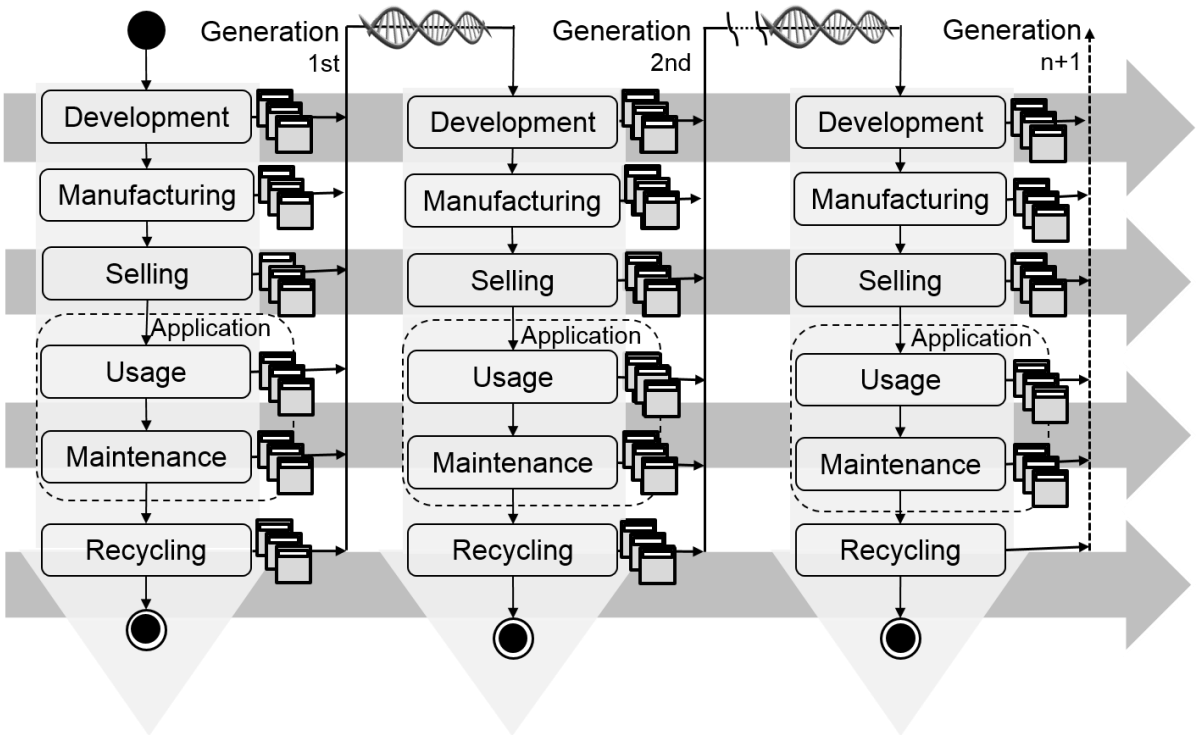

Fig. 2: Intergenerational development process in Technical Inheritance [12]

Technical Inheritance is defined as a transfer of assembled and verified information from the product's lifecycle and its application to the next product generation [8]. For the proceeding of for an intergenerational development is divided into four steps. First, die needed lifecycle information have to be identified. Second, the monitoring strategy has to be implemented. Third, a Data Mining Method has to be realized and finally the information have to be transferred back to the development.

2.3 Product Data Management and Product Lifecycle Management

The development of product generation requires consistent, structured and continuously information. It is provided to the developer as a tool in product creation and serves as an integration platform for various development systems (e.g. CAX-Systems or text processing Systems) [8]. It is used for the management of computer-generated 3D models, drawings and further development and product relevant documents [5]. The basic functions of PDM technologies are divided in five sections [4] [5] [6] [13] [14]:

- Document Management
  Creation, revision, changing, control, allocation and archiving of documents are organized by the document management function.
- Product Structure Management
  Relationships (belongs to or consists of) between single components and assemblies are built in a hierarchically structure

- Classification
  Classification systems are numeric systems that are used to arrange objects according to their features, which describe and difference them from others. With classification systems the identification of objects is possible.
- Workflow Management
  Business processes and workflows can be created, controlled and represented with in PDM system.
- Project Management
  Timetables, activities and project management information, e.g. project specific roles, mile stones or stakeholders, are administrated in the project management.

A PDM System is a part within a Product Lifecycle Management (PLM) concept to integrate all lifecycle phases in one continuous system, where different system components describe the product life [6] [8] [15] [16] [17]. An overview over the different lifecycle phases and their software applications are depicted in Fig. 3. Although PLM is understood as a concept in literature, commercial PLM-Software is provided. PLM Software functions are expanded to include considerations of the product's lifecycle, so that PLM came to be founded on the basis of PDM [6]. To complete the lifecycle concept the PLM Software can be supplemented with additional modules, e.g. for services, manufacturing or costumer relationships, from the provider.

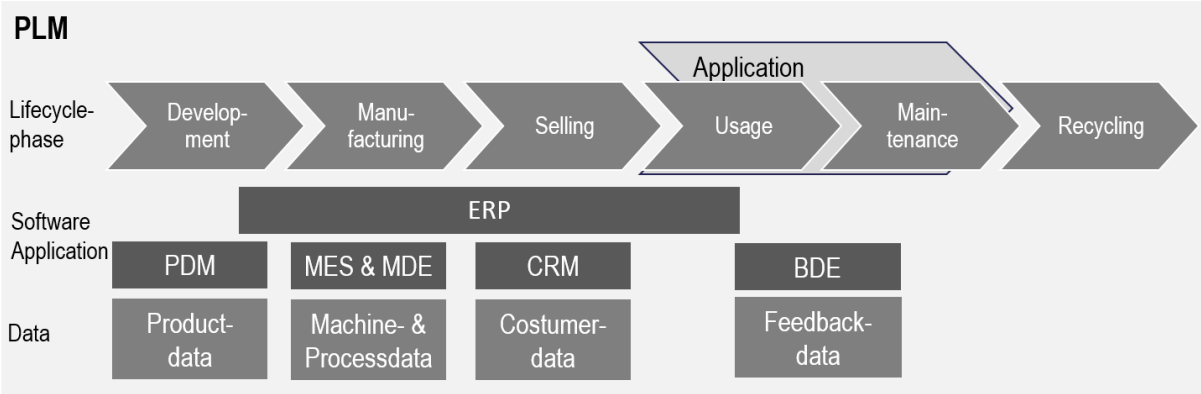

Fig. 3: PDM systems in the context of PLM

In this way individual PLM solutions are compiled, to serve the company's needs with one software. On the other hand, the single software applications for a particular lifecycle phase can also be connected with different interfaces. So an extensive PLM Software is not needed and every lifecycle phase has its own software solution.

3. PDM for Industry 4.0

PDM Systems are focused on the management of data during the development phase, but Industry 4.0 products require different point of view. The challenge is to manage all different aspects and the relevant data in one system to provide a continuous data source about current and previous product generations for the product developer. The use of feedback information is an integral part to develop Industry 4.0 products. Consequently an expansions of a PLM concept is necessary [2]. For this reason knowledge areas are important for Industry 4.0 products and their requirements for the data management during the development phase have

to be identified. Afterwards different PDM Systems need to be reviewed with these requirements and investigated for their suitability for the development of Industry 4.0 products.

Mechatronic products are the basis within Industry 4.0 and can be expanded to a Smart Product. The development of IMPs are added with processors and data processing. For the development of CPS, IMP are expanded with information and communication technology. Moreover internet based services need to be available for Smart Products. Additional to the mechanical and electronical knowledge areas, informatics and software knowledge areas are needed. Service engineering is also a knowledge area, which needs to be considered and integrated during the product development.
IMPs, CPSs and SPs have in common, that the development phase are expanded by new knowledge areas. Hence, the interdisciplinary development is a significant requirement, for which the possibilities need to be examined in a PDM System [3]. Furthermore the examination of access rights, project plan and workflows for a continuous development are necessary. A new product does not need to be developed completely new, rather than have to be adapted and expanded by a previous generation Therefore it is significant to relay on information about the previous generation for a gapless and efficient development of Industry 4.0 products. For the new requirements set by the development of Industry 4.0 products are investigated with six different PDM Systems with the greatest market share in 2016, listed in Tab. 1 [18].

Tab. 1. PDM Systems with the requirements of Industry 4.0 products

Provider	Autodesk	Dassault Systems	Oracle	PTC	SAP	Siemens
System Description	Autodesk Vault Professional	SolidWorks Enterprise PDM	Oracle Aglie	PTC Windchill PDMLink	SAP PDM	Teamcenter
Integration of different knowledge areas						
Mechanical Engineering	yes	yes	yes	yes	yes	yes
Electrical Engineering	yes	yes	yes	yes	yes	yes
Software Engineering	no	no	yes	yes	yes	yes
Service Engineering	no	no	no*	no*	no*	no*
Definition of access rights	yes	yes	yes	yes	yes	yes
Definition of Project Plans	no	no*	yes	no*	yes	yes
New and Adaption of Workflows	yes	yes	yes	yes	yes	yes
Examination and Release	-	-	yes	yes	yes	yes
Adaption and Enhancement of products and documents	yes	yes	yes	yes	yes	yes

*additional module from provider available

It is noticeable, that all PDM Systems conclude the mechanical and electrical engineering areas and can be seen as state of the art. Four of them include the support of software engineering, but not one concludes the service engineering. The systems of Oracle, PTC, SAP and Siemens can be complemented with additional modules from the producer for service engineering. Five

of six systems can define access rights, but just three of can define project plans and for two are additional modules available. Defining new workflows or adapt existing workflows can be done by every PDM System. The adaption and enhancement of products and documents is possible with every analyzed PDM System. By that the collected and verified data from the products can be returned to the PDM system to be available for the next generation with the meaning of Technical Inheritance.
The analysis shows that all the PDM systems support the state of the art functions, e.g. mechanical and electrical engineering or definition of access rights. Differences are in the integration of other engineering areas, e.g. software or service engineering. PDM Systems, which are extendible to other lifecycle phases, have additional modules to integrate these engineering areas and have a greater functions volume, so they define project plans and support examination and releases.

4. Application of the PDM System Autodesk Vault Professional for developing a Smart Product

To demonstrate the use of a PDM System for an Industry 4.0 product, a torch is applied as a demonstrator. The first torch generation owns two adjustments for the brightness and the light distribution can be adjusted with the slide of the reflector in the head unit. As depicted in Fig. 4 the torch has a designed for assembly product structure for the mechanical parts and is saved with the CAD Models in the PDM System Autodesk Vault Professional 2017. Next to the mechanical Bill of Material (BOM) is also a Bill of Material for electronic components. In this BOM all electronical components are listed, e.g. battery, cables, resistors or capacitor.

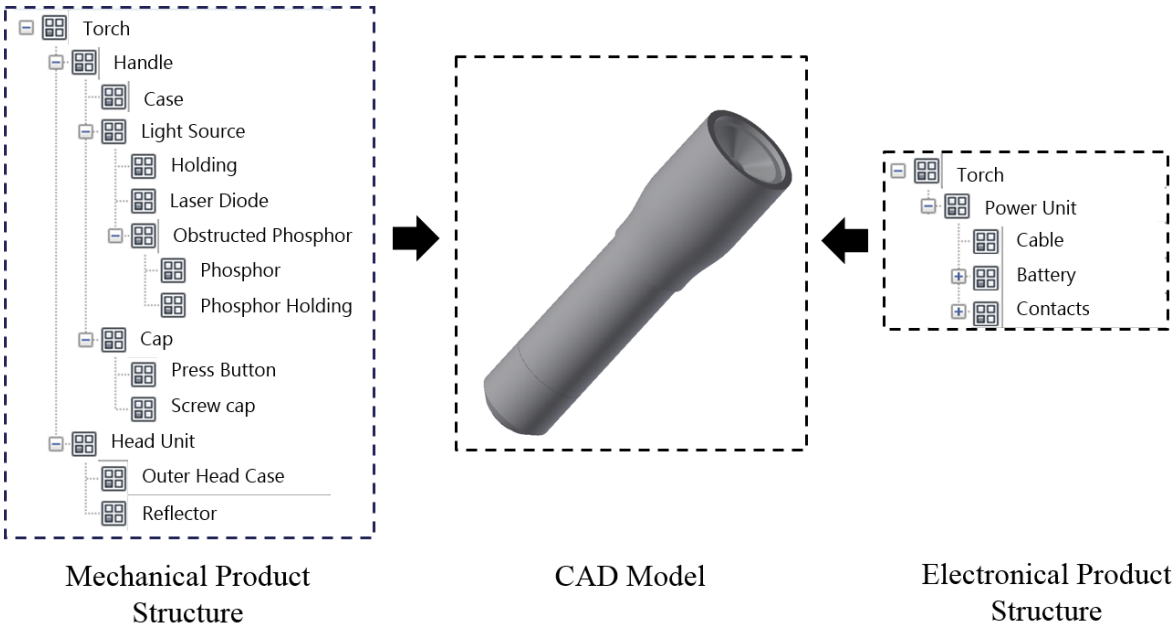

Fig. 4: Product structure and CAD Modell of the first torch generation

In the first step the new product properties have to be defined. The second torch generation has the ability to send its battery status to the producer for the analysis during usage. With these information about usage the torch can be better adapted to the user's behavior.
In the second step the needed extension have to be analyzed. The torch is expanded with a communication module to send usage data. The communication module shall be places inside the Cap and has to be powered. Its electric components, e.g. the receiver, the transmitter and the antenna, are listed in the E-BOM. In the third step the previous generation has to be

examined, to check, if components and CAD models can be adopted. Therefore the available space is examined. The old generation can be used to develop the new one. In Autodesk Vault Professional the first generation with its CAD models, product structure, drawings and documents is copied into a new project folder. In the next step the Screw Cap CAD model is expanded to hold the communication module. The product structure is complemented with the communication module and its components. Next to the mechanical engineering proceeds the electrical engineering. New electrical components are implemented in the E-BOM. Furthermore the communication module has to be programmed, so it can transfer the usage data. The program is developed with software engineering tools, e.g. LabView or Visual Studio. The program is added to the torch within the PDM system, although Autodesk Vault does not support the software engineering. For that purpose the torch is expanded with another position, the source code for the module, in the product structure, depicted in Fig. 5. In the final step the additional documents and drawing are adapted or generated. After releasing all production relevant data, they can be transferred to the next lifecycle phase.

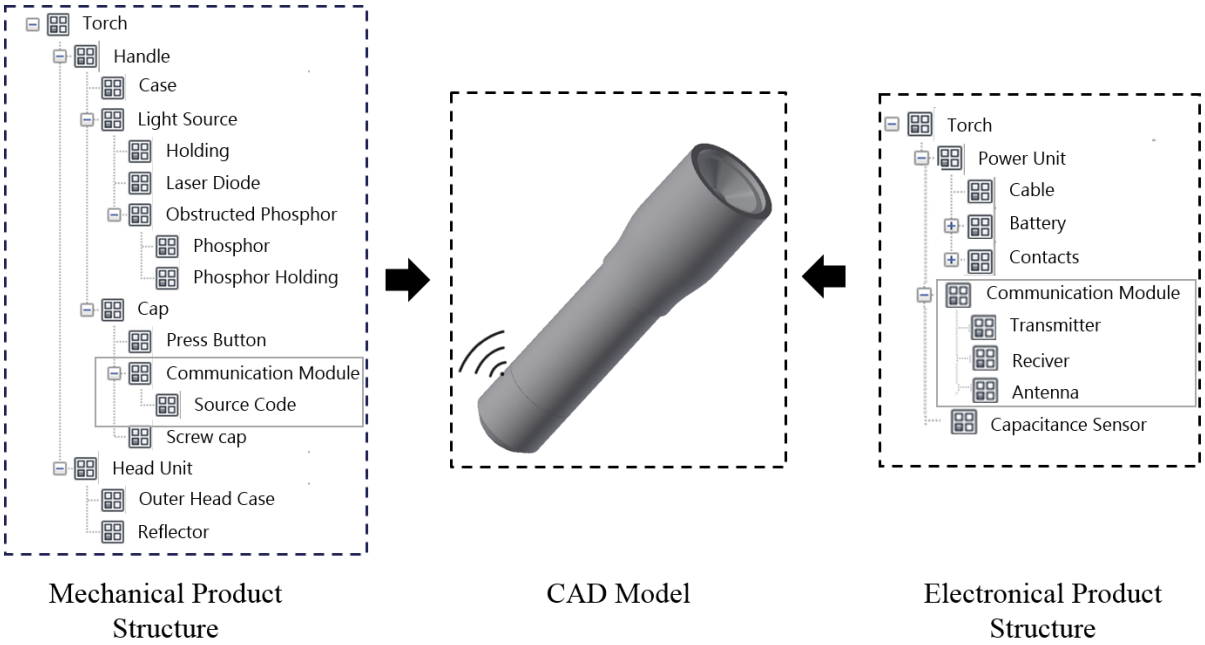

Fig. 5: Product Structures and CAD Model for the second torch generation

5. Conclusion

Industry 4.0 offers new possibilities for the production, but also for product development. With Industry 4.0 a product can be developed and offered with communication technology and with internet based services. Information about the product are generated and collected during the development phase and subsequent lifecycle phases. Therefore PDM Systems are used to manage and ensure accessibility to information for a further development.
The requirements of Industry 4.0 products to a PDM System are investigated on the six greatest systems on the market. The investigation has shown, that PDM Systems have different function volumes and can fulfill the requirements differently. Functions, which are not fulfilled by some systems, can be expanded by additional modules from the provider.

For a practical analysis of the suitability of a PDM-System for the development of Industry 4.0 products the case study was organized. Using the PDM System Autodesk Vault Professional 2017, the functions of the demonstrator are expanded with a communication module to transmit

usage data. In the next step the mechanical and electrical product structurs are expanded and implemented into the PDM system. It is shown how a communication module can be integrated to enable a torch to transmit its battery status.

For a continuous lifecycle management further investigations are necessary. In this course, various requirements have to be clarified. For example, the different interfaces between the software applications have to be investigated and the data exchanges between lifecycle phases. In addition the usage information preparation needs to be investigated and detailed to provide development relevant information for a product generation development.

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