Available online at www.sciencedirect.com

ScienceDirect

Procedia Technology 26 (2016) 199 – 206

Procedia Technology

3rd International Conference on System-integrated Intelligence: New Challenges for Product and Production Engineering, SysInt 2016

An Approach to describe Gentelligent Components in their Life Cycle

Roland Lachmayer[a], Iryna Mozgova[a], Wieben Scheidel[a]*

[a]Leibniz Universität Hannover, Institut für Produktentwicklung und Gerätebau, Welfengarten 1A, 30167 Hannover, Germany

Abstract

Information about products and their life cycle are often required for the product development and manufacturing process. So the application of life cycle data of smart products offers new opportunities to pass information to a new product generation. In the Collaborate Research Center (CRC) 653 smart products, so called “Gentelligent Components”, which collect information about themselves and from their life cycle and store it inherently, are developed. For structuring and standardization of the life cycle information a classification system is used. A classification system for gentelligent components has to consider aspects from the development, manufacturing and usage phases as well as the environment and also the remaining life cycle phase. Therefore different classification systems are compared to their suitability for gentelligent components. Based on the most suitable existing system an approach to describe gentelligent components in their life cycle is developed. The information from development and manufacturing as well as from the usage phase of components life cycle are considered. The resulted classification system is exemplified by a wheel carrier, one of the demonstrator of the CRC 653. The applied classification system shows how gentelligent components and their information can be structured and standardized.
© 2016 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the organizing committee of SysInt 2016

Keywords: Classification System; Life Cycle Information; Gentelligent Components

1. Introduction

The interest in and importance of Industry 4.0 raises continuously. This entails the possibility for today’s industry to observe the whole life cycle of a product. Information of a product, collected during its different life cycle phases, can be used to validate assumptions and make adjustments. The research and development of new products and production techniques is within the focus of the Collaborate Research Centre (CRC) 653 to develop components

* Corresponding author. Tel.:+49 511 762 4507; fax: +04 511 762 4506.
E-mail address: scheidel@ipeg.uni-hannover.de

2212-0173 © 2016 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the organizing committee of SysInt 2016
doi:10.1016/j.protcy.2016.08.027

with sensory features. These gentelligent components are able to recognize information about themselves and from their life cycle and to store it inherently. In this context a new approach called *Technical Inheritance* is developed [1]. The Technical Inheritance is the transfer of collected and verified information form the manufacturing and usage phase to the next adjustment [1,2].

The collected life cycle information has to be structured, unified and standardized for a feedback and processing in the development process. So it can be guaranteed, that an exchange between development, production and usage happens lossless. A classification system provides the necessary standardization and structuring. A significant feature of the classification system and its classification key is the repetition of characteristic features of the component, the production and the usage. Additional relevant information have to be included for the technical inheritance. Therefore different classification systems are investigated and compared for their ability for gentelligent components and technical inheritance. A suitable and modified classification system is demonstrated at the demonstrator of the CRC 653. It is adapted to the requirements and properties of a gentelligent component and its life cycle.

2. State of the art

Classification systems are numeric systems that are used to arrange objects according to their features, which describe and difference them from others [3]. They also refer to deposited product data, for example a strength value of the chosen material [4,5]. The benefit of using a classification system is a clarity, order and standardization of information.

Generally the classification systems are structured in three different ways. On the one hand systems with a hierarchic structure exists. Hence, all key digits are interdependent. At the other hand parallel respectively coordinated structured systems exist. Within this system the key digits are independent. At last systems exist with a hybrid structure. In this case are some key digits dependent from other key digits, but at the same time some key digits are independent [6].

According to a research five essential systems are investigated.

2.1. DIN 4000

First, in german speaking countries, the DIN 4000 is most common. It is a standardized system, which is constructed in four stages hierarchically. So-called component properties are classified, which describe components in the way they are presented to the viewer. Component properties are for example color, mass, thickness or total length [7].

2.2. Opitz-key

The Opitz-key is a classification system for components. It is used to create part family formation of objects from metal cutting processes and to search for part family members. The hybrid classification key consists of two parts. The primary part is the geometrical key that describes the geometry of the component. The second part is a supplementary key that contains necessary information, for example material and tolerance [8].

2.3. Zimmermann-key

The Zimmermann key is a classification system, also used to classify components. Like the Opitz key it contains also a geometric and a supplementary key. However, the Zimmermann key contains more key digits and is more accurate and detailed than the Opitz key [9].

2.4. Wiendahl-key

The Wiendahl classification system is used for the classification of assemblies. The system has a hybrid structure, in which the functions of the integrated components are sorted. Similar to the Opitz and Zimmermann systems the Wiendahl system contains a primary function key and a supplementary key [10].

2.5. E-Cl@ss

The hierarchical E-Cl@ss classification system has implemented the DIN 4000 and contains four stages with four key digits. It is used for technical and commercial products [4].

3. Comparison of the systems

The classification systems have to meet more demands for the technical inheritance, as they have until now. A suitable classification system for gentelligent components is flexible, integrates different areas of the product life cycle, but at the same time it is easy to use. Furthermore the classification system contains approaches of the technical inheritance itself and displaces the usage of the component. The five introduced classification systems are checked for the suitability and compared to requirements of the technical inheritance in Table 1.

Table 1. The Comparison of existing classification systems

Criteria	DIN 4000	Opitz	Zimmermann	Wiendahl	E-Class
Flexibility	0	+	-	-	+
Expandable for different areas	-	+	+	+	+
Integration of Gentelligence	-	+	+	+	-
Easy to use	+	+	-	+	+
Classification of the life cycle	-	-	-	-	-

Legend: + = Suitable; 0 = Neutral; - = Inapplicable

The comparison shows, none of the introduced systems meets all requirements. The most suitable classification system is the Opitz key to classify components and serves as basic concept. Corresponding adjustments and developments are made for the needed classification system.

4. Structure of a classification system for gentelligent components

Different requirements have to be considered for structuring a classification system for gentelligent components. In this case the requirements are flexibility, description of the development, manufacturing, environment, an easy way to use and relevant information about and for the technical inheritance.

It has to be considered, that every component is unique and collects during its usage phase unique (individual) information. So the classification key is divided in two parts. The first part is universal for all components of current generation and the second considers the individual information.

The single key digits from the first part have to be arranged and sorted so, that they consider the information from development and manufacturing phases and do not have to be changed during time and proceeding life cycle. The second key part includes the information about environment and the usage phase, which can change during time. An overview is depicted in Fig 1.

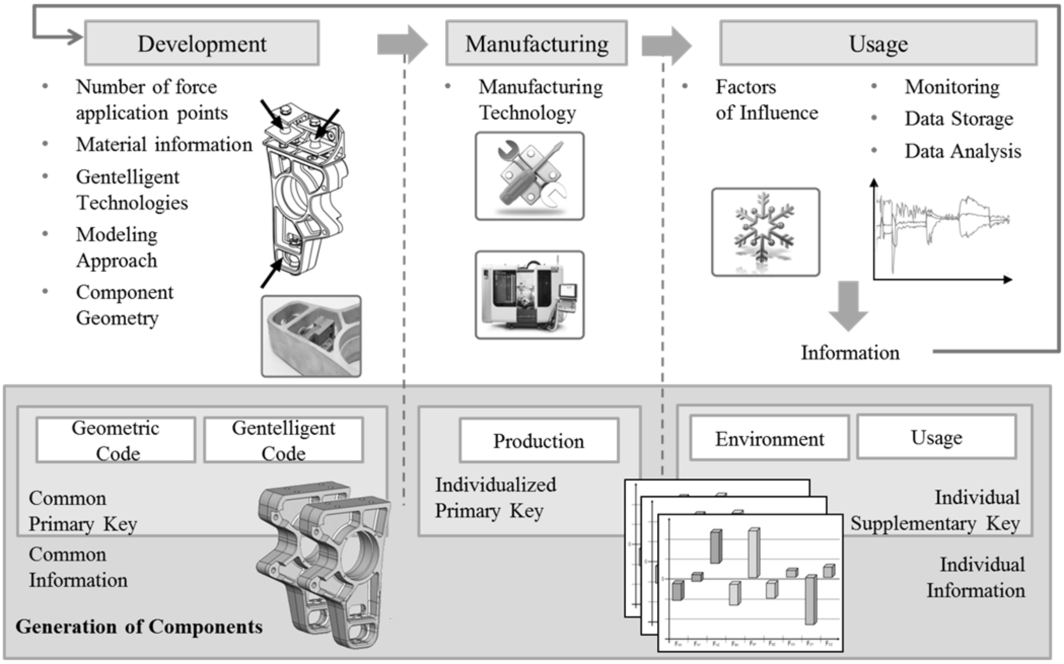

Fig.1. Differentiation between primary and supplementary key.

4.1. Primary key of the classification system

The primary key of the classification system is divided in the superior parts development and manufacturing, depicted in Fig 2. First, the development is divided in several areas. In the first instance the geometry is classified. Therefore the Opitz system is most suitable from all compared systems. First it is determined, if the component is rotationally symmetric or not. The next four key digits describe the outer shape, the inner shape, the surface machining and possible helping bore. From the sixth to the tenth digits the implementation of the gentelligence is classified. The gentelligence is ensured with sensor technology that is developed within the CRC 653. The component sensor technology can be differentiated in information contribution and information collection, which both are based on physical effects inside the component [10]. At first the information contribution is classified. The component sensor technology can be placed in the component and on the surface. In the next key digit the information collection is classified. Similar to the information contribution the sensor technology for information collection can be placed in or on the component. Some of the component sensor technology can be combined. The eighth key digit of the development area classifies the quantity of the measuring points. At last the material is classified in the ninth and tenth digit. To keep the opportunity to add more materials, which are not listed, a second digit is integrated. Firstly the material used for the sensor technology is considered. So the digits contain metastable austenitic steels, magnesium, aluminum and other materials. Furthermore nonferrous metals, cast iron or other steels can be selected.

The second superior area classifies the component’s manufacturing, depicted in Fig. 3. Therefore three key digits are existing. To use a standardized, accepted and known form for division of production processes, it is referenced to the German DIN 8580. So the main manufacturing processes are classified in forming, deforming, cutting, jointing, coating and changing of the material properties [11]. The second and third key digit includes the component’s primary post processing. Hence, each manufacturing process can also be used for post processing, so the manufacturing processes according to DIN 8580 are used for all three key digits. Additionally *no post processing* or *other post processing* can be selected.

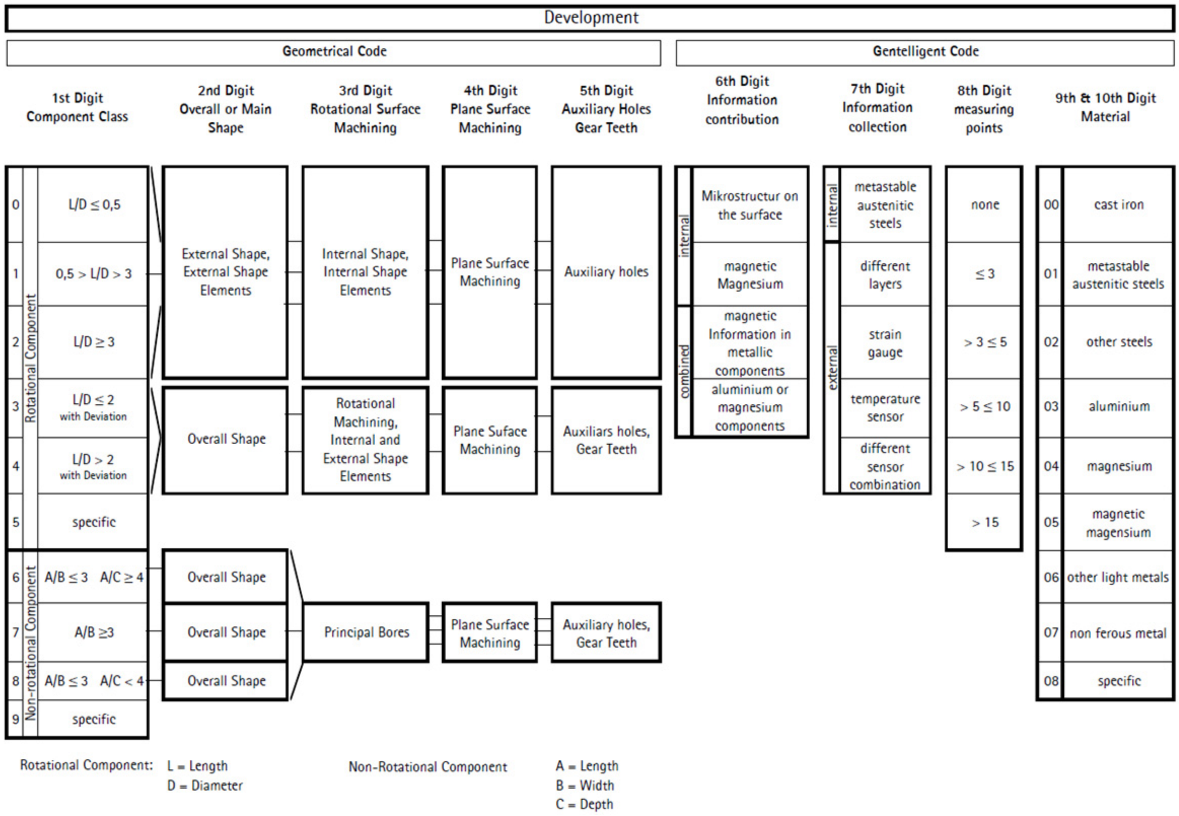

Fig.2. Simplified development key of the classification system.

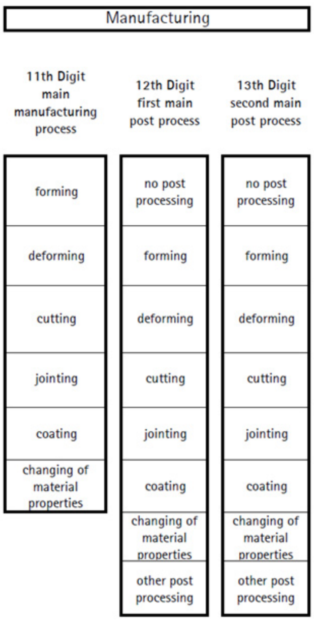

Fig.3. Simplified manufacturing key of the classification system.

4.2. Supplementary key of the classification system

This primary key represent the components development and manufacturing. The individual life cycles do not create individual keys until now. The next step is the development of a supplementary key, to record individual life cycles. The key digits are just used if necessary and contain component specific information. It is depicted in Fig. 3.

The first three digits classify the mechanical usage and mechanical strains. Therefore the usage and its different types of loads are classified. It is differentiated, if the component experiences mechanical static or mechanical dynamic loads. The mechanical strains are divides in tension stress, compressive stress, torsion, shear stress and shearing stress. A component can experience more than one mechanical strain, so this digit can be extended until all mechanical strains are considers. In Fig. 4 initially two digits are provided.

Next, the environment is classified, because components can be used in different environmental conditions. The atmospheric conditions, for example an atmosphere with high or low salinity, or the thermic, chemical, magnetic and electric conditions are considered. Therefore the maximal allowed usage temperature has to be deposited in a product data management system. The experienced temperature is compared with the deposited. So it can be determined if the temperature is fallen below, reached or passed the maximal allowed temperature.

To identify information directly for the technical inheritance, the supplementary key changes during the life cycle. Therefore the collected data during usage, measured with the sensor technology, are transformed with the help of a genetic algorithm to information [1]. The amount of the typical loads depend on the amount of force application points (m) and considered axes (n). So the exact amount of the typical loads are m · n digits. In the last two digits a global minimum and a global maximum is defined, which are not considered in the residual key but are necessary for the typical loads. These loads are the maximal and minimal load from all m · n measurements. In Fig. 4. the maximum and minimum are initially defined with 1000N and 4500N. The each typical loads has ten classes, which contain a width of 500N.

In addition to every digit in the supplementary key *no information* can be selected, if the sensor technology is not existing.

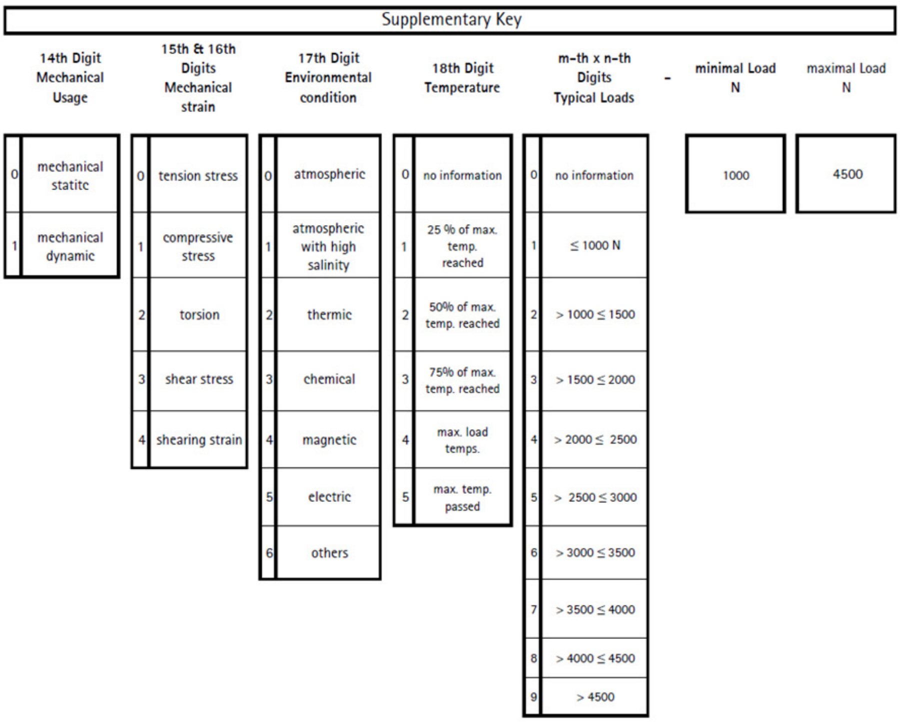

Fig. 4. Simplified supplementary key of the classification system.

The supplementary key is arranged in an open way. So different usage phases and life cycle can be considered and shown.

In this way a hybrid classification system is created, which classifies on the one hand the development and on the other hand the manufacturing, the environmental conditions and the life cycle. It can support the technical inheritance to create a new product generation. In the next step the classification system is demonstrated on one of the demonstrator of the CRC 653.

5. Example

The Formula Student race car of the Leibniz Universität Hannover represents one of the demonstrators of the CRC 653 [12]. To collect life cycle data, especially the applied loads, gentelligent technologies are integrated into wheel carrier. It is possible to measure the forces during a race with different techniques. Such information are used as basis for the development of the next product generation. To collect the life cycle information the wheel carrier has three develop relevant junction points, at which the forces are of particular interest [1]. At this junction points forces during the usage are collected with sensor technology and with a genetic algorithm the forces are transformed into loads. These forces are relevant for the next product generation. In Fig. 5 the forces at the junction points are depicted.

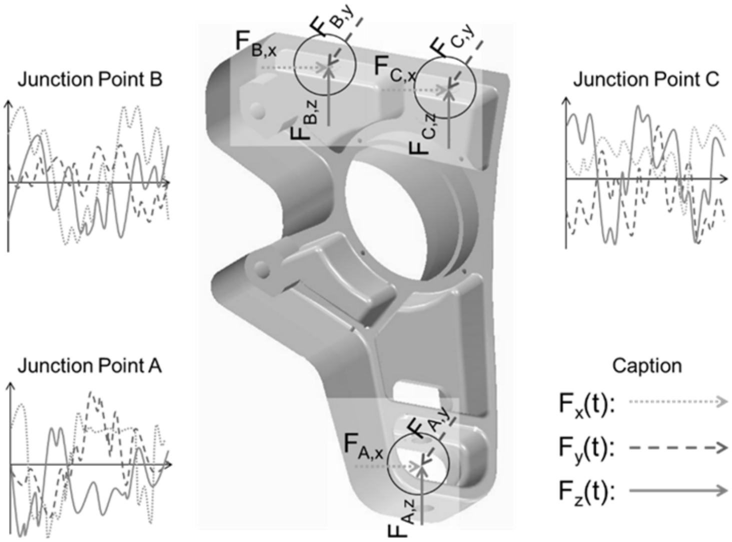

Fig. 5. Forces at the three junction points of the wheel carrier [1].

To use the classification system the geometry has to be analyzed first. The wheel carrier is a non-rotational component with length ratio of A/B≤3 and A/C≥4, which classifies it in class 6. It is a flat overall shape, so it classified in the class 6. As a principal bore the wheel carrier has one main bore in the center, which leads to class 2. It has opposite plane surfaces and two slits, which are classified with 44. For collecting information three stain gauges are used at three junction points in subproject N4. The demonstrator is made out of the aluminum alley AlSi7Mg. This results in a development key: 662440501.

The wheel carrier is made by casting. Afterwards it was just remachined. This results in a manufacturing key: 030. The complete primary key is: 662440501-030.

The supplementary key depends on the life cycle of the wheel carrier. During a race it is used mechanical dynamic and tension stress as well as compressive stress affect the wheel carrier. It is exposed to atmospheric conditions. A digit for the temperature is existing, but for the wheel carrier no temperature sensor is installed. The mechanical usage, mechanical strain, the environmental condition and temperature results in: 10100. The classification system receives with help of an algorithmic data feedback information about the typical loads from three force application points and three axes. So nine individual typical loads have to be classified. This results in the supplementary key for the loads: 666-789-877. The maximal and minimal loads limits are no part of the key. The complete supplementary key is: 10100-666-789-877.

The keys for development, manufacturing, environment and usage add up to the complete classification key: 662440501-030-10100-666-789-877.

6. Conclusion

The classification system shows how a gentelligent component and its life cycle is classified, so every relevant area is shown. Characteristic properties of the development, the manufacturing and usage phases are depicted. With this approach life cycle information can be used for the development of a new component generation and provides an overview about the current generation of components. The primary key of the classification system remains during the whole life cycle, the supplementary key changes with time and the component’s life cycle. Such approach causes standardization and structuring of the life cycle information.

As an application the classification system is specified for the CRC 653 and its demonstrator. To cover possible future gentelligent components and technologies, that are not included in the CRC 653, further investigations contain the aspects of openness and universal use of the classification system as well as loads ranges for the usage phase of the component’s life cycle.

Acknowledgements

The authors gratefully acknowledge the support from the Collaborative Research Center (CRC) 653 “Gentelligent Components in Their Lifecycle”, funded by the German Research Foundation (DFG).

References

[1] Lachmayer, R.; Mozgova, I.; Sauthoff, B.; Gottwald, P.; Evolutionary Approach for an Optimized Analysis of Product Life Cycle Data; 2nd International Conference on System-Integrated Intelligence; 2014

[2] Lachmayer, R.; Gottwald, P.; Integrated Development by the consideration of product experiences; Proceedings of the 10th International Workshop on Integrated Design Engineering; Magdeburg: Inst. Of Machine Design. Univ, 2015

[3] Holland, P.; Standring, P.M.; Long, H.; Mynors, D.J.; Feature extraction from STEP (ISO 10303) CAD drawing files for metalforming process selection in an integrated design system; Journal of Materials Processing Technology; p. 446-455; 2002

[4] Grabowski, H.; Lossack, S.; Weißkopft, J.: Datenmanagement in der Produktentwicklung; Carl Hanser Verlag München Wien; 2002

[5] DIN 4000 – 1 Sachmerkmal-Listen – Teil 1: Begriffe und Grundsätze

[6] Arnold, V.; Dettmering, H.; Engel, T.; Karcher, A.: Product Lifecycle Management beherrschen; Springer Verlag; 2011.

[7] Opitz, H.; Die richtige Sachnummer im Fertigungsbetrieb;Verlag W. Girardet Essen; 1971

[8] Zimmermann, D.; ZAFO – Eine allgemeine Formanordnung für Werksstücke; Technischer Verlag Günter Grossmann GmbH; Stuttgart – Vaihingen; 1967

[9] Wiendahl, H.; Methode zur Klassifizierung von produktunabhängigen Baugruppen; Beuth-Verlag GmbH; Berlin Köln Frankfurt am Main; 1973

[10] Gottwald, P.; Prozess einer generationsübergreifenden Produktentwicklung durch technische Vererbung; TEWISS – Technik und Wissen GmbH; 2016

[11] DIN 8580 – Fertigungsverfahren

[12] Denkena, B; Mörke, T; Krüger, M; Schmidt, J.; Bounjnah, H.; Meyer, J.; Gottwald, P.; Spitschan, B.; Winkens, M.; Development and first applications of gentelligent components over their lifecycle, CIRP Journal of Manufacturing Science and Technology, p. 139-150; 2014