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INTEGRATED DEVELOPMENT BY THE CONSIDERATION OF PRODUCT EXPERIENCES

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ABSTRACT

The approach presented in this contribution includes the elaboration of the interdisciplinary strategies and computer-aided tools in product development process during the whole product life cycle. The research project focusses on an algorithmic data feedback of life cycle information. With the fourth industrial revolution “Industrie 4.0” the crosslinking of machines and products is increased. By this way cyber physical products are developed and implemented in technical systems. This offers new opportunities for an integrated development process by considering products life cycle experience. The pursued approach, called “Technical Inheritance”, elaborates the development with collected life cycle information for an adaption of the next product generation.

Usually engineers apply formulas and tables for the design of technical products. The approach of the technical inheritance combines the old proven procedures with the consideration of product life cycle information. The hypothesis of this contribution is to illustrate how different life cycle information are included in the phases of product development for the approach of an integrated development process.

For representing this integrated process, specifications of different information during each phase of life cycle are analyzed. Afterwards the information flow is illustrated by the Unified Modeling Language (UML). For a more transparent process model some adaptions in the notations are implemented. By this way different types of life cycle information are identified. This integrated development process is exemplarily depicted by a demonstrator, which is equipped with cyber physical systems and components.

The result of the elaboration represents the information flow over all phases of product life cycle. Thereby an approach for an integrated development process for the goal-orientated designing of next product generation based on life cycle experience is created.

Another point of view represents the different types of life cycle information as well as their influence to the development phases. Finally the examination of the whole life cycle is necessary for an integrated design engineering.

1 INTRODUCTION

The research presented in this contribution investigates the methodology of product development in regard to the whole life cycle. With the development and application of cyberphysical systems and smart products, also the crosslinking of “intelligent” machine tools and products offers new opportunities for product development processes [AS13, FHS12].

In collaborate research centre 653 (CRC) “Gentelligent Components in Their Lifecycle”, smart components and smart machines are developed. By the combination of genetics and intelligence, gentelligent components are created which are featured to detect life cycle experience [DHL10]. With this innovative technology and their application it is possible to get suitable information of products life cycle for every discipline in engineering design [DMK+14].

This information could be used in different ways. On the one hand these products can be applied for the methodology of X-in-the-Loop [D10] and on the other hand product usage data is linked with product management systems [N10]. Furthermore this technology assists the integrated design engineering [V14].

In focus of this elaboration, an approach of an algorithmic data feedback in form of the technical inheritance is realized. The technical inheritance represents instead of the nature-inspired process model [PML12] and the autogenetic design theory [C05] an intergenerational development process [LMS+13].

By the application of different statistic operations the data sets of the experience collected by gentelligent components are prepared to extract development-relevant information. Therefor an analysis of various types of life cycle information is realized and exemplary illustrated by the application race car. Afterwards the information flow in product life cycle is elaborated. The results are presented in activity diagrams of the unified modelling language (UML). For this purpose, adaptions of the notations are implemented with the goal for a better understanding of the linkage between the different information in the integrated design approach.

2 METHODOLOGY

The present research activities elaborates an algorithmic feedback of life cycle information to the phases of product development [LMS+14]. By this way an intergenerational development process is implemented which embrace the technical inheritance, gentelligent components, a design evolution and the goal-orientated algorithmic data feedback. The approach of this process is schematically illustrated in figure 1.

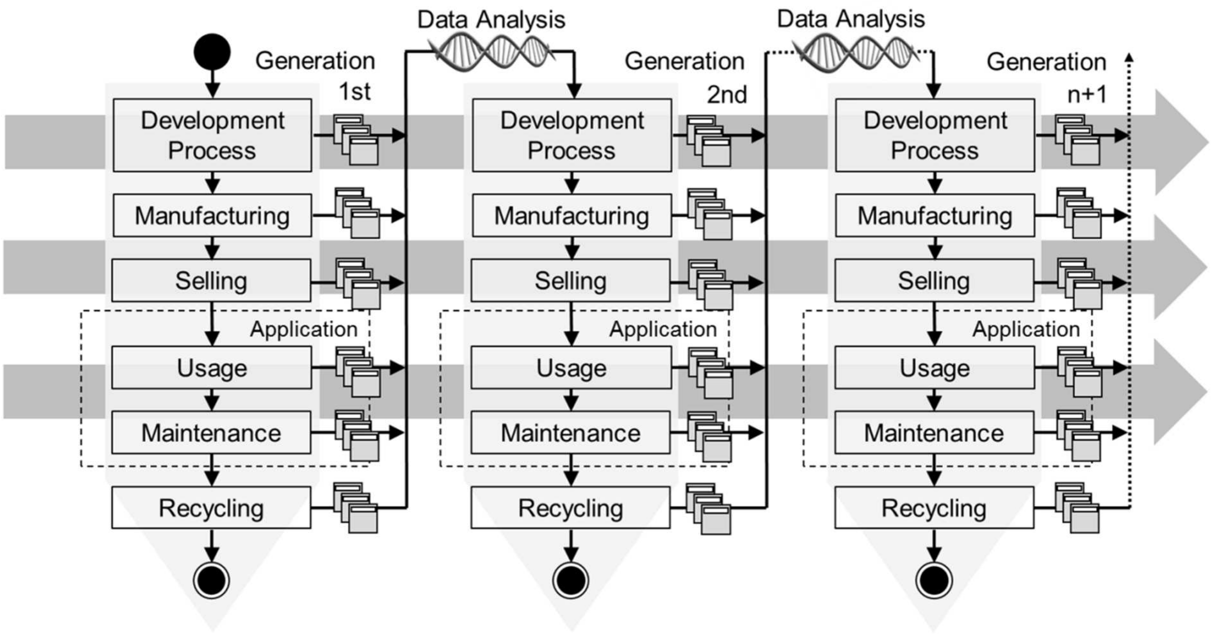

Figure 1: Approach of intergenerational development process

This approach of the intergenerational development process focusses on the adaption of components by the consideration of their life cycle experiences. The applied semantic of this methodology is defined as follows [LG14]:

Technical inheritance:

Technical inheritance is a transfer of assembled and verified information from production and application to the next product generation.

Design evolution:

The adaption of products by analysing product life cycle while taking evolutionary mechanism into account is defined as design evolution.

Algorithmic data feedback:

An algorithmic data feedback means a goal-orientated monitoring of products implementing methods of data mining in order to extract life cycle data. These data are attributed to the results of the development process of the next product generation.

Gentelligent component:

A mechanical / mechatronical component which is featured to collect, save and transmit product life cycle information is defined as gentelligent component.

The fundamental research in this subproject of the CRC 653 regarding the implementation of an intergenerational development process is divided into the three working packages “Design of gentelligent components”, “Statistic operator” and “Design optimization” [LSG12].

The first one investigates methodologies for the developing with each gentelligent technology as well as approaches to transform the inherent product data to useful information for the engineer. This packages is focussed on this contribution with the analysis of different types of life cycle information and the modelling of an intergenerational development process.

The second one elaborates various applications of data mining to extract development-relevant information in huge data volumes, which for example influences the specifications. The filtered results of this packages build the base for the third one [LMD+13].

In the “Design optimization” generative parameter models are developed. This methodology allows adaptions in concept and design phase with the same product-representing models [SL13]. These three research aspects complete the investigations of the design evolution and the subsequent process of the technical inheritance for an intergenerational development process.

2.1 Hypothesis

Nowadays lots of different things could be measured. In dependency of various applications, for example telecommunication or automotive engineering, a diversity of objectives for data acquisition are available. The following list represents an excerpt of these [H12]:

- Detection of failures
- Reliability and durability
- Recognizing of the potential
- Strategic product planning
- Feedback of data to development process

The approach of the technical inheritance examines the point of life cycle data feedback to the phases of development process with the objective to adapt the components shape design to its environment.

The hypothesis of this contribution is that for a goal-orientated data feedback different types of life cycle information has to be identified. Therefor an analysis of the process and its illustration is necessary. By this way the approach of an intergenerational development process is to be expanded. Afterwards for each phase in products life cycle the possible general information has to correlate to each step.

2.2 Demonstrator

In the CRC 653 one of the demonstrators is a race car which was developed in the year 2009 by the Formula Student Team “HorsePower” of the Leibniz Universität Hannover. The rear wheel suspension, depicted in figure 2, is equipped with gentelligent technology. These four components are applied to collect life cycle data from manufacturing, testing up to racing and maintenance. With this demonstrator the results of the following analysis are exemplarily illustrated.

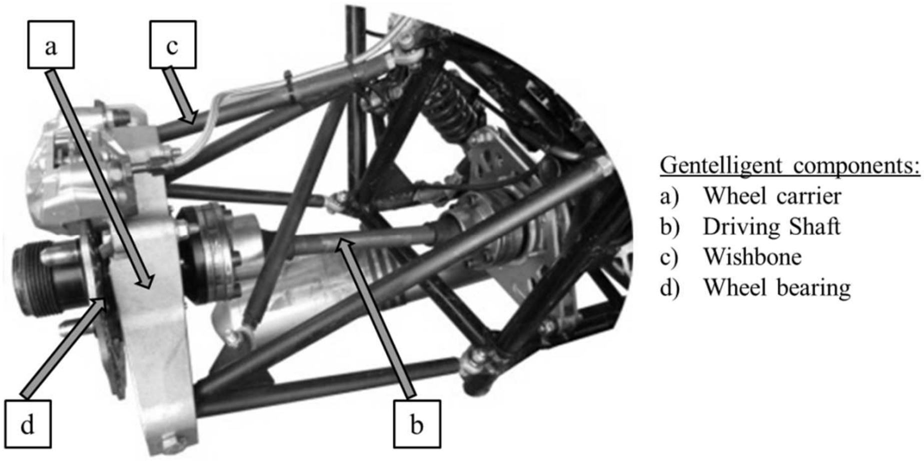

Figure 2: Wheel suspension of a race car with gentelligent components

3 INFORMATION FLOW IN LIFE CYCLE

The intergenerational development process with the objective to implement a technical inheritance considers information of the whole life cycle. With the application of gentelligent components it is possible to detect and collect several life cycle data.

3.1 Adaption of UML notation

The mostly suitable life cycle information are represented by manufacturing, application and remaining service information. This result is applied to adapt the notation of the activity diagrams of the modelling language UML for a better comprehension of the information flows. Therefor the arrowheads are changed in dependency to their type of information, depicted in figure 3.

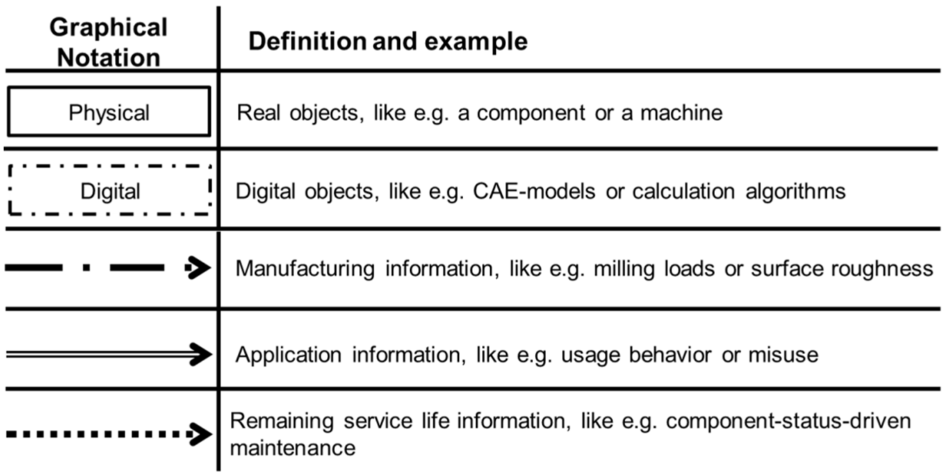

Figure 3: Adaption of UML notations for illustration of technical inheritance

Another point of adaption is represented by the notation of the objectives in the diagrams. Nowadays considering an integrated approach of development a lots of digital objects in development phase like CAD-Models, algorithms as well as the digital recorded monitoring data sets are appropriated in the life cycle of a smart product. In this way the illustration of the objects in the activity diagram is also assimilated to this fact. The applied notation is depicted in figure 3. This adaption supports the understanding of an intergenerational development process including different kind of information flow in the product life cycle. In the next step, the application of this illustration of a process model is executed for the demonstrator.

3.2 Application of UML adaption

The approach of the intergenerational development process is illustrated by UML with the utilization of activity diagrams with enhanced notations. This approach demonstrates the linearized product life cycle of the example wheel suspension. On the one hand the focus in this process is presented by an integration of data mining methodologies in the phases of development [LG14].

On the other hand the contribution is the elaboration of the whole life cycle including different information flows which supports the technical inheritance. Therefor the adaptions of the notations are applied in the illustration of this process model to clarify the dependencies between life cycle steps and their information content. In Figure 4 an excerpt of this model is depicted.

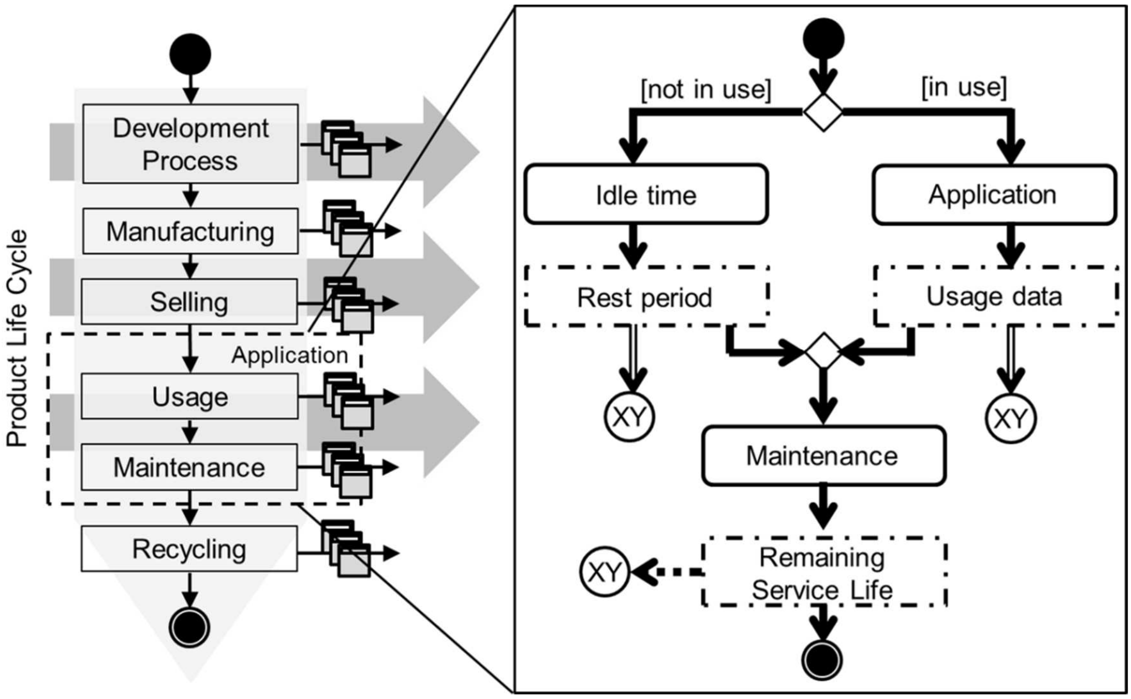

Figure 4: Excerpt of the information flow at application phase in life cycle

The excerpt demonstrates the information flow in the application phase of the gentelligent wheel suspension. These data sets of “Usage Data” are illustrated by the digital notation whereas the consumed product is represented by the real object. The collected life cycle information from application are stored in a knowledge base. The information flow is also adapted and illustrated by the arrowhead for application information. Similar to the collected “Usage Data” the “Remaining Service Life” as well as the “Rest period” information are edited in this approach. The information of these steps are also stored in a knowledge base.

The approach to illustrate the information flow in the intergenerational development process is applied for the whole product life cycle. The benefit of such an illustration is divided into two results. Firstly the information flow of different life cycle information is depicted and the dependencies could be analyzed to support the process of a technical inheritance. Moreover the information could be used in current development or for an optimized process planning in manufacturing. Secondly another view is represented by the simplified illustration. Nowadays there are not sequential steps in product life cycle including the development. But the focus of this process model is the result of each aspect in life cycle. By the linearization of the complex product life cycle a better comprehension is realized. In addition this approach demonstrate a lots of potential life cycle information which could be applied for the technical inheritance and thereby the realization of intergenerational development process in regard to an integrated design engineering approach.

4 ANALYSIS OF LIFE CYCLE INFORMATION

The technical inheritance is defined as a technic-biological process [LG14]. In this case physical parameters are measurable with the gentelligent technology. In addition, this approach considers all facts and steps in the product life cycle. Consequent various life cycle information are potentially be allocated. According to Roth, every phase of life cycle contains different physics characteristics [R00]. For example, the loads in manufacturing of the tool on the work piece or in application by misuse are measurable parameters which are also of special interest for the development of next product generation.

For the determination of information in individual step in life cycle four analysis aspects are necessary:

- Which physical principles are measurable or being located?
- What influence has the result to the physically or mentally of the humans?
- What are the economic aspects?
- Which other general points are from special interest (e.g. standards, etc.)?

The results of such an analysis are exemplified demonstrated by the information in step of application. Therefor the four aspects are considered. The possible information are depicted in figure 5. There exists some dependencies between each, but the illustration in combination of this presented approach allows a better comprehension for the information during the product life cycle. In the next step this approach is applied for the demonstrator.

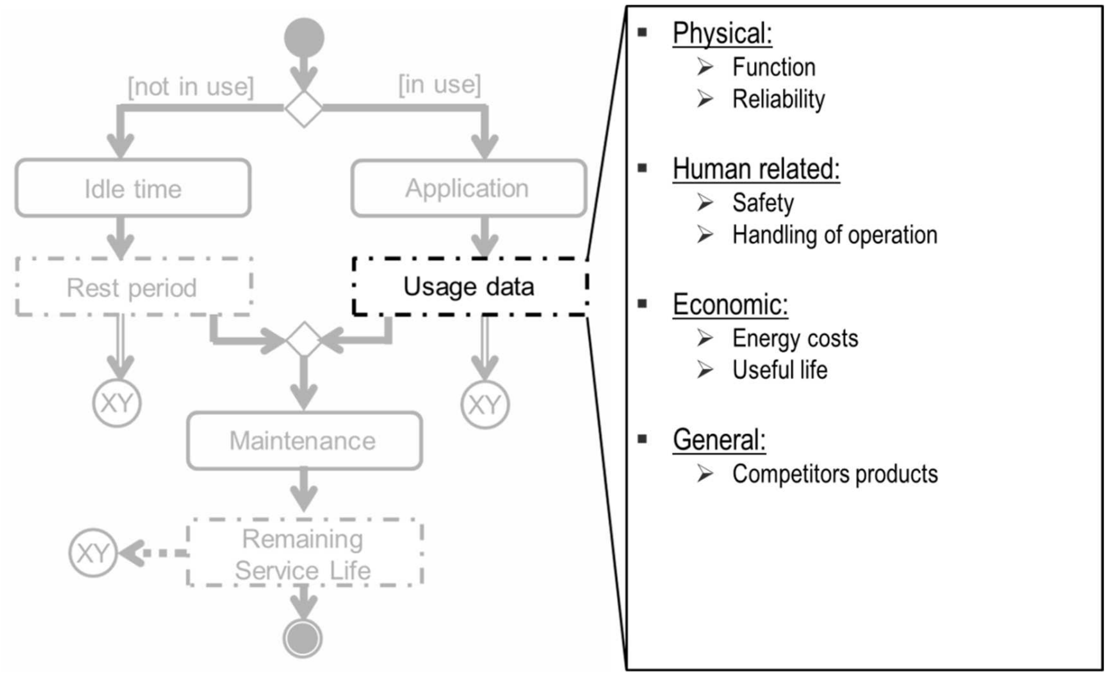

Figure 5: Excerpt of the four possible information in usage data

4.1 Application race car

The race car as a demonstrator restricts the feasible measurable life cycle information. In conclusion three aspects are conceivable to analyse. Firstly the loads during the manufacturing phase, secondly the application of driving and thirdly the maintenance strategy represents the most suitable purposed points of interest. In this subproject the second point of the application of the race car is in focus.

At the beginning the dynamics of the race car are divided into three aspects [H11]:

- longitudinal (acceleration, braking, slope)
- lateral (cornering)

- vertical (wheel load variation)

This dynamic behaviour occurs in its application. Different driving situation are evolved during a race and linking the dynamics where each situation exhibits different characteristics. The driving situations are stationary position as well as continuous, accelerated, retarded straight-line motion and stationary or unsteady cornering [R12].

This situation generates different loads at the race car. In the next analysis steps the wheel carrier, as a part of the wheel suspension, is focussed. This component is equipped by gentelligent technology and allows to collect experiences during its life cycle.

4.2 Classification of detected life cycle information

From the gained experience of the gentelligent component different mechanical load situations are measurable. For example the loads during manufacturing step are applied for an optimized process planning [DSK14]. Another representative is the utilization of load situations during components application for a component-status-driven maintenance [WBN13].

In this project the life cycle information is attributed to the development of the next product generation. In the following the application data and the resulting development-relevant information are defined. As depicted in figure 6, three junction points at the shape of the wheel carrier, linkages with other kinetics like the wishbone or pushrod, are identified. These three points are fixed for the analysis and the adaption of the next generation because a variation of these relativize the collected load cases as well as the driving behaviour of the race car.

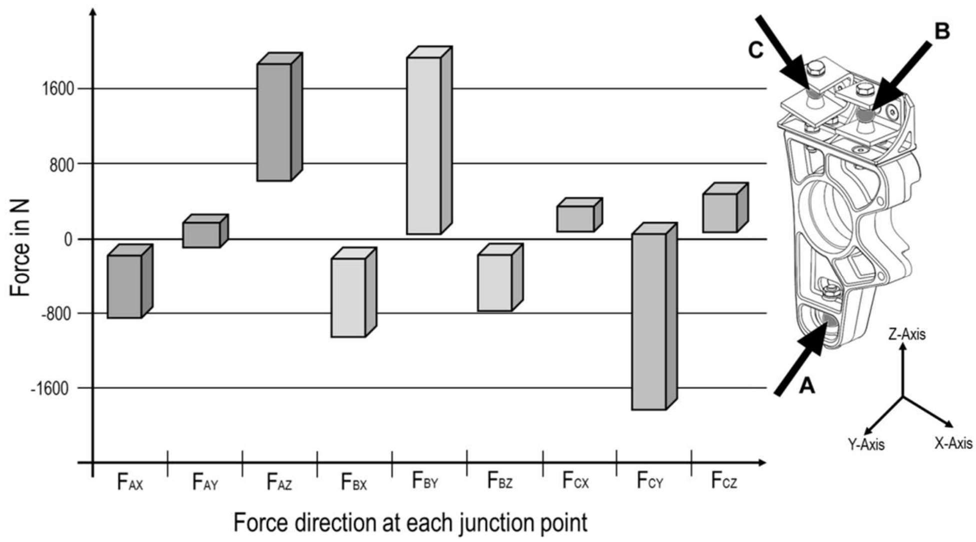

Figure 6: Load case: Acceleration from stationary position

After the identification of the development-relevant junction points at the wheel carrier the data set has to be analyzed for life cycle information. Therefor the inherent data is transformed into forces at the junction points by mechanical substitution model. Afterwards three aspects (significant, maximum and critical) are suitable to identify in the data set which represent development-relevant information.

The loads in this case are the couple of forces at the three junction points in every dimension. With the objective of a reduction of the application data volume, the load cases are clustered. Therefor each cluster width is adapted to the optimal range of the expired forces. This procedure is realized for every aspect of the detection of development-relevant information.

The first aspect of the significant loads are defined as most frequently occurring couple of forces which could be set into dependency to the driving situation. For example the loads during the acceleration from the stationary position is depicted in figure 3. With this approach a handful of significant load cases could be identified in dependency to the different driving situations with the resulting dynamics behavior. The second aspect are the maximum load cases. These occur during life cycle incidents, like a crash or a drive through a curb. These values are of special interest for safety-relevant components because the next generation has also be resistant against these kind of loads. This aspect represents development-relevant information for the dimensioning of the next generation. Thirdly identified aspect is represented by the information about the critical loads. These load cases are corresponding to the current shape of the product. It is defined as the force combination which generates stresses in the component which values are located in short-term strains area considering the stress-intensity factor. To elaborate this information firstly the kinetics of the wheel suspension was analysed. By the determination of the operating forces including their direction, mapped by the corresponding angles, the potential critical load cases could be identified. Therefor some FEM-analysis, regarding the kinematics of the wheel suspension, are performed. After organizing over thousands of analysis two positions with associated angle and force values for every dimension at each junction point are detected, which is depicted in figure 7. For example this information could be applied for plausibility or safety test of the current product generation.

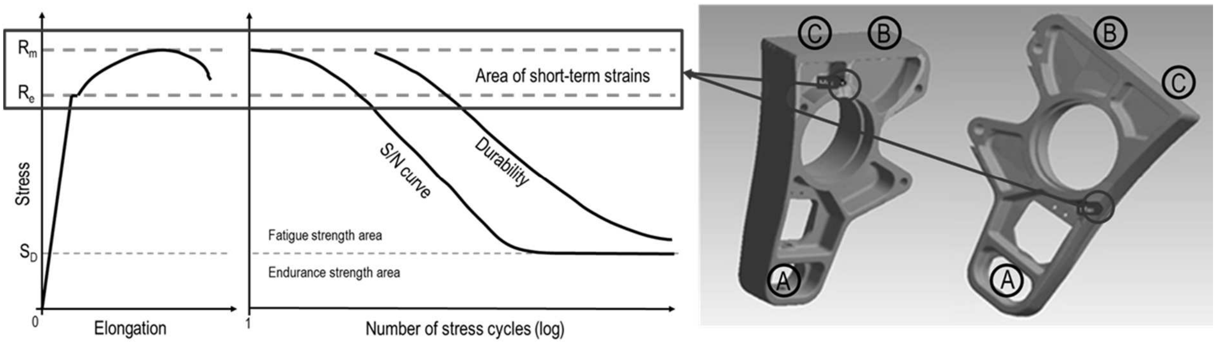

Figure 7: Critical loads and its position at the wheel carrier

On the one hand the analysis of life cycle information for the application of a wheel suspension demonstrates that there are potentialities checking its current development status. On the other hand collecting life cycle information to adapt the next generation of its product to the real environment. With this approach the integrated design engineering is supported and in addition an intergenerational development process is examined.

5 CONCLUSION AND FURTHER WORKS

In this contribution the methodology of an intergenerational development process with the focus on a technical inheritance is presented. The three research aspects are introduced. Afterwards the hypothesis of this analysis was defined as that for a goal-orientated data feedback the different types of life cycle information has to be identified. Moreover the instance for an application is demonstrated by the race car of the formula student team “HorsePower”.

In the next step an analysis of various life cycle information follows. First the operation of different monitoring objectives are declared. Thereafter the focus was set on the race car. Thereby the dynamics as well as the driving situations were identified. Accordingly in dependency to wheel suspension and its gentelligent equipped components the development-relevant life cycle information are identified and defined. These three aspects could be analyzed after transformation the inherent gentelligent information to the three junction point at the wheel carrier. The different load types could give suitable information to different phases of the product life cycle, like process planning of manufacturing or the development of the next generation of the product. In the second step these life cycle information are illustrated in the approach of the intergenerational development process. For a better comprehension of the information dependencies and a goal-orientated feedback of these an adaption of the activity diagrams is necessary. The applied notations are demonstrated at the wheel suspension as well as the different types of information flow during its product life cycle. Thereby the possible information in product life cycle could be identified.

In summary by the analysis of the product life cycle information and the adaption of the notation for the illustration of the approach of an intergenerational development process regarding a technical inheritance the goal-orientated feedback is supported. In addition the identification of different life cycle information is configured easier by the application of a process model illustrated in activity diagram. This result underlines the necessity of these analysis for a technical inheritance and the integrated elaboration of the product life cycle for an integrated design engineering.

The further works of this research project are divided into three aspects. The first one elaborates the linkages of the life cycle information with the product-representing models of the development. The mechanism and formulas are analysed and at the application of the race car demonstrated. Moreover guidelines for the development of the gentelligent technologies are currently in preparation. By this way the storage in knowledge bases as well as their handling has to be analysed. The second step analyses how to identify recurring events in products life cycle. These methods pursues the goal of a reduction of the data volume as well as the identification of development-relevant information. In the third one the analysed results were applied for the design optimization. The identified load cases were used to adapt the shape for example of the wheel carrier to complete the approach of the technical inheritance and thereby the intergenerational development process for integrated design engineering.

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