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INTEGRATED APPROACH FOR EFFICIENT TOLERANCE OPTIMIZATION ON SHEET METAL PARTS

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Abstract

The focus of this paper is on pointing out the opportunities of a deeper interlinking of dimensional management into product-/ and production-development environment. Today, these opportunities are arising because of a reduction in hardware prototypes during the development process. Instead of prototype build-up a shifting into the digital CAx-world is performed, caused by the cut down of development time. To ensure the deeper interlinkage, an integrated approach is set up to efficiently optimize the data. Thereby data from both domains (product-/ and production development) is considered and the optimization is based on the results of a tolerance analysis. An implementation of the approach offers several opportunities. Tolerance analysis can then be used, to rapidly calculate several options which result out of a Design of Experiments of the optimization. This offers the possibility to increase the product maturity level at a very early stage of the development process.

Keywords: dimensional management, Robust Design, automation, Design methods, Design for X (DfX)

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1 INTRODUCTION

Nowadays the main component of a passenger vehicle is the self-supporting structure of the body in white (BiW), which consists of several hundred parts. To ensure the overall manufacturability, for each attached subassembly on this BiW, there are so called dimensional technical specifications existing. In a large scaled production, all manufactured parts and assemblies are subjected to deviations. Thus the dimensional technical specifications must be limited in a certain range (tolerances) to ensure manufacturability. Today, during the product development process, the range of these specifications is backed by tolerance simulations. To be successful on the market, today a broad product portfolio is required in the automotive sector. Thus the number of derivatives of a car is increasing. To ensure manufacturability of all the cars, during the product development process, several tolerance simulation models have to be created. The build-up process for these tolerance simulation models is time consuming and, due to human interaction, fault prone. In context of the shortening of development times to ensure success on the market, an automated tolerance simulation model build-up process is required. Therefore dimensional management must be deeper connected to the product-/ and production development environment. Furthermore the automated build-up process offers several opportunities regarding optimization of product-/ and production development data.

1.1 Focus of the research

An approach for deeper interlinkage of product development and production development by the help of simulations in dimensional management will be investigated in this research, of which a part is presented in this paper. The research begins with a review of the state of the art, the definitions and different methods, techniques and strategies for dimensional management and optimization which are separated from each other. Thereby deficits and challenges are identified and described. The definition of the term "integrated approach for tolerance optimization of sheet metal parts" is given and first challenges and organizational-/, methodical-approaches complete the first part of research. Furthermore, there is a short consideration of the requirements in certain tools.

As the research progresses, concepts of data provision during the product development process for the involved domains have to be defined. The interchangeability of data between the different departments over the whole lifecycle has to be ensured. Therefore neutral data formats have to be investigated for their suitability in context of dimensional management. Moreover existing IT-tools and systems are to be analysed (e.g. concerning onto existing interfaces). A demonstration has to be build-up to investigate which data can be optimized with the help of appropriate algorithms. Also the build-up process of the tolerance simulation model has to be automated. Therefore an algorithm has to be developed to ensure the correct linking of different kinds of data. While summarizing the facts the main research question is arising:

- Is there a possibility for an efficient optimization of product-/ and production development data by the help of tolerance simulations?

1.2 Approach and structure of this paper

This paper presents an approach to the non-explored field of an optimization of product-/ and production development data during the development process by the help of tolerance simulations. It begins in chapter 2 with a literature review of the definitions and descriptions of dimensional management and optimization. Potentials and challenges are presented. Based on the need for action (chapter 3) and the summarized challenges of the two disciplines (chapter 4), an approach for the integrated tolerance optimization of sheet metal parts is given in chapter 5. It firstly deals with the definition of the term, secondly the approach is considered in more detail (organization, methods, IT-tools). Thirdly potentials rising up out of the new approach are presented. The paper closes with further research questions regarding the integrated tolerance optimization.

2 STATE OF THE ART

2.1 Dimensional Management

2.1.1 Definition of Dimensional Management

The literature proposes a lot of different definitions of the term "Dimensional Management". In [Bohn 1998] the meaning is defined according to the meaning of quality management which is described in DIN ISO 8402. Thus the meaning of dimensional management is a procedure of dimensional policy, dimensional planning, dimensional control, dimensional assurance and dimensional improvement [DIN EN ISO 8402]. [Bohn 1998] waives in his work to subdivide into the announced points and clearly emphasises a method for a continuous dimensional management for the product development process. For getting a deeper understanding in dimensional management the following chapter will describe it's methodology.

2.1.2 Methodology of Dimensional Management according to the literature

First of all the methodology of dimensional management according to the literature is presented.
[Wandebäck et al 1998] proclaims in his work, dimensional management including a number of activities which are performed during the design and manufacturing process of a product. The main activities take place in the design stage, during the manufacturing stage, at the part inspection stage, during the assembling progress and at the end of the production at a final inspection. Also according to [von Praun 2002, Weidenhiller 2014, Wartzack 2014, Kretschmer et al 2004, Kenneth] dimensional management takes place in every step of the product development process:
During the conceptual phase first of all the requirements of the new product have to be defined. Also it has to be analysed which variants of the product and process are to be realized. The conceptual phase closes with a first definition of datum target points for the assembling process of the parts. This implies a first draft of the assembly graph of the product in the manufacturing plant. In the design phase the datum target point system is getting more detailed for each part of the product. Also the functional interactions of surfaces between parts are becoming more obvious. Thus the dimensional, shape and position tolerances can be created. During this phase several optimizations of parts, due to the results of the tolerance analysis and other CAx simulations (e.g. FEM), are frequent. By the help of the tolerance simulation it is also possible to identify the most critical quality features at the product. Having consistent CAD-data enables defining the audit relevant parameters of the product to validate the hardware in a further step. In the prototype phase first of all the measurement devices, jig devices and operating funds have to be validated and also the repeatability of the measured results has to be proven. In a further step the capability analysis for single parts and assemblies are possible. With the start of the series production process it is possible to install statistical process control as well as a continuous process of improvement. Also a return of real time measured data into the simulation environment is possible to optimize the product- and production design during production. It becomes obvious that on each step of the product development process, dimensional management is interacting with multiple departments in the company. This cross domain status of dimensional management is necessary to grant a high quality product which can be manufactured at acceptable costs and is able to fulfill its requirements.

2.1.3 Methodology of Dimensional Management in large scaled enterprises

Comparing the methodology of dimensional management to the implemented methods in large scaled enterprises shows differences and similarities. Often in industries, the cross domain status of dimensional management exists only in a slim version. This means, due to organizational requirements, dimensional management is attached to development-/ or quality management-departments. This influences the level of penetration into the other departments. Only if the persons involved are able to decide for their whole department it is possible to form a working dimensional management process [Bohn 2013]. If not, some of the explained activities are performed in a weaker form. This might result in quality issues or increase the manufacturing costs.
The methodology is also different if the manufactured product is more complex. In these cases for each stage of development, dimensional management requires several loops [Bohn 2013]. The core of the methodology to define a tolerance concept, for example in the automotive industry [Bohn 2013, Mölzer 2014], is similar to the general method, which was described in the previous chapter.

2.1.4 Potentials of and challenges trough Dimensional Management

Manufacturers are committed to provide the highest possible product quality to the final consumer at acceptable costs. Therefore rigorous quality management is required but beyond that it is necessary to specify the product tolerances in the right manner at an early stage of the development process. Today the market requires a shortening of the development period for new products. This causes a shifting from the hardware prototype phases into the digital CAx-world. Thus in early stages of the product development process, no physical data exists. Tight tolerances lead to high costs whereas large tolerances can decrease the final product quality right up to a total loss on functionality. Performing dimensional management means finding a compromise in the area of tension between costs, quality (functionality of the product) and, time to market.

An appropriate way of looking at engineering process analysis and syntheses is to subdivide the case into the three dimensions of processes, methods and tools [Burr et al 2007].Thereby the challenges are getting more obvious.

From a process point of view, the challenges have already been mentioned in chapter 2.1.3 as organizational installation of dimensional management in the company and as decision-making power of the persons involved.

Methodological challenges are often interlinked to certain tools. For example in the conceptual phase of the product development process, the requirements on the product have to be defined. These requirements have to be stored in a system which is accessible to all follow-up processes. The number of requirements rises by the complexity of the product. Thus methods have to be developed to enable the storage in a user-friendly way. In [Litwa a et al 2014] the methodological challenge of representing the assembly graph in a digital way is concerned. Regarding the design phase, optimization caused by results of the tolerance simulation, is performed. Therefore methods have to be developed how input and output parameters of the tolerance simulation model can be interlinked to an optimization tool. An up to date stable return of data to the development environment has to be ensured. Even in the prototype phase methods have to be developed to return real time measurement data into the tolerance simulation environment.

Due to the cross domain status of dimensional management, the tools involved in this process are widespread. Often the flow of information is insufficient because of missing interfaces in certain tools. An example is the interface between CAD and CAT environment as shown in [Litwa b et al 2014].

Straightening out the data sinks results into an efficient flow of information. Through new methods for the explained challenges and an efficient dimensional management process (organisation), the maturity level of the product can be increased in a shorter time with consideration of the products functionality and its costs.

2.2 Optimization of parts during the product development process

2.2.1 Definition and requirements

There are also a lot of definitions existing in the literature to define the term "optimization". For example in [Littger 1992] optimization is explained as a systematic process to solve a short-timed, mid-timed or long-timed problem using quantitative methods to find an optimal or approximately optimal solution. Therefore the problem has to be modelled in an abstract way. Defining the abstract problem always means a separation of the problem out of its context. Changing of the boundary conditions has to be avoided.

This means the optimization is closely related to the modelling process of the problem using a mathematic description [Gerdts 2014]. For these models unknown parameters and functions have to be found which are able to fulfill the target function (minimum or maximum of the function). A violation of the boundary conditions is not permitted.

In the field of mathematics the problem of finding an optimum can be defined as follows [Gerdts 2014, Jakob 2014]:

$opt\ f(x)\ with\ x\ \in\ X$ which fulfills the requirement $\forall x \in X\colon \big(f(x) \leq opt\ f(x)\big) = f_{opt}$ (1)

Thereby $X \subseteq R^n$ is an arbitrary nonempty quantity and $f : X \rightarrow R$ is an arbitrary function. The $opt\ f(x)$ is defined eighter as $min\ f(x)$ or $max\ f(x)$ and can be transformed into each other by the help of a multiplier ($k = -1$).

Modelling a problem requires several variables to represent input parameters, output parameters and boundary conditions. These variables can be distinguished into integer, float, boolean, string and discrete alternatives [Littger 1992, N.N. 2014]. There are several techniques and strategies of how optimization can be used (also concerning the product development process). This shall be explained in the following chapter.

2.2.2 Techniques, strategies and methodology

There are more than 1000 tools existing on the market using different kinds of optimization algorithms. In this paper the state of the art is on giving a brief overview about the different optimization methods. There is a description of the different algorithms which are focusing on convex optimization problems as well as on algorithms regarding non-convex optimization. Furthermore the optimization problems can be subdivided into restrict problems (problems which have boundary conditions) and non-restrict problems (problems where only the target function is regarded). The following different optimization techniques (algorithm) shall be explained in short.

Optimization without any restriction (one dimensional case):

Optimization without any restriction can be distinguished into one-dimensional optimization (line search) and multidimensional optimization:

- *One-dimensional optimization [Schumacher 2013]:*

Discovering an optimal solution by the help of line search requires in a first step a research direction. Finding this research direction is explained in the multidimensional optimization. During the research for the optimum the direction isn't changed any more.

- *Multi-dimensional optimization [Schumacher 2013]:*

Using the multi-dimensional optimization means fulfilling several iterations in "finding the research direction" and "performing one-dimensional optimization". To find out at which optimization loop the research direction has to be changed a stop criteria has to be defined. The stopping criteria can be found either by analysing the sum of the gradients in the determined optimized position or by analysing the normalized progress of the optimization. To find the research direction there are two main methods existing. The algorithm of VMCWD and the method of the steepest descend.

Optimization with restriction:

Optimization with restriction can be distinguished into methods using a penalty function and direct methods without penalty functions.

- *Optimization using a penalty function [Schumacher 2013]:*

Integration of the penalty function into the target function of the optimization problem allows treading the optimization problem with methods of the non-restrictive optimization.

- *Optimization with restrictions (without using penalty function)[Schumacher 2013]:*

To solve optimization problems directly first of all the method of the steepest descend is used. If a restriction is reached, the directions (gradient of response surface and gradient of restriction) are compared. If these directions are not collinear, the optimum is not reached. This also can be proven by Kuhn-Tucker conditions [Eppler 2011]. An extension of this method is shown in the Modified Method of Feasible Directions [Martins 2002]. Starting the research for an optimum will result in one of the restrictions. The research for the optimum then follows along this restriction function. The Modified Method of Feasible Directions helps to find the right research direction along this restriction.

Approximation of real problems:

The fundament of an optimization algorithm is to approximate efficient to the target function and the restrictions. Additional grid points in the approximation leads to less iteration in finding the optimum, and also lead to more precise results in finding the optimum. These additional grid points cause more complex calculations (due to e.g. more complex polynomial functions) which need more time to be solved. Thus a compromise has to be made. It can be distinguished between a local approximation and global approximation. Local approximation is used in cases where the derivation in a specific position can easily be detected (local sensitivity). For a global approximation the whole design space is considered. Therefore normally a design of experiments is performed to scan the design space. Based on the design of experiments the coefficients of the approximated function are calculated (e.g. by error square calculation). This function is called response surface model (RSM).

Stochastically search methods:

Besides the considered mathematical methods stochastic search methods are also used. These methods do not require a research direction and also do not use one dimensional research. The main advantage of these methods is to skip the local optima and to then find the global optimum. Thus the optimization problems do not have to be convex any more. Restrictions of the problem have to be considered by penalty functions. The disadvantage of these methods is a significant ascent of calculation time. Frequent used stochastically methods are e.g. Monte-Carlo methods, generic algorithms or evolutionary algorithms.

Strategies for optimization:

Applying the above described different algorithms of optimization for a problem during the product development process requires a certain strategy. There are often problems which cannot be directly solved by the described algorithms like:

- optimization problems with multiple objectives (finding an Pareto optimum).
  Here strategies like target weighting or distance function are frequently used.
- multidiscipline optimization (finding an optimum in a domain spanning environment with several departments involved in the problem).
  The global sensitivity matrix, separated pre-optimizations in the individual departments or a domain-spanning multidiscipline optimization are the strategies to solve this problem.
- multilevel optimization (finding an optimum for several levels of detail)
- optimization problems with deviating input parameters (finding an optimum in context of robust design)

Today during the product development process there are several cases where optimization is used. An extract of the different cases shall be given in the following chapter, taking thereby used strategies and optimization algorithms into account.

Extract of methods for optimization during the development process:

During the conceptual phase it is necessary to evaluate several concepts for e.g. a body in white structure. This structure is subjected to several requirements out of e.g. crash, stability, manufacturability and driving-comfort. These requirements are demanded by different departments in the company. [Will et al 2014] presents an approach of how overall vehicle concepts can be found with the help of optimization, taking the multidisciplinary requirements into account. Therefore in a first step a parameterized conceptual model is created. Due to opposed boundary conditions and ill conditioned optimization [Will et al 2014] recommends a generic search strategy to find the best concept (global optimum). In [Duddeck 2014] different optimization algorithms are benchmarked in context of multidisciplinary requirements for an optimization of a front-end in automotive industries. [Duddeck 2014] concludes evolutionary algorithms being the optimal algorithm to fulfill the multi-layered requirements on a front-end. [Wartzack et al 2014] describes a method for tolerance-cost-optimization on deviating systems in motion. Thereby the conflict of objectives between manufacturing costs and fulfilling the function of the system is considered. In a first step a design of experiments is performed. For each of the resulting samples of the DOE the deviations of the single components in the system are calculated across the whole movement cycle. Afterwards the response surface model is calculated. To find out the global optimum in [Wartzack et al 2014] particle-swarm optimization algorithms are used. In [Stockinger 2011] an integrated approach is described of how methods of robust design in combination with dimensional management can be used to improve the products robustness.

2.2.3 Potentials and problems of optimization during the product development process

Thanks to increasing computational power the integration of optimization during the product development process is getting profitable. More complex but expedient algorithms can be used in the same amount of time. Furthermore the shifting of development into the digital CAx-world opens up new opportunities for optimization. Thus new fields of activities are arising. To integrate multidisciplinary optimization into the development process it might be necessary to adapt the product development process. New common milestones have to be defined to grant accessibility to development data or department internal requirements (boundary conditions for the optimization problem). Today the large scaled enterprises are facing the problem of data accessibility in very early stages of the product development process. During this stage of development the influence on the products final cost is the highest, but the entity of requirements towards the product are often not known. Efficient optimization also needs an automated pre-/ and post-processing of data which is considered in [Duddeck 2014]. Therefore it might be necessary to develop additional interfaces between the different systems of the departments involved in a multidisciplinary optimization. Also strategies have to be developed how changing requirements (e.g. changing material concepts, conceptual change of visual effect on gaps) during the product development process can be handled by the optimization.

3 NEED FOR ACTION

Today in large scaled enterprises tolerance simulation during the product development process is not frequently used to validate certain concepts due to the time consuming build-up process of the tolerance simulation models. Instead of the simulation often an experienced tolerance planning engineer is validating the concepts by his expert knowledge. The increasing complex products and the shortening of development time make it hard to consider all possible concept variants. Thus the optimal concept might be overlooked even by experienced tolerance planning engineers. Furthermore if changes in the product or the manufacturing process are necessary a decision based on experts' knowledge might be unconvincing. Comparing certain concepts by the help of tolerance simulation is the more appropriate way (numbers and facts). Therefore it is indispensable to interlink the departments involved to dimensional management processes. An automated pre-/ and post-processing of the tolerance simulation is getting inevitable.

Regarding the existing methods of optimization in context of dimensional management, methods have to be developed which are considering all the input parameters into a tolerance simulation model. Existing approaches only take the optimization of the tolerance range into account (e.g. regarding manufacturing costs). Changing this parameter should be considered as a last opportunity. In fact the focus of attention should be on all parameters and components which are responsible for the resulting quality feature (shape / dimension of certain geometries of the parts e.g. tolerance compensating elements, location of datum target points, jig- and fixture concept, connecting elements, assembly graph, etc.).

4 CHALLENGES FOR AN INTEGRATED APPROACH

As mentioned in [Burr et al 2007] the challenges for an integrated approach for optimization of product- and production development data shall be distinguished into processes, methods and tools.

The integration of dimensional management in the departments involved into the product- and production development process is one of the challenges from a process point of view. Also it is necessary to grant the dimensional management engineer the power of veto in designing themes as well as manufacturing themes. This is the only way to implement the determined optimization results into existing concepts.

The challenges for the methods can be subdivided into methods for PDM/CAD to CAT environment and CAT to optimization environment. Furthermore a solution has to be developed to integrate continuous and discontinuous variables into the optimization tool.

As mentioned before the deepening interlinkage of the departments involved requires additional interfaces regarding the different kind of data. Mentioning an example, the interface between the development data and the interface from PDM/CAD-data to the tolerance simulation environment has to be developed. Also an interface to an optimization tool has to be implemented.

The challenges in the different areas can be phrased into a general task:

Efficient optimization of product- and production development data by the help of tolerance simulation.

5 INTEGRATED APPROACH FOR TOLERANCE OPTIMIZATION OF SHEET METAL PARTS

5.1 Definition of terms and classification

The term "integrated approach for tolerance optimization of sheet metal parts" shall be explained in more detail. Therefore the approach has to be dissected step by step. In context of the development process the meaning of an "integrated approach" considers both domains, product development and production development. "Tolerance optimization" thereby is standing for an optimization of all kinds of input data into the tolerance simulation to reach certain targets (e.g. gap- and flushness dimensions). The approach shall be limited on sheet metal parts because of tolerance simulation models for sheet metal parts are mostly build-up in a point based way. The amount of data to create and modify these point based models is easier to manage regarding the interfaces to certain tools, variables of the optimization problem etc.. Transferability of the approach into other disciplines has to be ensured.

5.2 Structure of the integrated approach

The approach is structured similar to its challenges into process, methods and IT-tools.

5.2.1 Process:

First of all to ensure a domain spanning organizational, functionality of dimensional management, it has to be implemented in between the organization units of product development (design, development, etc.) and production development (preplanning, planning, etc.). Also the power of veto in concept decision has to be ensured. To grant an efficient optimization during the different stages of the development process common milestones have to be defined. This is the only way to ensure accessibility to the multi-layered data out of the different development processes.

5.2.2 Method:

The relations and dependencies of the data in the product development process are shown in figure 3. Thereby figure 3 is an extended representation of the figure 5 published previously by the authors in [Litwa b et al 2014] to show the overall concept. Compared to [Litwa b et al 2014] the figure is extended by the field of automated CAT-simulation and the field of optimization.

On the one hand, the field of automated CAT-simulation uses data from the product- and production development process like CAD-geometry, assembly graph, jig- and fixture information, connection information, datum target information, tolerance information and measurement information. In large scaled enterprises this information is stored in a 3D master model, if the 3D-master method is used (principle of single source) [N.N. 2013]. All the different kinds of information are then stored in a database structured by parts and assemblies (see ① in figure 1). Considering the information which is needed to build-up a tolerance simulation model, it is obvious that a reduction of the information is required. This reduction of data is fulfilled by an algorithm (see ② in figure 2). Defining this algorithm will be a part of future work done by the authors. Applying the algorithm on the database of a specific set of data then results in a reduced database, which can directly be used for tolerance simulation purpose (see ③ in figure 1). In the next step, it is necessary to transform this information in software specific format (e.g. XML, Excel, etc.) to ensure an import into the tolerance simulation environment (see ④ in figure 1). Using tolerance simulation software which offers a batch mode in addition to the model import in a neutral data format (XML, Excel, etc.), allows running the tolerance simulation on the set of data (see ⑤ in figure 1) and furthermore enables to export the specific simulation results to the database (see ⑥ in figure 1).

On the other hand, the database of the CAT-simulation environment is used for performing multidisciplinary optimization. Thereby in a first step the input parameters of the system have to be defined. Considering efficient optimization of product- and process information, the input parameters of the system are those used to build-up a tolerance simulation model. Thus it is necessary to interlink these parameters to the optimization environment (see ❶ in figure 1). Also to specify the optimization target the results of the tolerance simulation model is used (see ❷ in figure 1). As soon as the parametric system for optimization is defined, it is possible to set up a sensivity analysis on the input parameters to evaluate their influence on the resulting dimension(s) (see ❸ in figure 1). Basically the sensivity analysis requires a variation of the input parameters and therefore it is necessary to limit their variation in certain range. For each class of input parameters the permitted variation is stored in a database (see ❹ in figure 1). Calculating a mathematical substitute model (Response surface model) requires in a first step to perform design of experiments (see ❺ in figure 1). Thus only a few tolerance analysis have to be performed to give an adequate feedback about the influence of all the input parameters (product- and production development data) on the resulting dimension(s). Due to the permitted variation of the input parameters the design of experiments results in a modified database (① in figure 1). Hence it is necessary to perform step ② to ⑥ again to calculate the resulting dimension(s). Based on all the samples of the design of experiments it is possible to calculate the mathematical substitute model. An optimized design can then be found by the use of the before explained optimization algorithms (e.g. evolutionary algorithms).

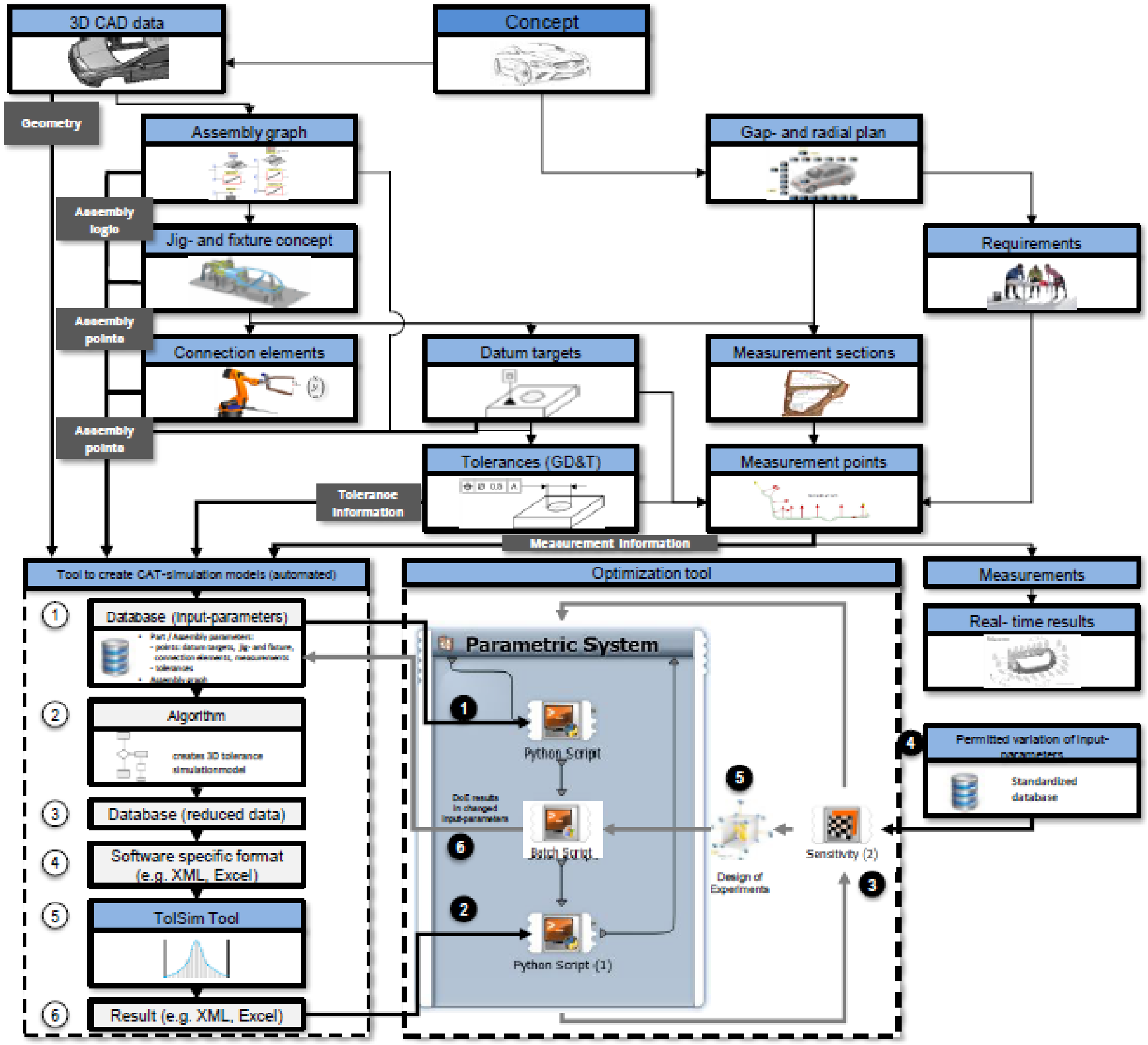

Figure 1. Methodical approach for tolerance optimization of sheet metal parts

5.2.3 Tools:

From the IT-tools point of view a domain spanning development department interacting in between product development and production development requires several interfaces to certain tools. To realize the concept of tolerance optimization for sheet metal parts basically three different environments have to be brought together through interfaces:

- PDM/CAD environment to optimization environment
- PDM/CAD environment to tolerance simulation tool [Litwa b et al 2014]
- CAT environment to optimization environment

Exchanging data between different systems and tools during the whole development process requires platform independent exchange formats. Therefore existing formats have to be evaluated for the concerns of a higher interlinked dimensional management.

5.3 Potentials of the integrated approach

Performing the tolerance optimization of sheet metal parts offers several success potentials. Tolerance simulation of several concepts is possible and due to the optimization tool, the required changes of product-/ and production development data can be calculated almost in real time. Thus during the product development process decisions can be made more quickly and easily because of the obvious impact onto departments involved. It is consequently possible to realize the best concept concerning costs, functionality and manufacturability. In a first step the focus for an efficient optimization is on the shape of the parts. In [Litwa et al 2015] a basic concept for optimization on tolerance compensating elements is presented by the authors. Another possibility for efficient optimization is on datum target points and jig- and fixture positions. Displacement of this information may lead to a more stable adjustment of the parts in the fixture and also reduces deviation of the resulting dimension(s). Of course tolerance optimization not only provides an efficient method to reach the target values, but often leads to increasing manufacturing costs. Future work of the authors will investigate those targets of optimization based on an example. Regarding optimization of the assembly graph causes several changes in data which is based on the assembly graph like connection elements, jig- and fixture concept, datum targets, etc.. Thus an efficient optimization of the assembly graph is only possible if there are several concepts existing including all the data of the follow up processes.

6 CONCLUSION AND OUTLOOK

Today the market requires a shortening of the product development time. Thus it is inevitable to shift the hardware phases into the digital CAx-world. This shifting opens up several possibilities. In this paper a deeper interlinkage of dimensional management into the product-/ and production development process is demanded. Thus a more efficient optimization of data by the help of tolerance simulation and optimization tools is possible. After giving a short explanation of the two fields dimensional management and optimization during the development process, the challenges in combining these two fields were presented. Based on the success potentials for tolerance optimization of sheet metal parts an approach for an integrated consideration has been illustrated. Regarding the research question given in the introduction, the basic structure of the approach for tolerance optimization has been created. It consists of organizational, methodical and IT-tool components.

Forthcoming research will have to give a more detailed look on the methodical part of the approach based on a demonstrator. Thus the feasibility of optimization of different input data can be proven.

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