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An Application of Enhanced Knowledge-Based Design in Automotive Seat Development

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ABSTRACT

Management of product complexity in virtual development establishes as an important challenge that has to be considered to ensure efficient product creation. The main goal is to provide a virtual environment, which allows the simultaneous definition, representation, verification and alignment of involved components. As a key aspect of the present publication, an integrated approach based on a novel configuration of a design-related master model that connects different development disciplines is introduced. Several methods are integrated to this approach and support a continuous efficient development even in early phases. The paper completes with an exemplary application in automotive seat development, representative as one of the complex disciplines in automotive engineering.

Keywords: knowledge-based design, product complexity, 3D-CAD master model, seat development.

1. INTRODUCTION

The virtual development of complex products, like seats in automotive engineering, is characterized by numerous influencing factors which can either stem from internal boundary conditions like product specifications or from external requirements, e.g. standards, regulations or specific customer-demands. In addition, the different components and modules of complex products can have functional and geometrical interdependencies, and simultaneously they are developed in different departments, respectively by application of different engineering disciplines. Due to the development within different computational environments, the impacts of product-related modifications and variations are often difficult to understand and traceable. Considering the requirements of data consistency throughout the development process, the development statuses of each component have to be aligned continuously which can cause enormous efforts through data and information transfers. In today's development of complex mechanical or mechatronic products, several product-related data are centrally administrated in process-oriented PDM (product data management)-systems, that do not consider an alignment with regards to technical-oriented content, e.g. packaging-related aspects or ergonomic influences. These boundary conditions in course of multidisciplinary optimization call for the development of new approaches which use integrated 3D-CAD (3-dimensional computer-aided design) master models as central product definition and representation. Detailed information is included in previous work [9,13]. The implementation of such models within 3D-CAD environment is based on the fact that the product itself (especially the geometry model and the product structure) continuously is in focus of the entire development process. Such high integrated geometry models enable a continuously alignment of the actual data statuses and at the same time they are able to reduce time-consuming and error-prone data exchange procedures between different development environments. The rising complexity of these advanced CAD-models can lead to logical errors in different types of application because of enhanced product structures and deep parameterization. However, to use the manifold advantages of highly integrated master models and to enable an efficient workflow during product development, an effective management of these models is indispensable.

The challenge is to develop a virtual environment based on the approach of a centralized 3D-CAD master model as published in [14]. This master model configuration allows the continuous representation and alignment of the involved engineering disciplines

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within one CAD system. In automotive application, it mainly focuses on the early conceptual stages and considers the main modules of a full vehicle. In contrast to the approach of [14], the present approach focuses on specific modules and products with a high degree of complexity. The present findings intensively support product design, beginning with initial development stages up to production release. In particular the early concept phase of product design is supported using comprehensive parametric-associative and knowledge-based features of modern CAD systems to enable desired degrees of freedoms. High flexibility in the course of geometry variation and control increases the risk of geometric inconsistency errors. As a key aspect of the present design related master model, integrated process control and automation routines enable a user friendly and efficient design process including a comprehensive error-handling management. In previous works [8], a product model was developed which contains the main components for conceptual seat development. Combining this seat model and the present design-related master model approach, an integrated modeling strategy results in an effective 3D-CAD based solution for complex seat development including functional simulation modules.

2. KNOWLEDGE-BASED DESIGN

Knowledge-based engineering in general includes a technology-oriented focus on methods and tools for the support of product development. Knowledge-based design in particular concentrates on product design and its related procedures. In this way, knowledge-based design supports design processes by re-using predefined methods, algorithms or results, and it is integrated into specific tasks or workflows that are involved in the design processes. Knowledge-based design methods and tools can include the use of rigid or variable geometry data, the integration of calculation and simulation procedures into the design process, or the application of problem-oriented software solutions that can be integrated into the design environment. Besides geometrical modeling tasks, knowledge-based applications can provide functionalities that integrate procedures which were previously accomplished via separate calculation or simulation software. On the one hand, knowledge-based design starts with the parameterization of geometrical objects in the course of the design process including the implementation of mathematical and logical relations. The creation of extensive, problem-oriented simulation algorithms within a design environment represents a transition into complex software applications. A wide range of functionalities and applications of knowledge-based design is discussed in more detail in relevant literature [6,7,11,12]. In addition, Verhagen et al. [15] collected and reviewed literature on KBE and KBD, exemplary to identify research issues and limits of KBE-methods.

2.1. Knowledge Integration using Template Models

Template models represent a kind of master models that can be integrated into development processes. Because templates are prepared for re-use, they include specific know-how. In this way, the application of templates transfers knowledge from former development projects into current product-generation processes. Template-based development methods are used in various domains (e.g. design, simulation, software development). The present publication focuses on design processes, whereby the ability of modern CAD software to perform calculation and simulation procedures using design templates enables an integration of CAD and CAE. Here, template models are understood as predefined design model structures or geometry models, which can be augmented with additional functionalities. The diagram in Figure 2 presents a classification of CAD templates. Process templates support the development and management of different types of processes (e.g. for production engineering or cost calculation). The product templates discussed below focus on product development and can include a variety of knowledge that supports design-related tasks. Product templates

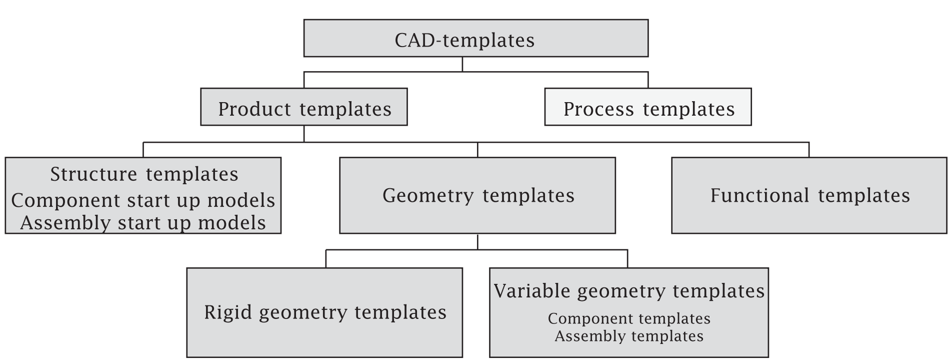

Fig. 1: Categories of CAD templates [4].

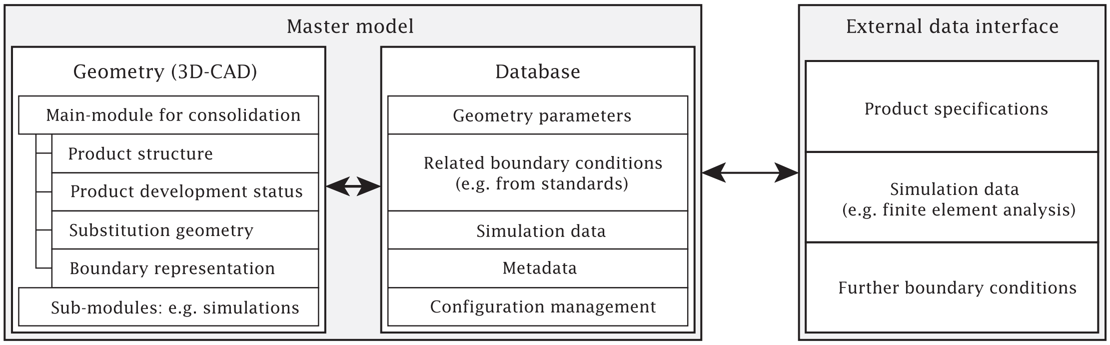

Fig. 2: Design-related master model configuration.

can be divided into structure templates, geometry templates and functional templates.

Structure templates address the predefinition of the internal design model arrangement. This is mainly accomplished by the introduction of startup models, which prescribe the sequences of geometry creation and the integration of different additional design-related aspects and automated functionalities (e.g. mass calculation, surface area computing). The application of structure templates ensures that design rules and specifications are considered throughout the entire development project. This plays an important role, especially in the case of complex product development, in which numerous engineers and departments are involved. There are two types of structure templates, startup models for component design and startup models for assembly design. Assembly startup models define the structuring of a product by predefining groups, modules and components with the goal of generating a predefined product structure that persists through the entire development process.

Geometry templates include rigid and variable geometry models. In the case of rigid geometry templates, the geometry of the models is not adjustable by direct access. Rigid templates are not normally built up by parametric-associative design methods, and they include no enhanced functionalities for geometry creation. In general, rigid templates are provided in native data formats, which restricts the application to a specific CAD environment, or in neutral data formats, which enables a broad distribution independent from a specific software. This type of template is used to represent carry-over parts (COP), which are delivered from former models and integrated into new products. Besides 3D components, 2D models are also used to define the design or reference sections. One major advantage of rigid templates is their ease of reproduction and re-use in different types of development cycles, as well as the relatively simple data management, since there are not relations or linkages to other components, modules or assemblies.

Variable geometry templates represent predefined component, module or assembly models, which can include several functionalities for supporting the design process. The separation of geometry from underlying parameters enables the definition of flexible models, which can be modified by simply changing the parameter values. These highly variable templates include all structural and geometric information and are controlled by input parameters. The geometry creation process for these templates has to offer a universal usability, so that changing lengths or distances has no negative influence on the stability of the model. When generating variable template models, it is essential that both the range of possible parameter values and the flexibility of the created geometry fulfill the requirements of the intended application. Mathematical connections of parameters and restrictions of input values to reasonable rates support the definition of expandable templates for many standard components. Every variant of a template component represents a variation of the basic model, including the same design methods and rules. In this way, variable templates support the collection of expert knowledge and integrate know-how into the design processes. Beyond components, variable template models can also include several parts, which are (variably) organized in assembly structures. This provides flexibility in the geometry characteristics, as well as in positioning and structural configurations. In the case of complex variable assembly templates, skeleton or adapter models can support the control and linkage of different model structures.

Finally, functional templates in a CAD environment include specific, problem-oriented calculation and simulation procedures, which can support different areas of product development (e.g. design and dimensioning, production engineering, cost calculation). Functional templates can exist as special programs or may be integrated into simulation or design software. In the case of CAD-external software, data transfer from calculation to design and vice versa is accomplished by integrating data interfaces. This approach can be applied for everything from simple computations up to integrated software solutions, which enable complex product layout. In many cases, functional templates are integrated into development processes and serve as problem-oriented tools. Embedding them into variable geometry models makes it possible to integrate them into the (existing) parameter structure of CAD models. In this way, an unambiguous parameterization strategy supports efficient data transfer between design and calculation cycles. The combination of variable geometry templates and functional templates within one data structure enables the generation of efficient tools for product development. Because of their integrated programmed functions and algorithms, such tools are advanced knowledge carriers that include company-specific know-how.

The following approach is based on the application of enhanced knowledge-based design methods and includes several categories of CAD templates.

3. KNOWLEDGE INTENSIVE APPROACH IN PRODUCT DESIGN

As previously mentioned, this paper focuses on the improvement of virtual development processes of complex products. Such products are built up of several sub-products and components which are characterized by a considerable number of influencing factors. Internal dependencies between correlating components and modules in combination with external influencing factors, which exemplarily stem from legal requirements, regulative boundary conditions or customer demands, can lead to system constellations with complex and even unclear relations of participating entities. As a consequence, the impacts of varying system parameters are difficult to retrace and therefore the input of expert knowledge through the development is often indispensable. In this way, the range of possible (experienced) users in design of complex products is limited which can involve higher development risks. The development of the related sub-products and components is typically performed in different development teams and system environments. According to the requirements of data consistency and data integrity, the continuously balancing and adjustment of actual component data status is necessary. Regarding the development of multiple variant studies, this leads to increased effort and therefore reduced development efficiency. In addition these circumstances can lead to a limitation of design quality related to early development phases which are often characterized by reduced product information and high degrees of development freedom.

Derived from the concluded challenges of complex products above, some general requirements on the implementation of product models can be determined. On the one hand the goal is to develop a method that leads to increased development efficiency, by implementing as much knowledge from experts and other knowledge sources. On the other hand the simultaneously increasing complexity of the applied methods must be prepared user-friendly to enable an efficient handling of the rising amount of information throughout the entire development processes. This can be achieved by the implementation of methods and algorithms, which lead to a simplification of complex relationships, without neglecting relevant information. In this way, a certain degree of ease of use can be reached to support engineers, which are not primary involved to the complex design methods but bear responsibilities of product-development related decisions.

3.1. Design-related 3D-CAD Master Model

This chapter presents an approach that constitutes the possibilities and potentials of the introduced types of knowledge integration to accomplish the requirements of developing complex products. The widespread utilization of CAD-systems in virtual product development and their abilities of knowledge integration and automation offer a suitable basis for this approach to be based on 3D-CAD. One key to an effective coupling of design-influencing aspects can be the use of a centralized master model, which contains the product geometry, as well as additional information. The realization of master models in 3D-CAD environment is based on the fact that the product itself including its geometry and structure continuously is in focus of the entire development process. Master models not only contain geometrical information but also function-, production- or process-related metadata, depending on their field of application. An example of a comprehensive process-related master model supporting the multidisciplinary collaboration in conceptual development is published in [14]. Within the framework of this research work a novel design-related master model approach was developed which is described in the following. Figure 2 shows the configuration of a design-related master model, which can be used for the development of complex mechanical products. A 3D-CAD based geometry module for visualization and calculation as well as a related data repository represents the main integral parts of the model.

3.1.1. Geometry section

A pre-defined main-module of geometry section includes all components and modules of the entire product as 3D-CAD components and therefore it represents the actual product development status. At least those components with strong functional and geometric interdependencies are content of this module. It simultaneously serves as an assembly structure template where the modules or components of the product can be arranged and managed. In this way, the entire product structure is defined at the beginning and can be filled gradually with geometry data during development progress. Due to the fact, that in initial phases product geometry is only partially or not defined, additional parametric substitution geometry data is integrated to this main-module. These variable geometry models, in terms of component and assembly templates, enable a temporary substitution of all product components and can be hidden after stepwise creation of the original components in shape of rigid or variable geometry models. In this way, continuously meaningful alignments considering important influencing factors can be performed due to a permanent representation of the main-components among the integrated geometry section. Characterized with a high degree of freedom by means of geometry parameterization, these centrally controlled geometry models allow an easy elaboration of variant studies and consequently they are able to increase the efficiency of the development process.

The consolidation of geometry data within a high integrated geometry module for the alignment of product related data is not less caused by the idea of checking the actual development status. Therefore the entity boundary representation in Figure 2 is represented by geometry data in the master model structure for the visualization of predefined boundary conditions to enable spatially-based checks of product geometry positions for instance. Sources for those conditions can stem from internal product specifications or different development disciplines, e.g. a maximum length of product overall dimensions, as well as from external standards and regulations. In particular, such geometry representing boundary conditions is effective by simultaneously depicting different standards, exemplary in case of disposing products in global markets with specific requirements. Caused by the integration into one structured template the boundary geometry can be related to all implemented products, even to the parametric substitution geometry. Furthermore it can be implemented using simple rigid or variable geometry templates up to fully integrated mathematical and logical routines.

An additional benefit of a design-related master model is the integration of simulation- and calculation-procedures into the 3D-CAD environment. Background of this simulation integrated approach is the focus on early development stages in combination with a comparatively low required level of detail. The goal is to enable short simulation cycles in early phases due to geometry-based simulation procedures with adequate level of quality and significance. Especially the integration of kinematic investigations is very efficient, e.g. for products which are using slope or switch mechanisms, where small deformations can be neglected at the beginning of development. Due to the integration into sub-modules within the geometry section, the former extensive data transfer can be omitted which enables advantageous short development cycles particularly regarding variant studies. In addition, CAD-external simulation processes are supplied with required information by use of integrated data interfaces. One important feature of the presented master model approach is the organization of geometry parameters in a pre-defined order, which includes a consistent parameter structure in each component and assembly level, as well as a centralized parameter structure in the main level of the product assembly. This centralized parameter structure is used for direct information exchange with an associated database.

3.1.2. Database section

The data exchange between geometry and database section can be performed in both directions. Depending on the degree of automation, the database section can be directly connected with the geometry section or centrally controlled by a problem-oriented knowledge-based interactive application as presented in the following chapter. Within the framework of this design-related master model, the data repository contains several product-related parameters. The configuration in Figure 2 shows a selection of the types of data used for the present design-related master model. Numerous parameters for control of parameterized geometry, like a previously described substitution-geometry or parameters defining boundary-conditions regarding check geometry, represent the main content of this section. In addition, relevant simulation data or intermediate computation results can be included into the master model approach. All product-related data are tracked in a closed data set, whereby each of them represents a certain configuration of the overall data status. Besides the role of archiving parameters, the database supports intentions regarding data consistency by a compact configuration management to provide common data status and consequently to ensure reproducible development results. In this way, the database serves as a central unit for storage and tracking of product characteristics and functionalities throughout the virtual product development process.

The entire master-model uses a bi-directional interface to external development tasks. External performed simulations, e.g. fatigue- or fluid-dynamics-simulations can be supported with actual product data from the master-model and vice versa the master-model is able to process delivered results within a design-related environment. Based on this interface, several boundary conditions, exemplary derived from production engineering, life-cycle related aspects, initial product specification or information sources, can be considered continuously.

3.2. Process Control and Automation

Based on the application of different knowledge-based design methods and tools in combination with related CAD-templates, the presented master model approach represents a potential basis for efficient design processes. However, a high degree of integration requires the administration of various information and data. As typical characteristic of complex products, this fact leads to a decrease of usability which can result in inefficient development processes.

In addition to the architecture of the introduced master model, a further key element of the present approach is represented by a problem-oriented application as central control unit, illustrated in Figure 3. Using highly-integrated knowledge-based design methods within the CAD-system, this interactive application enables an efficient management of the centralized master model supported by a target-oriented user-friendly GUI (graphical user interface). Due to this, not only super-users but also persons that are not primary involved to the underlying design methods are able to handle the entire system. A bidirectional data interface of the application ensures the management of the automatic controlled design-related master model in terms of separated access to database and geometry section. The latter is built up of a 3D-CAD model for the support of the central data alignment and representation as well as possible sub-modules for different purposes (e.g. simulation). The ability of external controlled master model entities allows the avoidance of fixed linkages and interdependencies. Hence this approach enables a flexible configuration considering the entities' location or maintenance operations. Besides the management of master model-related tasks, this configuration is able to provide several possibilities of data exchange, like the import or export of parameters or CAD-data. Furthermore, the approach can be connected to product data management systems to enable the exchange of different project data, supporting the actual data status.

The adaptive bidirectional interface is controlled by internal routines and procedures as part of the VB.NET-based application, as depicted in Figure 3. Core element of these functions is represented by a comprehensive parameter management unit which enables the handling of all parameters related to the integrated master model. Besides the main idea of exchanging parameters between CAD-environment and database, this unit administrates several parameter changes coming from user inputs or other sources, e.g. results from sub-modules (e.g. for simulation). In this way it serves as a basis for additional internal routines of the application. An implemented CAD-document management enables the administration of all involved CAD documents of the master model by opening and closing the actual required documents according to the performed function. Out of this, the present approach allows a splitting of the sub-modules into several CAD-documents which enables an adjusted load of the workstation and thus an efficient usability even for computers with limited resources. In addition, Figure 3 includes several functions for the management of the master-model's database. Using the bidirectional data interface, an internal database management provides functions for archival storage, tracking of parameters or supports the exchange of datasets to further local installed master model databases of the same type. The main idea includes the deposition of all CAD documents on local workstations to prevent user conflicts within CAD environment. In contrast to the CAD documents, the entire data section of the master model can be located on a centralized server. Each user of the local- or server-installed application is connected to the central located database. In this way requirements for collaborative engineering can be supported and an efficient data exchange among the treated product, especially in early product development phases, can be achieved. As an important feature considering process integration, the present approach is able to perform transfers to external environments or applications which are handled by an implemented data exchange management. In this way, the application can be connected to traditional PDM-systems, exemplary for exchange of actual project data. For

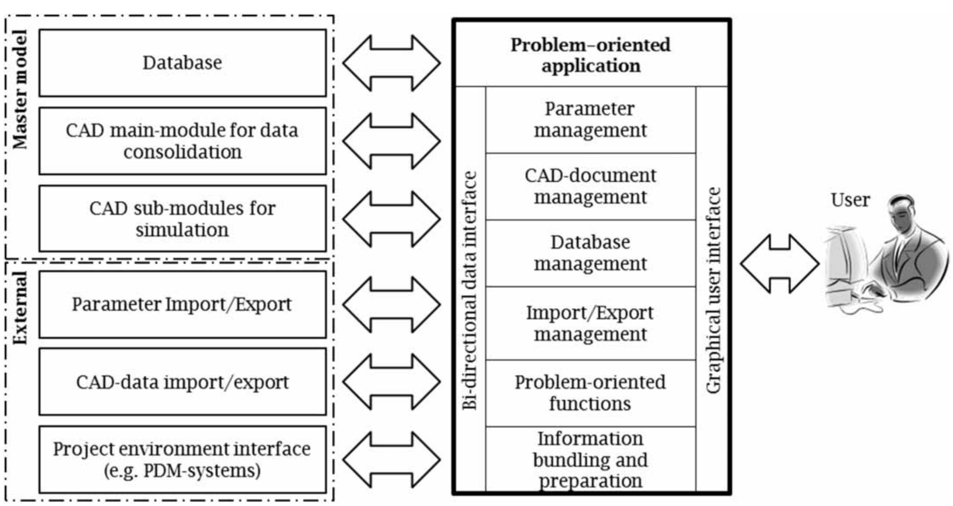

Fig. 3: Problem-oriented application as centralized control unit of the design approach.

additional specific purposes the application allows an import or export of master model parameters or geometry data. Database extracts or imports and exports of native or neutral CAD data can be performed, depending on the available features.

Several units of this application offer a wide range of functionalities which can be supported by automated routines. A main reason for the process control and automation using an interactive application treats the implementation of problem-oriented functions. For example, such routines could be represented through automatic archiving or preparation of actual datasets including the automatic creation of drawings in combination with user-defined visualization features controlled by the graphical user interface. Specific functions can be implemented to handle the simulation data of sub-modules, to allow comparing parameters by means of different datasets or simple but effective features like parameter reset or calculation of recommended parameter values. Besides these problem-oriented functions, the present application contains another key element for filtering and preparation of the handled information. In particular, this functionality is represented by KBD-entities within the CAD system in combination with an external VB.NET-application, which supports the user by feeding the GUI with parameters and information. In addition, this feature serves as data-filter to prepare meaningful and user-acceptable information. Latter is necessary due to a novel kind of handling complexity and stability of the presented approach as described in the following.

3.3. Management of Complexity and Geometric Stability

In this chapter, a method for the management of the introduced approach is presented, which allows the geometric representation and user-friendly handling of complex interdependencies by a simultaneously perpetuation of geometric stability. Product complexity is not only characterized by numerous sub-components but also through complex relations between influencing factors which often have to be represented on component level. In the same way, the implementation of complex relations on component level of modern parametric-associative 3D-CAD environments is very suitable due to a wide range of available knowledge ware in combination with the parameterized geometry.

The present method is based on the intensive usage of the introduced KBD-types. As shown in Figure 4, a comprehensive functional CAD-template states the core element which contains the parametric geometry including necessary parameters. Several boundary conditions, which can stem from various standards or user-defined pre-definitions, are managed in an internal unit for knowledge preparation. This one contains various calculation functions like rules and integrated macros to prepare the complex interdependencies, controlling the parametric geometry. The control of comprehensive parametric geometry as well as the handling of mathematical and logical relations can cause geometry errors due to instable geometry constellations, e.g. undesired geometric intersections.

For this purpose, an erroneous constellation of the user's input can lead to a crash of the CAD-model and furthermore to a time consuming debugging. To avoid this behavior and to ensure effective error prevention, the introduced method contains a combination of KBD routines. In particular, the CAD-template includes a problem-oriented geometry and parameter monitoring unit by use of integrated conditions for stability by application of logical checks, rules, macros and further KBD-entities. The results of these CAD-implemented KBD-functions are handled by the presented interactive VB.NET-application and visualized in the GUI. Considering complex geometries with several degrees of freedom, there can be numerous checks in the template which have to be prepared for user-acceptance. An according unit which is integrated into the presented interactive application bundles the complex response of the template to prepare a simplified feedback message for the user. This enables the engineers to a target-oriented change of their previous parameter inputs. In addition, the method uses an input monitoring unit which prevents obviously faulty insertion to the application. This novel method of monitoring and

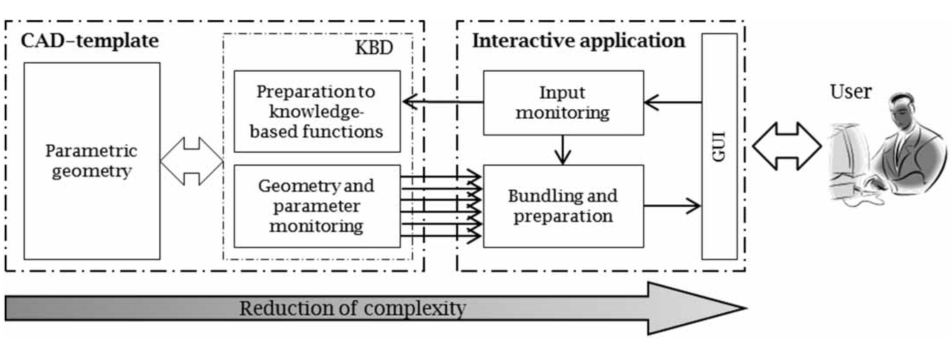

Fig. 4: Knowledge-based method for handling of complexity and stability.

feedback preparation for the operators enables an efficient application of the presented master model approach. Considering the necessity of maintenance, the centrally controlled interface reduces the maintenance effort due to neglected fixed connections between CAD-documents. In addition, the template-based structure enables an easy adaption according changing boundary conditions.

4. APPLICATION OF APPROACH IN AUTOMOTIVE SEAT DEVELOPMENT

Based on the fact that automotive seats represent a main interface between customer and vehicle, seat development states an important field in automotive engineering. It represents a complex challenge in automotive engineering which is mainly caused by numerous interdepend influencing factors. To give a short overview about this challenge, Figure 5 illustrates a selection of these factors grouped in different areas of development disciplines. A styling department works out the outer surfaces of the seat cover and further visible components. To satisfy varying customer demands, the entire seat has to fulfill different comfort issues, reaching from seat structure suspensions up to additional comfort features like electric seat adjustability, seat heaters, integrated air ventilation or even massage-functions to name just a few. In addition the ergonomics point of view plays an important role, for example considering the driver's comfort and the accessibility of pedals, steering wheel and plenty of other control devices at the instrument panel. During the development process several components and modules have to be confirmed with further requirements which exemplary stem from production engineering or financial project controlling. These individual possibilities of seat configurations lead to numerous variants which have to be developed and managed simultaneously.

The most significant influencing factors are caused by safety requirements due to the direct human-machine interaction of a seat. Besides standard demands regarding stability of a seat base frame or the connection to the vehicle body, a large number of further safety issues, especially regarding belt anchorage positions are regulated by legislation. All the different variants of seat configurations have to meet these strong legislative boundary conditions to reach an admission to the related markets. A main challenge in automotive seat development is to survey and handle the complex functional and geometrical dependencies of components and modules which most of them are developed separately in different environments. A continuously adjustment of product data and information in concurrently performed engineering tasks establishes as time consuming and cost intensive work. For instance, the variation of coordinates of a belt anchorage point requires a new simulation loop to evaluate a new belt track in correspondence to a virtual human dummy which again has to be validated to meet the legislative requirements.

The goal is to enable an efficient virtual seat development, especially in early phases which are characterized by a high degree of freedom with comparatively less available product data and knowledge. Comparing this complex situation of automotive seat development with the capabilities of the previously discussed design-related master model, a good correlation can be determined. Thus, the ability of the presented master model approach for supporting the automotive seat development is shown in the following section.

4.1. Design-related Master Model for Seat Development

Based on the configuration of the master model of chapter 3, an exemplary design-related master model was created for automotive seat development as seen in Figure 6. Core elements are represented by a comprehensive geometry module which consists of a main module for consolidation of product-related data and sub-modules for CAD-based simulation of different issues, e.g. belt track.

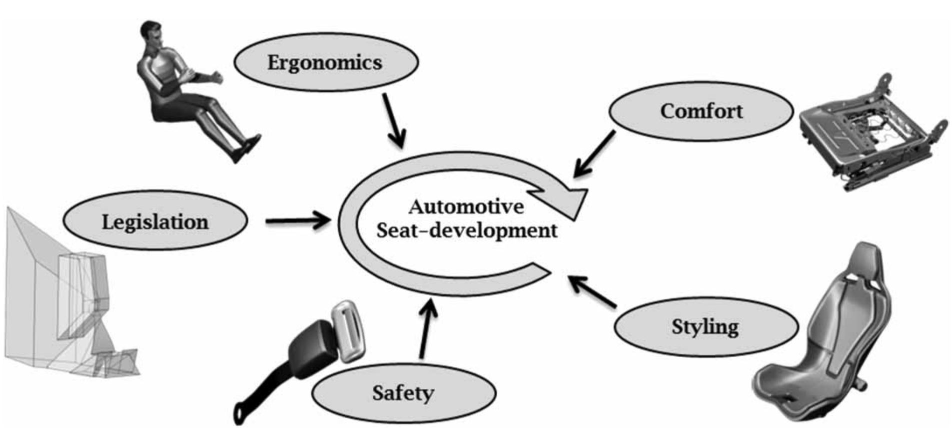

Fig. 5: Main influencing factors of automotive seat development.

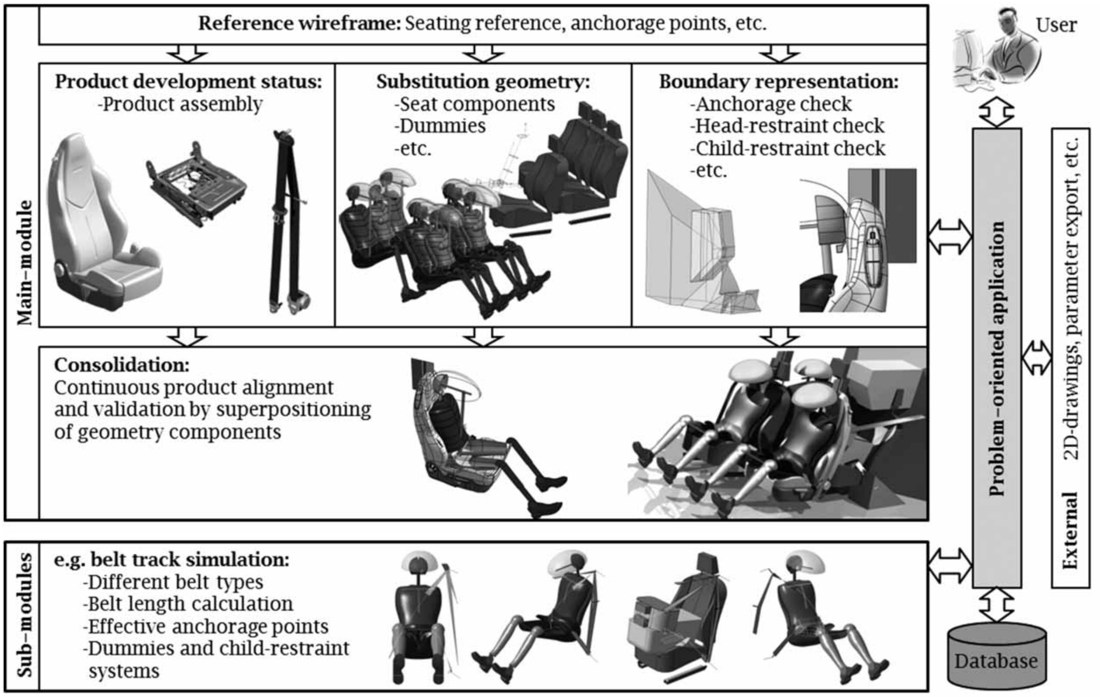

Fig. 6: Design-related master model approach for seat development.

4.1.1. Main-module

In the present application, the main-module is represented by a structured template, an assembly startup model respectively, within one CAD-document. A reference entity contains parametrically controlled geometry, like seating reference points or belt anchorage points. In this way it enables a centralized control for positioning of further CAD components, which are separated into three groups. The first group contains the product structure of the entire seat including close components and holds their actual development status. This enables a continuous overview of the actual data status. A challenge in early development phases is often caused by not completely defined or even not yet available product data. To prevent such lack of data and simultaneously to ensure possible checks regarding legislative requirements, this master model contains parametric substitution geometry. In this way, the conceptual geometry of different dummies, seat components or belt anchorage parts can be used continuously. In addition, this comprehensive high-parameterized substitution geometry allows the efficient elaboration of variant studies and derivations of improvement suggestions.

Independent of the actual representation of data (detailed product or conceptual substitution geometry) several checks considering anchorage points-, head-restraint- or child-restraint-position to name just a few, can be performed using the geometry of the boundary representation entity. To give an example: Due to legislative requirements the belt anchorage points of a seating position have to be located within specific defined areas, which are deposited in the boundary representation entity. The geometric definition of these boundaries is mainly caused by their comprehensive and detailed prescribed standards [1–3] which stem from different legislative organizations. In the following a method for effective implementation of these mentioned areas, as illustrated in Fig. 5 (Legislation), is presented. The goal is to represent these areas considering all influencing factors of different standards within one part document. Background of this idea is the reduction of document amount and size which is a precondition for efficient usage of high integrated master models. Furthermore, the possibility of an efficient maintenance considering changes with regards to content in standards should be ensured. The part document can be seen as an extensive variable CAD-template which contains the parametric geometry of the areas and a KBD-unit according to the template of Figure 4. Within this KBD-unit, several influencing factors are defined in shape of parameters in combination with implemented rules and checks, which are controlled by the interactive VB.NET application. Regarding the present case, these parameters allow the selection of a standard, the type of seat adjustability, passenger position and further influencing factors. Based on the settings of these parameters, the geometry is calculated by use of implemented mathematical and logical relations according to the implemented boundary conditions. An incorrect constellation of these interdepend influencing factors could lead to inconsistent geometry definitions. To prevent such inacceptable behavior the perpetuation of stability has to be ensured continuously. In this way several parametric controlled geometry components from substitution or boundary representation entities are featured with a permanent geometry and parameter monitoring mainly based on KBD-rules and checks as illustrated in Figure 4. The interactive application filters the response of the monitoring to advice the user with constructive information of the geometry status.

As a big advantage of the introduced master model, the super-positioned geometry of several entities can be visualized at the same time, seen in Figure 6. This enables continuous alignment, validation and checks of actual data status through the entire product development process, even in challenging early stages of development.

4.1.2. Sub-modules

Besides the presented main-module for consolidation, there are also deposited sub-modules for CAD-based simulations. Especially in early development phases many variants have to be approved concurrently within short simulation loops. In many cases, the applied CAE environments are mesh-based which often leads to a higher accuracy but simultaneously the effort of simulation preprocessing and thus the duration of the simulation loops increase immediately. Above all, in early development phases such high accurate results of common expensive simulations are often neither necessary nor productive, considering the comparatively coarse input data. Thus a main idea of this master model approach is the replacement of mesh-based simulations by sufficient exact CAD-based calculations which are performed among the mentioned sub-modules.

Within automotive seat development there are several disciplines which allow a CAD-based simulation not only during initial phases but also until series production readiness. Exemplarily the right track of the seatbelt states an important issue. To reach an admission to the Canadian market, the requirements of the so called electronic Belt-Fit Test Device (eBTD, [5]) have to be fulfilled, which prescribes a specific area of the belt track over the upper part of a human dummy's body. In the present approach, a former mesh-based simulation of the belt-track was replaced by a CAD-based calculation, which is implemented in a master model's sub-module, as illustrated in Figure 6. The track of a seatbelt depends on many influencing factors, like the position of the dummy, the bracket dimensions, the selected type of restraint system or the position of belt anchorage points, to name a just few. Therefore these factors represent the main components of this sub-module. With every change of one of these factors in the main-module, an update cycle becomes necessary, which is performed and controlled automatically through the interactive application. The calculation of the belt track is based on a minimum belt length as optimization criterion. The rotational degrees of freedom of the belt brackets for instance require an iterative calculation of the belt track. As a result of this sub-module the belt track including webbing, positions of effective belt anchorage points and components are transferred back to the main-module to check the modified geometry model. This automatically performed procedure allows very short re-design cycles and efficient evaluations of variant studies. Besides the calculation of the belt track, there are further sub-modules which exemplary elaborate distances between structure components and seat cover or even enable the calculation of kinematic-based issues.

4.1.3. Data handling

Several logical and geometrical parameters of the geometry module are administrated and stored in a bidirectional connected database. The parameters are bundled to configurations which each of them defines a complete data status. Analogous to the general approach of chapter 3, the data and information exchange between the modules is centrally controlled by a problem-oriented CAD-external VB.NET application, as seen in Figure 6. A high degree of automation enables an efficient management of parameter configuration and data tracking to earn reproducible results. An external data interface connects the master model with further development disciplines and environments. For product homologation for instance, the user is able to export specific required 2D-drawings containing numerous sections which are created automatically by the application. Furthermore, specific functions are implemented which support an efficient archival storage and data tracking. Besides the possibilities of exporting data, this interface also enables an import of external data, e.g. results from finite-element simulations, or specific information in shape of data-sheets from other relevant development environments like a full-vehicle development department.

5. CONCLUSION

The presented approach of an integrated CAD-based master model is applied in automotive seat development and increases the working efficiency, in particular in terms of collaborative and concurrent engineering. Several involved development disciplines are working locally using the CAD-model and are connected to the centrally deposited database. Even external disciplines, like structural analysis, have access to this database. In this way, they can download the actual data status and upload significant results. These capabilities mean a valuable contribution to support project management in product design. The integrated master model supports initial development stages with intensive parameterized geometry including high degrees of freedom for concept modeling. The results of the implemented functional modules, e.g. for belt track simulation, show a good correlation with the test results in costly hardware-based development. Furthermore, the virtual elaborated results correspond to the outcomes of measurements with extensive certified virtual human models, [10]. In this way it is demonstrated, that a smart usage of KBD methods and interfaces enables an efficient process control by use of integrated automatisms and therefore improves the efficiency of product development cycles.

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