ACTA TECHNICA CORVINIENSIS
– Bulletin of Engineering
Tome X [2017]
Fascicule 2 [April – June]
ISSN: 2067 – 3809

[1.]Mario HIRZ, [2.]Patrick ROSSBACHER

# ENHANCED KNOWLEDGE-BASED 3D-CAD METHODS SUPPORTING AUTOMOTIVE BODY-IN-WHITE PRODUCTION ENGINEERING

[1,2.] Graz University of Technology, Institute of Automotive Engineering, Inffeldgasse 11/II, Graz, AUSTRIA

**Abstract:** Automotive development is based on virtual product and process models and covers both the development of the car itself as well as of the corresponding production and assembling processes. Considering simultaneous engineering approaches, the integration of product-related and production-associated development plays an important role. Based on an exemplary application in automotive body-in-white development, the present paper introduces and discusses the efficient application of enhanced knowledge-based 3D-CAD methods, including data exchange and management. Target is to support data creation and processing through the implementation of specific algorithms. In this way, a continuous method is provided, which closes the gap between different design, simulation, and production engineering processes.
**Keywords:** automotive body in white, joining technology, enhanced design, knowledge-based engineering

## INTRODUCTION

Automotive development has to face numerous challenges, which are resulting from the accelerated change in ecological, technological, economic and social perspectives. Due to growing globalization, vehicle producers and affiliated suppliers focus on profitable market niches in order to react on a rising market saturation. This "search" for niches results in an increasing variety of different vehicle types and so called derivatives, which represent technical variants of a basic vehicle. As a consequence, the development of several car body variants challenges established development processes and requires the introduction of enhanced knowledge-based 3D-CAD methods.

In addition, the need for fuel consumption reduction leads to amplified application of lightweight technologies in automotive body design. This comprises both, lightweight materials and new design solutions including joining technology. Exemplary, the potential of weight reduction with high-strength steel is about 10 % in relation to conventional steel. Aluminum shows potential between 30 – 40 %, and a full carbon fiber body weights about 50 % less than a comparable standard steel body in the same vehicle class.

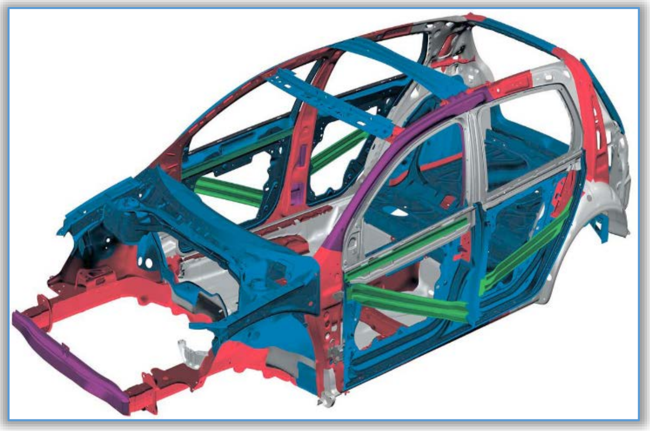

Figure 1 – Steel body structure of the Volkswagen Golf, shown without blanking. The different colors indicate different types of steel [15].

Another important influencing factor for the selection of body material in mass production cars is the cost situation, which can be divided into the consideration of investment costs for production facilities and variable costs for raw material, body panel and parts manufacturing, joining technology, corrosion protection and painting. Details of design, simulation and cost planning in automotive body development can be found in several literature, e.g. [6, 10, 21, 24].

Considering market requirements, lightweight design and development trends, steel bodies show economic advantages in case of larger production sizes above about 100000 pieces per year. But in case of lower numbers of produced car bodies, investment costs for steel deep-drawn and forming tools put this technology in question.

Figure 1 shows an exemplary mass production steel body. Considering investment costs, aluminum body technology comes into play: besides advantageous behavior in view of weight, aluminum space frame design enables the introduction of relatively simple components, which reduces investment costs, but increases costs for assembly and joining techniques.

Figure 2 shows an exemplary space frame aluminum body. Carbon fiber body design represents itself as high technology-solution for sports cars and premium electric cars. The striking physical characteristics of carbon fiber supports development of very stiff and lightweight body structures, which provide leading-edge driving behavior for upscale sport cars, e.g. [3, 13, 14, 19]. Moreover sports cars, one manufacturer has introduced a carbon fiber body for its compact electric car to reduce weight-caused driving resistances, increase driving dynamics and expand the driving range, Figure 3 [4]. Carbon fiber provides advantageous physical behavior, but this technology is the most expensive one for automotive body design by far.

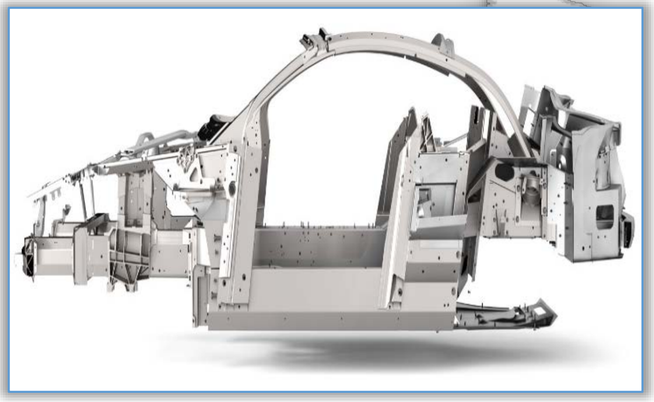

Figure 2 – Aluminum space frame design of the Aston Martin Vanquish, without blanking [13].

Bearing in mind the mentioned aspects of lightweight design, production technology, costs as well as the trend of raising number of car-variants, combinations of different materials will increasingly play an important role in automotive body-in-white design. In this context, joining technology plays a major role for combining components of same or different materials. In automotive steel body production, spot welding plays a major role. A standard car steel body is equipped with about 5000 weld spots, which have to ensure different functional requirements, e.g. body stiffness, durability and crash behavior. In addition, (laser) weld lines come to use in specific applications as well as screws, bolds and rivets. Due to varying material characteristics, aluminum bodies require different design-related solutions and different joining technologies, e.g. (laser) weld lines, bonding, screws, bolds and rivets. The number of weld spots is much lower there.

Figure 3 – Carbon fiber body of the BMW i3 with some adjacent parts [4].

Carbon fiber requires the application of specific joining technology, because of the fundamental different material characteristics, which influence entire body design significantly. In carbon fiber design, the orientation of the fibers within several layers states the basis for advantageous behavior in view of strength, deformation and durability [23]. This anisotropic material behavior must be considered in the structural design as well as in the definition of joining technology. In this way, most components are integrated into the carbon fiber structure, so that an additional joining is not required. In case of adjacent components that have to be mounted, bonding, screws or bolts come to use.

Combining different materials represents the biggest challenge for joining development. Each component pairing has to be optimized in view of functional behavior, lightweight design, production processes and costs. In this context, multi material design requires the application of different, specific joining techniques, which includes all the mentioned technologies with a certain main share of bonding, bolts and screws.

The present publication focuses on the integration of bonding technology into body-in-white development with a focus on the design phase. The design phase plays a major role in automotive development, because the product main characteristics are defined there, [5, 17]. Virtual product models are built-up in computer-aided design (CAD) environment and optimized by use of different types of computer-aided engineering (CAE) applications, [12].

In addition, production-related aspects are considered, and production processes are developed by application of computer-aided manufacturing engineering (CAM) [7, 10]. In digital mock-ups (DMU), the model data are put together and verified for fulfillment of different geometrical, packaging-related and functional requirements.

Figure 4 – Body of Audi R8 e-tron: aluminum space frame technology combined with carbon fiber components, displayed without blanking [1].

The various process steps involve a continuous evaluation and verification of vehicle properties and functions, which is accomplished by the application of proper computer based tools and methods. Within the virtual tool landscape, CAD tools play a key role. Besides the sole geometric description of a part or an assembly, modern 3D-CAD systems provide essential information for subsequent processes, e.g. simulation and production engineering [16]. As illustrated in Figure 5, the consideration of production-related demands and requirements has to start already in the concept phase because of the long preliminary lead-time.

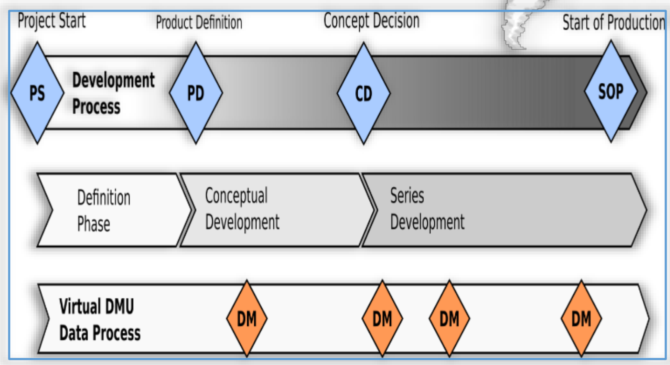


Figure 5 – General schematic overview of a vehicle development process

In order to evaluate and prove the different vehicle properties virtually, a corresponding data process is required, capable of delivering the right data at the right moment with the necessary amount and quality, e.g. for production engineering.

Figure 5 illustrates a schematic data support process with corresponding data milestones (DM). They have to be planned carefully to ensure that the required data can be provided at the right moment with the necessary quality. This forces production requirements to be defined very early in order to be taken into account in data planning. This is a challenging task, since available production tools and mounting elements may vary as a function of global location of the production facility.

## INTEGRATION OF PRODUCTION-RELATED ASPECTS INTO JOINING TECHNOLOGY DESIGN IN AUTOMOTIVE BODY-IN-WHITE DEVELOPMENT

A virtual vehicle body model is created in CAD under consideration of technical aspects and simultaneously or subsequently verified within different CAE systems. Examples for CAE-based verification include the simulation process in the course of vehicle stiffness, durability and crash analysis [11, 16]. The calculation programs identify problem areas and then the results lead to optimization cycles of the CAD model. These loops can be run through several times during the development. A similar loop can be found between CAD and computer-aided production engineering. CAD data are passed to the CAM environment, where they are checked regarding manufacturing related aspects. Again, the improvements within CAM are transferred back to the CAD system and may lead to modifications of the CAD models. One goal of process optimization is to improve the communication and data transfer between CAD, CAE and CAM to accelerate the overall development processes, [7].

Joining technology represents a specific area in automotive body-in-white design. It is used to combine different components of an automotive body, e.g. sheet metal parts, but also components made of different materials. In many cases, production engineering of joining techniques has to ensure the accessibility of robots and provide well-arranged configurations for automated processing [18].

In a body-in-white development process, information regarding the applied joining methods is created in CAD by definition of the corresponding flanges at the concerned components, e.g. sheet metal parts, [9]. The CAD model also includes relevant information about the specific joining technology, e.g. weld spots, screw or bond lines. The simulation processes, which verify the stiffness, durability and deformation behavior in case of different crash scenarios, are supplied with the required information regarding joining techniques. Finally, production engineering is also supplied by the CAD-model with required information, e.g. positions and dimensions, the unambiguous definition of involved components and material information.

During data transfer between these different disciplines of development, the CAD model provides central information of the entire development process chain. Besides a considerable effort for the creation of joining techniques models, the definition of metadata, which cannot be provided geometrically leads to amplified engineering workload. Among others, metadata include the type of connection, the involved components, and the number of circuit of the connections. In joining pairings, the position of the connection surfaces is of great importance, because they provide information about durability and safety-relevant areas.

Due to the increasing importance of specific joining technologies for automotive multi material body development, this publication exemplary focuses on the development process of adhesive technologies within CAD environment [20, 22]. Besides spot welding, weld seams, screws, bolts and rivets, the bonding technology plays a major role because of advantages in view of lightweight design, functional characteristics, lean production as well as low costs. New bonding materials enable powerful connection with an advantageous durability behavior. In addition, different materials can be connected together, which is important for the realization of multi-material design [2].

Figure 6 shows an approach for the efficient integration of bonding technology in virtual automotive body development. The approach includes a comprehensive CAD template model, which provides both technology and process-related information. Within the CAD-model, all relevant connectivity information, as well as the created geometry are prepared for visibility in the connection technique part. This joining technique oriented CAD model includes a specific model structure, which holds the entire data structure of geometry and additional metadata. The structure is used for better overview during development and it also enables to distinguish between different types of joining measures. The implemented tool supports design engineers when processing data from existing components. After selection of the elements to be joined, material properties and wall thickness of the respective flanges are analyzed and tracked as parameters in a designated area in the model structure. The CAD model supports during processing of existing (delivered) information, and it also allows access to additional joining technique related information. All metadata are handled with the help of specific GUIs (graphical user interfaces), which are programmed within the applied CAD software. These GUIs are prepared for the different types of joining technology differently (welding, bonding, screws and rivets), so that all relevant information can be managed.

In addition to the functional aspects of the software, the tool enables an unambiguous denotation and numbering of the various types of applied joining techniques. The nomination considers the specific components, which are combined in the bonding process, the materials and other related aspects. In this way, the design engineer defines the each bonding surface. After that, the numbers of affected surface are defined automatically for the subsequent components. Finally, all connection elements with the previously defined number ranges are labeled with annotations automatically. This text flags support the creation of 2D-drawings, which provide all required information for further simulation processing and production engineering.

Finally, an automated algorithm elects the previously created data. This data monitoring takes place in a neutral format that is transferred to the involved simulation programs. The data bundle not only includes the required parameters, but also the concerned geometry models.

As important information, all coordinate data and geometrical extensions of each bonding surface is included. This information is saved in a predefined structure as it is exemplary shown in Figure 6. For the transfer to the CAE environment, e.g. for simulation purpose, a pre-defined data format is used. That format includes the type of the connection in a predefined way, so that it can be proceeded by the calculation program automatically.

The same applies to functional characteristics, e.g. identification number, safety relevance, materials of component pairings, wall thickness and part-IDs of the joined components. In addition, another format comes to use, which provides information for data transfer into CAM environments.

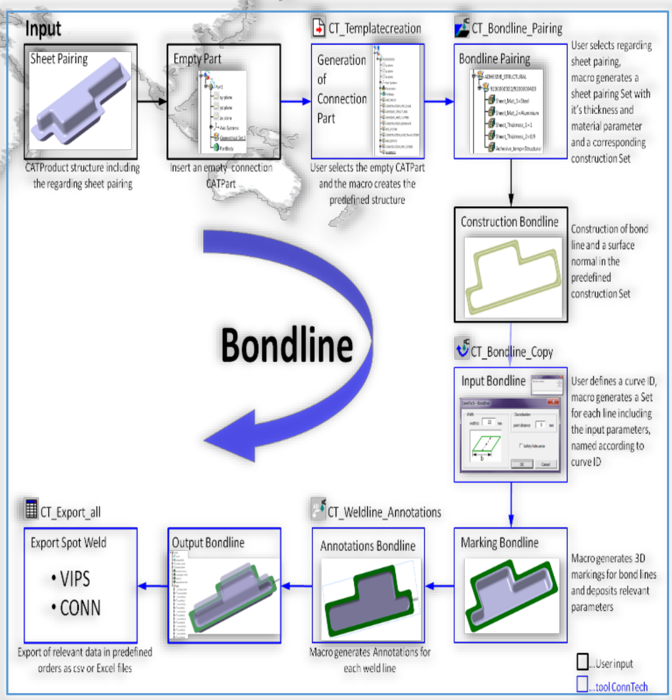


Figure 6 – Exemplary process of bonding in automotive body-in-white development by application of the presented approach.

All the information is specifically tailored for these formats, so that the calculation program or the CAM program prepares no longer obstacles by reading-in the relevant data, supporting effective data transfer.

Respective modifications that may arise during simulation-based investigations in CAE are discharged in a neutral format and transferred back into the CAD environment for further modifications of the design models. The data feedback to the CAD program provides uniform and consistent process results.

The described approach has been implemented in an industrial application, to support the creation, optimization and verification of joining techniques in automotive body-in-white design. The tool is realized as a VBA (visual basic for applications) macro, which is implemented in commercial CAD software [8]. The integration into a commercial software package enables an efficient combination of standard functions for geometry creation and data management with specific programmed operations for the treatment of joining techniques.

**CONCLUSION**

Taking into account steady decreasing development times in automotive industry, automated processes are becoming increasingly important to support engineers in both product development and data management. In this context, automation is able to accelerate development processes significantly, but it also contributes to process reliability.

By a combination of knowledge-based engineering and structured template geometry models in standard CAD systems, a method has been presented, which maintenances creation and structuring of joining technique-related geometry in automotive body-in-white design. It also supports the CAD-based preparation of relevant data for simulation processes and production engineering.

The paper points out new possibilities for improvement of the entire development process of joining techniques by provision of a comprehensive data model, enabling the integration of styling, design, simulation and production engineering. In this way, the application leads to both, reduced development effort as well as increasing data quality.

**Note**

This paper is based on the paper presented at The International Conference Management of Technology – Step to Sustainable Production (MOTSP 2016), organized by the Faculty of Mechanical Engineering and Naval Architecture, Croatian Association for PLM and the University of North, in Porec/Parenzo, Istria, CROATIA, June 01–03, 2016.

**References**

[1] Audi Media center, www.audi-mediacenter.com/en/photos/detail/audi-r8-lms-20154, date of access: 2016-02-15.
[2] Bhowmik, S., Benedictus, R., Dan, Y.: Adhesive Bonding Technology, Handbook of Manufacturing Engineering and Technology, 765-784.
[3] BMW i8, www.bmw.com/com/en/newvehicles/i/i8/2014/showroom/index.html, 2016-02-15.
[4] BMW i3, www.bmw.com/com/en/newvehicles/i/i3/2015/showroom/index.html, 2016-02-15.
[5] Bonitz, P.: Freiformflächen in der rechnerunterstützten Karosseriekonstruktion und im Industriedesign, Springer Publisher, 2009.
[6] Bubna, P.: Impact of light-weight design on manufacturing cost – a review of BMW i3 and Toyota Corolla body components, SAE 2016 World Congress and Exhibition, USA, 2016.
[7] Burr, H.: Informationsmanagement an der Schnittstelle zwischen Entwicklung und Produktionsplanung im Karosserierohbau, Lehrstuhl für Konstruktionstechnik/CAD an der Universität des Saarlandes, 2008.
[8] Dassault Systems, www.3ds.com/products/catia, 2016-01-20.
[9] Frener, G., Thum, K., Hirz, M., Harrich, A.: An application of enhanced 3D-CAD methods with integrated geometry creation algorithms for PVC-seams in automotive body in white design, Journal 3D Research, Springer, 2012.
[10] Grabner, J., Nothhaft, R.: Konstruieren von Pkw-Karosserien, Springer, 2006
[11] Hiermaier, S.: Structures Under Crash and Impact, Springer, 2008.
[12] Hirz, M., Gfrerrer, T., Lang, J., Dietrich, W.: Integrated Computer-Aided Design in Automotive Development - Development processes, Geometric Fundamentals, Methods of CAD, Knowledge Based Data Management, Springer, 2013.
[13] www.astonmartin.com, 2016-02-15.
[14] McLaren Automotive, www.mclaren.com2016-02-10.
[15] Volkswagen AG, www.volkswagenag.com2016-02-10.
[16] Meywerk, M.: CAE-Methoden in der Fahrzeugtechnik, Springer, 2007.
[17] Pahl, G., Beitz, W.: Engineering Design: A Systematic Approach, K. Wallace (editor), Springer Publisher,
[18] Pires, J. N.; Loureiro, A.; Bölmsjo, G.: Welding Robots, Technology, System Issues and Application, Springer, 2006.
[19] Porsche Spyder, www.porsche.com/uk/models/918/, 2016-02-10.
[20] Rossbacher, P., Hirz, M., Harrich, A., Dietrich, W. et al.: The Potential of 3D-CAD Based Process – Optimization in the Automotive Concept Phase, SAE International Journal of Materials and Manufacturing 2, 2009.
[21] Tecklenburg, G.: Karosseriebautage Hamburg, Wie Leichtbau und Elektromobilität nachhaltig die Karosserien beeinflussen, Springer, 2014.
[22] Thum, K., Hirz, M., Mayr, J.: An integrated approach supporting design, simulation and production engineering of connection techniques in automotive

body-in-white development, Journal Computer-Aided Design and Applications, 2013.
[23] Wisner, G., Stammen, E., Dilger, K., Behrens, B.-A.: Adhesively Bonded Blanks for local reinforcements in body-in-white manufacturing, The Journal of Adhesion, Taylor and Francis, December 2015.
[24] Wallentowitz, H.: Freialdenhoven, A., Olschewski, I.: Strategien in der Automobilindustrie, Technologietrends und Marktentwicklungen, Springer, 2009.

ISSN:2067-3809