Title:
A Contribution to Optimized Data Exchange Supporting Automotive Bodywork Engineering

Authors:
Alexander Kreis, alexander.kreis@tugraz.at, Graz University of Technology
Mario Hirz, mario.hirz@tugraz.at, Graz University of Technology
Severin Stadler, severin.stadler@magna.com, Magna Steyr Fahrzeugtechnik AG & Co KG

Keywords:
CAD, Data Exchange, Joining Technology, CAx Information Exchange, CAD-CAE Integration, Knowledge-based Engineering, xMCF, Process Optimization, Automotive Industry, Bodywork Development

DOI: 10.14733/cadconfP.2019.18-23

Introduction:
Continuously strengthened boundary conditions in the automotive industry require constantly performed improvement of development processes. Besides propulsion technology and automation systems, the automotive body (BIW – Body-In-White) development, including the entire field of material- and joining technology, represents an important field of investigations. Development targets include body stiffness and durability, optimized crash behavior and the reduction of body weight to decrease driving resistances and thus fuel consumption and exhaust emissions [14]. This reduction of vehicle body mass can be achieved by a variety of ways, whereby the use of different materials – respectively material combinations – plays a significant role. This means that joining technologies have to be adapted to the increasingly applied multi-material design solutions, which leads to new challenges in both areas, the creation and administration of joining technology data as well as the exchange of these data and meta data between different computer-aided design and engineering (CAx) disciplines.

The present extended abstract provides an overview of state-of-the-art automotive bodywork development processes and derives the enhanced requirements on the management of joining technology data; in particular on data creation, administration and exchange procedures.

Problem Statement – from the Viewpoint of an Automotive Tier 1 Supplier:
Due to the fact that an automotive engineering service provider has to deal with different customers and OEMs (Original Equipment Manufacturers), each project differs from the others. This means that every customer, has different requirements in view of data management and data exchange processes. Management processes cover the full range of data lifecycle, starting with creation of data, followed by administration and data processing, and ending with the transmission of the resulting information. In order to describe the different customer requirements in more detail in the present work, they are divided into the following three project types:

- Type I – Projects, where the main engineering workload takes place in the customer-specific CAD environment (e.g. by use of remote machines). In Type I projects, the customer provides all processes, tools and methods for the data exchange process, which means that the degrees of freedom in terms of data management are restricted. This requires that the supplier must be able to handle the specified processes, tools and methods and cannot use its own.
- Type II – This type of project is a mix between Type I and Type III projects. Data created in the customer-specific CAD environment are imported into the supplier-internal environment, where the main engineering workload is performed. Resulting data are exported into the customer environment for evaluation and implementation into the customers full-vehicle data structure.

- Type III – This type of project uses processes, methods and systems from the supplier-internal environment only. So, there are nearly no boundary conditions regarding software systems to be used. The entire workload is performed within the internal environment, which leads to a higher degree of freedom in terms of data administration. Typical Type III projects (e.g. cooperation projects with start-up companies) use supplier-internal development processes.

The above-mentioned classification of typical project types enables a segmentation of customer requirements and serves as a basis for the subsequently performed creation of enhanced data management processes. Target is to define consistent processes, which enable the exchange of CAD development data of BIW joining technologies in all three types of projects.

State of the Art:

Automotive Body Design – As mentioned, BIW development has changed in recent years, whereby this work is concentrating on the changes of material combinations and different applied types of joining technologies [11], [21]. One main goal in the automotive industry is to reduce the vehicle weight by reducing the body weight [16], [19], [22]. This weight reduction was achieved during the past few years by using new material combinations. For example, the application of an aluminum body can reduce the body weight up to 40 percent in comparison with a standard steel body [6]. Tab. 1 shows selected examples of currently used body material combinations. It should be noted that the different types of aluminum, steel, high strength steel and SMC (Sheet Molding Compound) are not distinguished here.

Material	*Volvo V90*	*Peugeot 3008*	*Aston Martin DB11*
aluminum	6%	5%	53%
standard steel	27%	27%	5%
high strength steel	67%	62%	
SMC		6%	42%

Tab. 1: Comparison of BIW material combinations of exemplary selected cars manufactured in 2016 [12], [17], [18].

Compared with the situation about 20 years ago, when a vehicle bodywork was mainly manufactured out of standard steel, the current situation is more complex. Besides standard steel bodies, which are mainly used in low-budget vehicles, different types of material – respectively material mixes – occur. This leads to the fact that the development of joining technologies became more complex, too.

Type of joining technology	*Volvo V90*	*Peugeot 3008*	*Aston Martin DB11*
spot weld	5250 pcs.	4157 pcs.	
rivets			1278 pcs.
clinches		14 pcs.	
weld stud	247 pcs.	83 pcs.	
screws			52 pcs.
hemming flanges		19,87 m	
seam weld	9,3 m	150,29 m	
adhesive line	79,4 m	20,22 m	152 m

Tab. 2: Comparison of different types of joining technologies of exemplary selected cars manufactured in 2016 [12], [17], [18].

One example represents the FIAT Uno (manufactured in 1986), which had a full standard steel body with all components connected by about 2700 spot welds in total [13]. As a difference, modern multi-material design bodywork requires the implementation of different types of joinings. The complexity in view of modern cars is displayed in Tab. 2, which shows the numbers of the different applied types of joinings in three selected state-of-the-art cars.

CAx in Automotive Industry & Data Exchange – Because of rising complexity of materials, manufacturing procedures and joining technology, the complexity and amount of data in the development of automotive bodywork is increasing. In this context, effective data management processes have to be introduced to ensure that all information is handled and transmitted between the different CAx environments effectively [7], [10]. These exchange processes of 3D CAD models incorporate the usual appropriate data formats [4], [5] and the applied tools are responsible for correct data exchange processes [8]. For all further considerations, the term data is distinguished into the following two terms:

- Geometry data: contains information about geometric dimensions and meta data (e.g. thickness, weight, etc.) of the sheets/parts.
- Joining technology data: contains information regarding all joinings, including meta data (e.g. type of joining, coordinates, normal direction, diameter, length, etc.).

While the file format JT is often used for the exchange of geometry data, the situation is much more complex for the exchange of joining technology data. In the field of joining data exchange, there are various ways in which these data can be transferred. A new and more efficient approach must consider that joining technology data can be available any file format.

Approach – Data Model to Support an Optimized Data Exchange Process:

As mentioned there is a variety of different formats and ways how CAD data, especially joining data can be transmitted between CAx environments (cf. [9]). In addition, existing data exchange processes have to be adapted in a way that they are suitable for different occurring projects (cf. Type I, II and III). Furthermore, the data exchange process must be optimized in such a way that no unwanted information losses occur and a variety of data formats can be processed. Fig. 1 shows an approach of an optimized data exchange process, which is supported by specific tools to guarantee a full working process.

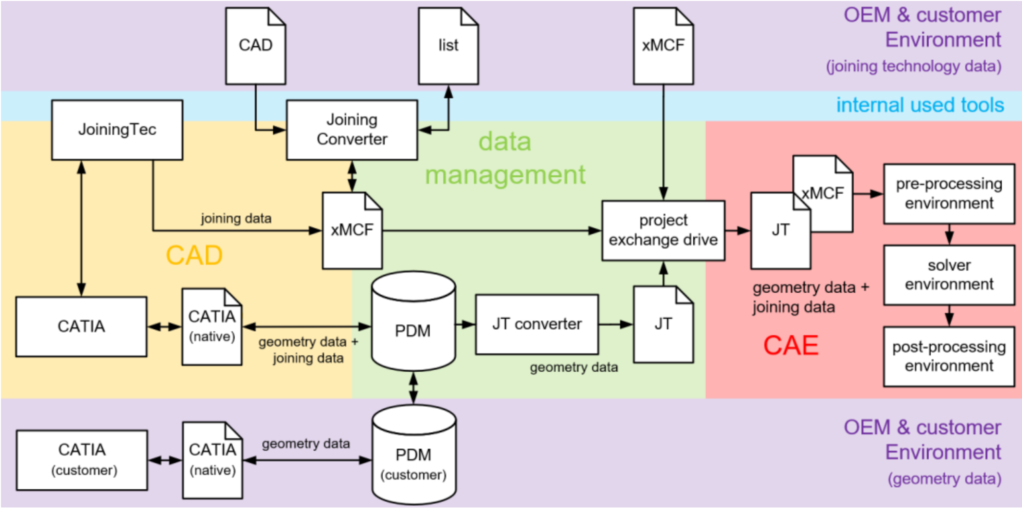

Fig. 1: Optimized data exchange process.

For a better understanding, the optimized process between CAD and CAE environment is divided into five areas (CAD, CAE, customer and internal used tools environment and data management), highlighted by different colors.

CAD environment – The creation of geometry and joining data takes place in the CAD environment, whereby it does not matter if the CAD environment is placed internally (Type III), partly or completely in the customer environment (Type II) or the access is enabled by a remote system (Type I). In the CAD environment there are different tools for creation and administration of data. "CATIA" [2] and "Siemens NX" [20] (Fig. 1 exemplary shows the optimized data exchange process by using "CATIA") are used to create geometry data and the internal tool "JoiningTec" or any customer-specific tool can be used to create joining technology data. Additionally, “JoiningTec” has included an xMCF converter, which allows the joining data export directly in xMCF file format [3].

Data management – Data management is responsible for managing the native data received from the CAD or customer environment. A PDM (Product Data Management) system is used to manage the data and by using standard converters the stored geometry data are converted into the neutral data format JT [1]. The converted geometry JT files are forwarded into the project exchange drive. As soon as the joining data are available in xMCF format, they are also transferred to the project exchange drive.

Customer environment – In case that the customer provides already available geometry or joining data, the process enables an integration of these data into the development process at the supplier. In order to import the already created customer data into the supplier system, two PDM systems (one installed at the customer and an internal one) are normally used. The joining data, which are provided by the customer, may occur in different CAD formats and different list formats (e.g. Excel, etc.). With the target to enable an integration of different data formats and structures delivered by different customers, the process provides a conversion into a uniform xMCF format that can be used for further processes. The xMCF data format, based on xml, is preferred for the exchange of joining technology data, because it is easily readable (xml structure), a neutral file format that can transmit all necessary information (no unwanted data losses), and it can be imported effortlessly into the CAE environment.

Supporting tools – Besides the already mentioned tool “JoiningTec”, used for administration and creation of joining data, the so-called “Joining Converter” is necessary. This tool allows to convert any type of customer-specific joining technology data (list or CAD format) into an xMCF file. Therefore, this converter must have a high flexibility in the settings and guarantee that the created xMCF file always has the same file structure. Although, “JoiningTec” provides an internal xMCF converter, the tool “Joining Converter” is necessary for projects where “JoiningTec” cannot be used (e.g. Type I and Type II projects). In addition, the “Joining Converter” provides the function to convert an xMCF joining data file into a customary list joining data file. This could be necessary for the re-import of joining technology data into the customer-specific environment.

CAE environment – The last area that is included in the data exchange process is the target zone, which receives both joining data (xMCF) and geometry data in JT format out of the project exchange drive. For geometry data, the incoming information must be in form of a BREP (Boundary REPresentation) [15], which means that the geometry can be described mathematically more precisely. JT offers the possibility to transmit BREP geometries while all background information (e.g. design history) is deleted, resulting in a smaller file size. As for geometry data, certain boundary conditions must be fulfilled for the transmitted joining technology data. This means that each joining technology point (linear and surface joinings are divided into several individual points with a defined distance) must contain the parts to be joint as well as the coordinates and certain parameters (e.g. diameter, thickness, height, etc.). Since each type of joining technology (can also be customer-dependent) uses different parameters (e.g. spot welds require coordinates and diameter, rivets require coordinates, head diameter, length, type of rivet, etc. [3]), the xMCF format is very suitable for transmission due to its flexibility.

Application of the Approach:

The application of the new approach of optimized data exchange is explained by use of the three previously introduced types of projects.

Type I projects – Fig. 2 shows the optimized data exchange process for Type I projects, where joining data are created in the customer-specific CAD environment, usually with remote machines.

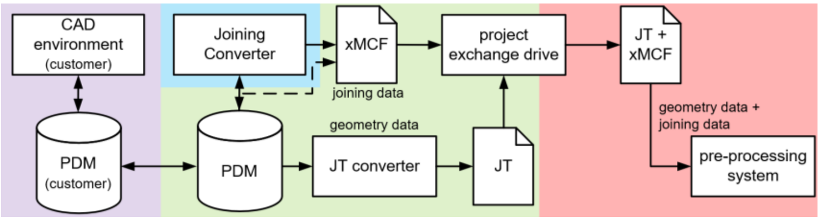

Fig. 2: Application at Type I project.

The data are then exchanged using two PDM systems, whereby joining data can be exchanged, either as list, xMCF or CAD format and geometry data, as CAD native or JT file. In case that geometry data are received as native CAD file, the required JT format can be produced by means of a “JT converter”. If the joining data are not available as xMCF file, the tool "Joining Converter" is used to create it. Once the correct data formats have been created, the files can be forwarded into the project exchange drive for use in the CAE environment.

Type II projects – In comparison to Type I projects, CAD data are created partly in the customer environment (so called COP – Carry Over Parts) and partly in the supplier-internal environment. This means that both must be combined in the PDM systems. After the combination, the two tools “Joining Converter” and “JT converter” create the two necessary file formats xMCF and JT, which are then transferred to the project exchange drive.

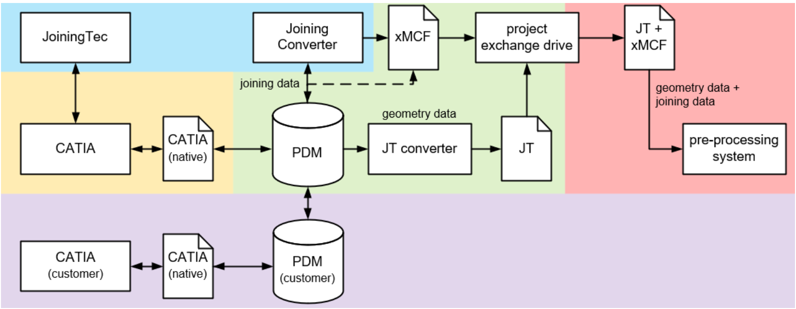

Fig. 3: Application at Type II project.

Type III projects – Since this type of project is a supplier-internal project, all internal tools and processes can be used. Data are created in the internal CAD environment. The tool "CATIA" is used for creating geometry data, while the creation of joining data takes place in "JoiningTec", an integrated sub-tool in "CATIA". The generated joining and geometry data are forwarded into the PDM system where it is stored. While it is possible to create the xMCF file directly with "JoiningTec", the JT creation takes place in the "JT converter". All necessary data can now be exchanged via the project exchange drive.

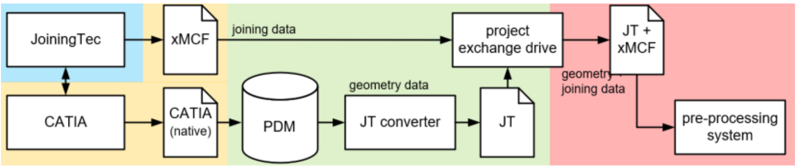

Fig. 4: Application at Type III project.

Conclusions:

In summary it can be stated that the introduced optimized data exchange process for joinings is working for all types of projects and furthermore for all possible occurring requirements an automotive supplier must deal with. Additionally, it is possible to implement certain customer requirements, like different file formats or the way how data are exchanged. Hence, it is possible, to use the processes and tools of the customer or the internal ones. Due to the implementation of a uniform exchange process, the amount of information can be minimized and the data transfer efficiency increases. Therefore, the introduced data model provides a good leverage point for an intelligent integration of knowledge-based design methods and design automation into automotive body development.

In a practical application in the automotive industry, it was shown that by applying the optimized data exchange process, including the above-mentioned tools, the time required to fulfill all tasks in the CAE environment can be reduced from around four to three weeks. This time savings corresponds to an optimization of 25 percent per simulation loop (4-6 loops for a complete vehicle development).

Acknowledgements:
This work was funded by the Austrian Research Funding Association (FFG) under the scope of the Beyond Europe Program.

References:
[1] Dankwort, C.-W.; Ovtcharoca, R.; Weidlich, R.: A Concept of Engineering Objects for Collaborative Virtual Engineering - Automotive Case Study, ProSTEP iViP Science Days 2003, Dresden, Germany.
[2] Dassault Systemés CATIA, http://www.3ds.com/benelux/, access date: 2018-12-19.
[3] Economidis, N.; Franke, C.; Golumba, J.: xMCF – A standard for describing connections and joints in the automotive industry v3.0, FAT, Berlin, Germany, 2016.
[4] Eigner, M.; Stelzer, R.: Product Lifecycle Management, Springer, Berlin, Germany, 2009.
[5] Hirz, M.; Dietrich, W.; Gfrerrer A.; Lang, J.: Integrated Computer-Aided Design in Automotive Development, Springer, Berlin, Germany, 2013.
[6] Hirz, M.; Rossbacher, P.: Enhanced Knowledge-based 3D-CAD methods supporting automotive Body-in-white production engineering, MOTSP 2016, Porec, Croatia, 2016.
[7] Hirz, M.; Rossbacher, P.; Gavačová, J.: Future Trends in CAD – from the perspective of automotive industry, Computer-Aided Design and Applications, 14(6), 2016, 734-741. https://doi.org/10.1080/16864360.2017.1287675
[8] Kovács, G.-L.; Kochan, D.: Digital Product and Process Development Systems, IFIP TC 5 International Conference, Springer, Dresden, Germany, 2013.
[9] Kreis, A.; Hirz, M.; Stadler, S.; Salchner, M.; Rossbacher, P.: Convenient Connection Technology Data Model Supporting Optimized Information Exchange between CAx-Systems, Computer-Aided Design and Applications, 15(5), 2018, 771-778. https://doi.org/10.1080/16864360.2018.1441244
[10] Lee, K.: Principles of CAD/CAM/CAE Systems, Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA 1999.
[11] Malen, D. E.: Fundamentals of Automobile Body Structure Design, SAE, Warrendale, PA, USA, 2011.
[12] Nedic, S.; D'Elia, A.; Palmquist N.: The all-new Volvo V90 car body, EuroCarBody 2016, Bad Nauheim, Germany, 2016.
[13] Nickel, W.: Sein Name war Programm, Zeit Online, https://www.zeit.de/mobilitaet/2013-11/autoklassiker-fiat-uno#comments, access date: 2018-12-22.
[14] Niikura, A.: The impact of the application of aluminum, ATZ Extra Issue - Motor Fan Special Edition illustrated (Aluminum Technology 4), 2018.
[15] Nof, S.-Y.: Handbook of Automation, Springer, Heidelberg, Germany, 2009.
[16] Pahl, G.; Beitz, W.; Feldhusen J.; Grote, K.-H.: Engineering Design: A Systematic Approach, Springer, Berlin, Germany, 2007.
[17] Pugh-Jones, Y.; Richardson, P.; Walker, F.: Aston Martin DB11, EuroCarBody 2016, Bad Nauheim, Germany, 2016.
[18] Robert, H.; Scherrer, J. M.: New Peugeot 3008, EuroCarBody 2016, Bad Nauheim, Germany, 2016
[19] Sama, H.: Holistic Integration of Product, Process and Resources in the Automotive Industry using the Example of Car Body Design and Production", Ph.D. Thesis, University of Karlsruhe, Germany, 2007.
[20] Siemens NX, https://www.plm.automation.siemens.com/en/, access date: 2018-12-19.
[21] Thum, K.; Hirz, M.; Mayr, J.: An integrated approach supporting design, simulation, and production engineering of connection techniques in automotive body-in-white development, Computer-Aided Design and Applications, 11(4), 2013, 411-416. http://dx.doi.org/10.1080/16864360.2014.881183
[22] Weber, J.: Automotive Development Processes – Processes for Successful Customer Oriented Vehicle Development, Springer, Munich, Germany, 2009.