Title:
Smart Joining Technology Tool – AI-based creation of Joining Technology Elements

Authors:
Alexander Kreis, alexander.kreis@tugraz.at, Graz University of Technology
Hussein M.A. Hussein, hussein@h-eng.helwan.edu.eg, Helwan University Cairo

Keywords:
Knowledge-based Design, Process Optimization, Smart Joining Technology, CAx, Automotive Body Development

DOI: 10.14733/cadconfP.2023.169-173

Introduction:
Due to a rapidly advancing automotive industry characterized by constantly changing boundary conditions and requirements, such as the reduction of local CO_2 emissions in the driving cycle, production processes and facilities as well as automotive development and engineering processes must also be adapted. On the one hand, entire production halls must be converted from the classic combustion engine to electro mobile applications, while on the other hand, advancing digitalization plays a major role, particularly in development and engineering processes.

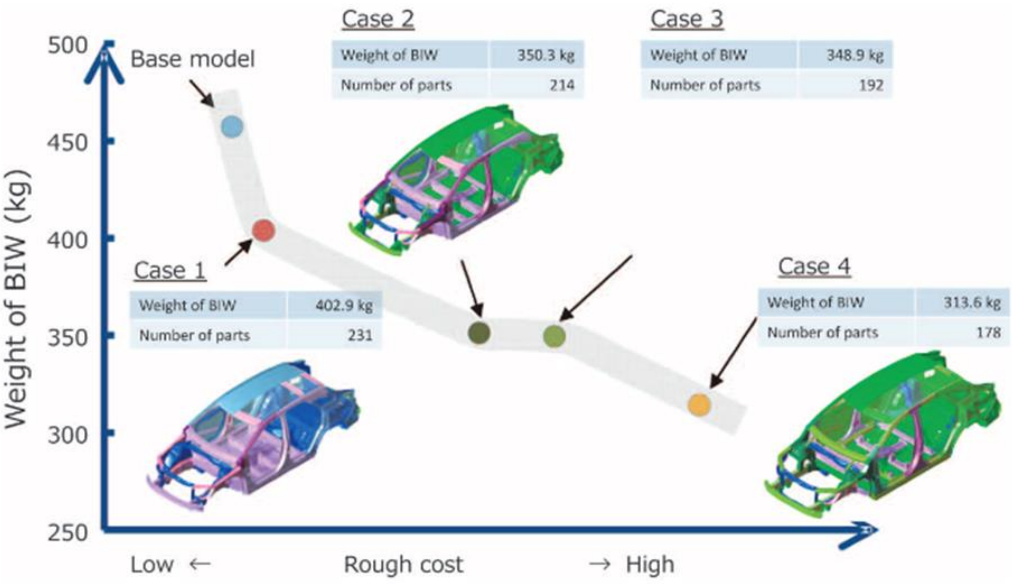
In addition, automotive suppliers and OEMs are under enormous pressure due to globalization, a highly competitive market and stagnating sales numbers in many major target markets. One way to withstand this pressure and increase competitiveness is to optimize the use of resources and time. Particularly in the development of vehicles or individual vehicle components, there is enormous potential to save resources and time to ensure accelerated development and thus earlier market launch of products.

Another trend in the automotive industry that has already been observed for several years is the use of different materials in the body-in-white (BIW). The so-called multi-material body design combines the advantages of a cost-effective and at the same time weight-saving body structure. In addition to the many advantages of multi-material body design, there is also the increasing complexity of the necessary joining technology elements. While BIW made of different types of steel only uses spot welds and weld seams to join two or more sheets, BIW made of multiple materials (e.g., steel, aluminum, CFRP (carbon fiber-reinforced plastic), magnesium or other plastics) usually uses a variety of joining elements. This diversity means that CAD as well as CAE and CAM engineers have an increased additional workload when developing BIWs [9], [12].

For these reasons, the extended abstract presents a novel approach in the context of an AI-based tool to support development and design processes. The aim of the tool utilized is to support engineers with the help of a large amount of high-quality data and to make a prediction as to which joining element is best suited for the components to be joined. The predictions incorporate knowledge and parameters from CAE and CAM development environments [9].

State-of-the-Art:
Vehicle bodies today are made from a variety of different materials. From pure steel bodies over aluminum bodies to multi-material bodies, engineers have to make a decision between cost efficiency and optimized weight and safety criteria. However, not only the material itself, but also the joining elements play a major role in the design and production of an automotive body. Modern car bodies consist of several thousand, up to 10,000 joining elements to assemble the entire body, c.f. [4], [6], [8].

Fig. 1 gives an overview of different material combinations in an exemplary automotive BIW in terms of BIW weight, cost, and number of parts. As shown in Fig. 1, there are different strategies for manufacturing a BIW. While decades ago, the predominant combination to produce a BIW was a steel-based body joined by various welding disciplines, today multi-material BIWs are mostly used in combination with a variety of joining technology elements.



Case 1

Material constitution	Rate (%)
< TS590 MPa steel	24.1
≧ TS590 MPa steel	32.9
≧ TS780 MPa steel	38.3
Hot stamping steel	3.8
Al Extrusion	0.9

Case 3

Material constitution	Rate (%)	
Steel		61.4
Al Extrusion	4.8	
Al sheet	26.2	38.6
Cast Al	7.6	

Case 2

Material constitution	Rate (%)	
Steel		50.1
Al Extrusion	12.0	
Al sheet	30.1	49.9
Cast Al	7.8	

Case 4

Material constitution	Rate (%)	
Steel		27.5
Al Extrusion	20.5	
Al sheet	37.6	72.5
Cast Al	14.4	

Fig. 1: Different material combination in an exemplary automotive BIW in regard to weight and costs, referred to [10].

This change to a cost-efficient and even lightweight body combined with optimized safety requirements has also an impact on development and engineering processes. The used variety of materials and joining technology elements causes a more complex development of automotive bodies and products. Currently, CAD engineers must decide whether to use element A or element B of the joining technology.

Of course, this decision is made with the support and feedback of CAE and CAM engineers; in so-called CAD-CAE respectively CAD-CAM optimization loops. However, these CAD-CAE / CAD-CAM optimization loops are very time-consuming and resource-intensive, which slows down the overall development and thus puts the manufacturer at a disadvantage in terms of competitiveness. In addition to the fact that current CAD-CAx optimization loops are very resource-intensive, the fact of data quality / data status must also be taken into account. Since in the automotive development and manufacturing process as many tasks as possible are to be shifted to the early phases (cf. [1], [2], [5], [11]), the selection of a suitable joining technology element depends on the data available at this point of development. For example, the selection of the appropriate material, weight of the components, mechanical dimensions, crash and durability properties, etc. couldn't be available at that stage. Since changes during the project, e.g., the integration of CAD-CAE or CAD-CAM optimization loops results, etc. may occur, the selection of suitable elements of the joining technology in automotive engineering had to be changed several times, which in turn delayed the development.

To overcome the barrier of a cost- and time-inefficient development in terms of selecting the appropriate joining technology the engineers must be supported by tailor-made tools which enhance automotive development and engineering processes [7]. Therefore, the next section introduces a novel approach of a smart joining technology tools (named *SJTT*), which supports engineers with predictions based on high-quality data, to select the appropriate joining technology element combined with an accelerated development.

Smart Joining Technology Tool:
According to [5] and [8], the automotive development process is divided into five sections: “definition”, “concept”, “pre-development”, “series development” and “pre-series & SOP”. Fig. 2. shows the different stages in logically sequenced order.

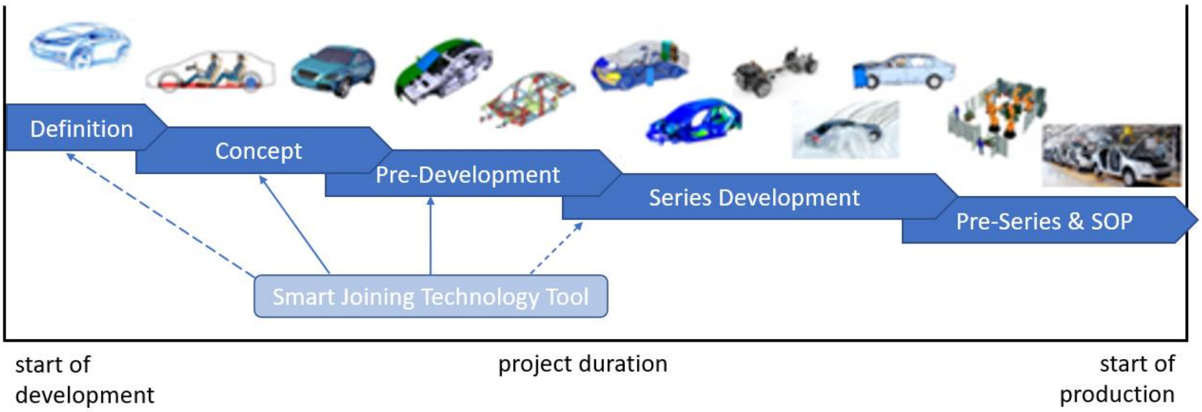


Fig. 2: Automotive development process, according to [5] and [8].

Computer-aided disciplines (CAx) play an important role, especially in the early stages, which means that these phases have the highest potential for intervention in development. Beside the phase “definition” in that among other things feasibility studies, technical assessments and cost analyses are carried out, the phases “concept” and “pre-development” are of utmost importance for the creation process of joining technology elements. For this reason, the tool supports the individual development stages in both phases, “concept” and “pre-development”, as well as in large parts of the phase “series development”.

Fig. 3 gives an overview of the systematic workflow of the *SJTT*. As initial input data, the *SJTT* either automatically or manually checks the 3D CAD model. In the "automatic check" mode, the *SJTT* checks all components; in the "manual check" mode, the user must check the components and thus find the

Proceedings of CAD'23, Mexico City, Mexico, July 10-12, 2023, 169-173

coordinates himself. The term components refers to all individual parts, such as metal sheets, which are necessary for the production of the BIW. In order to predict a suitable joining technology element, installation space tests are first carried out at the automatically or manually selected coordinates to determine which joining technology elements are suitable from an installation space point of view. Furthermore, the *SJTT* checks automatically how many components (usually between two and five in the automotive industry) need to be joined at the selected coordinates. The components to be joined are then analyzed on the basis of the underlying 3D CAD data. This means that all the necessary data and properties from the 3D CAD model, such as the number of components to be joined, the materials of the components and results from space analyses, are available.

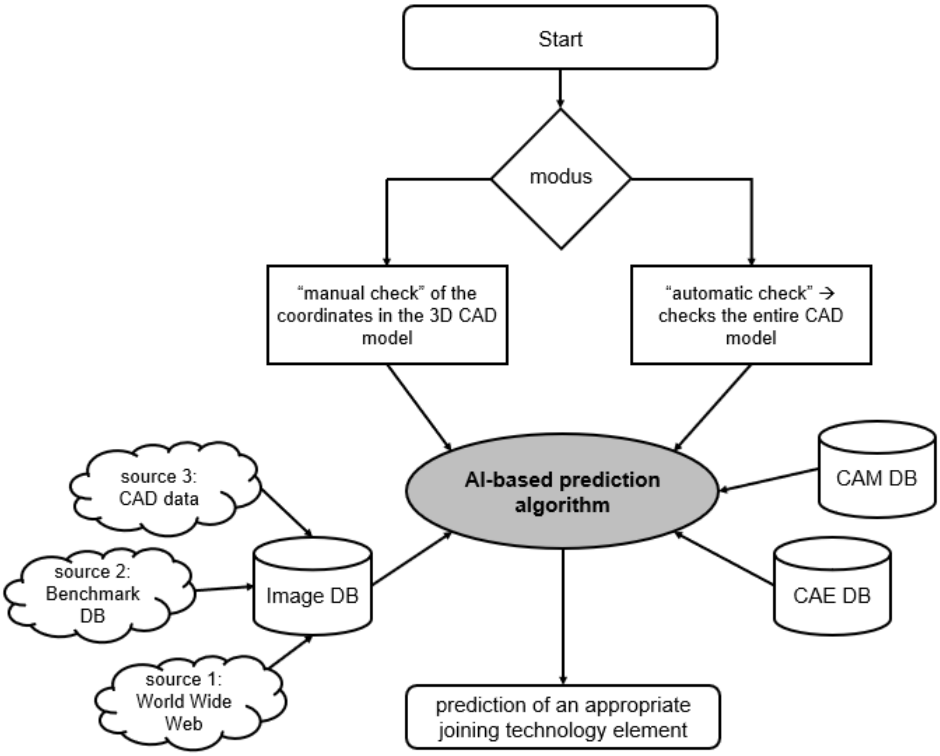


Fig. 3: Systematic workflow of the *SJTT*.

As a next step, the AI-based prediction algorithm in the *SJTT* checks whether further criteria and parameters need to be considered. Several databases (DB) are used for this purpose. On the one hand, high-quality data from CAE and CAM databases and on the other hand, image engine databases are available. The CAE and CAM databases contain a large amount of data from projects that have already been successfully completed and benchmark databases. These support the AI-engine in the prediction process. Furthermore, this prediction process is supported by a high quantity of images from different sources. An image engine generates high quality data out of the vast number of images by a developed algorithm. The last decisive point for the prediction is the economic aspects of the respective joining processes, c.f. [3]. At the end of the *SJTT* workflow, the engineer is provided with a prediction of the most suitable joining technology element, selected on the basis of the available parameters and criteria. These predictions support the engineers and offer an approach to reduce the number or even completely replace CAD-CAE or CAD-CAM optimization loops.

Conclusion:

The novel approach presented here offers a virtual product that support automotive development and engineering processes, as well as the engineers in their daily business. The *SJTT* uses an AI-based prediction algorithm which, on the one hand, predicts the appropriate joining technology for the individual components to be joined, by using the 3D CAD model data and, on the other hand, available data sources. These data sources provide a vast number of image data combined with stored knowledge of CAE and CAM environments.

The *SJTT* is a customized virtual product that helps accelerate automotive development and engineering processes while at the same time resources are saved, competitiveness for the manufacturer will increase and CAD-CAx optimization loops will be reduced. The utilization of the *SJTT* in automotive development processes opens great possibilities for significantly shorter project duration and thus leads to earlier market entries of the automotive products.

References:

[1] Binder, M., Gust, P., Clegg, B.: The importance of collaborative frontloading in automotive supply networks, Journal of Manufacturing Technology Management, 19(3), 2018, 315-331. https://doi.org/10.1108/17410380810853759

[2] 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, 2003.

[3] Malen, D. E.: Fundamentals of Automobile Body Structure Design, Warrendale, Pennsylvania, USA, SAE, ISBN 978-0-7680-2169-1, 2011.

[4] Hachino, M.: Evolving Joining Technologies for Aluminum, ATZ Extra Issue – Motor Fan Special Edition illustrated (Alumium Technology 4), 2018.

[5] Hirz, M.; Dietrich, W.; Gfrerrer A.; Lang, J.: Integrated Computer-Aided Design in Automotive Development, Springer, Berlin, Germany, 2013. https://doi.org/10.1007/978-3-642-11940-8

[6] Kreis, A.: Tailored Data Exchange Processes for Automotive Body Development, Ph.D. Thesis, Graz University of Technology, Austria, 2020.

[7] Kreis, A.; Hirz, M.; Rossbacher, P.: Methods for CAD-Automation – Possibilities, Limits and Challenges, Computer-Aided Design and Applications, 18(4), 2021, 849-863. https://doi.org/10.14733/cadaps.2021.849-863

[8] Kreis, A.; Hirz, M.; Stadler, S.: A Contribution to Optimized Data Exchange Supporting Automotive Bodywork Engineering, Computer-Aided Design and Applications, 17(1), 2020, 178-189. https://doi.org/10.14733/cadaps.2020.178-189

[9] Kreis, A.; Hirz, M.; Stadler, S.: Optimized Information Exchange Process between CAD and CAM, The 5th International Conference on Industrial Engineering and Applications (ICIEA), Singapore, IEEE Xplore, 2018, 184-188. https://doi.org/10.1109/IEA.2018.8387093

[10] Naito, J.; Suzuki, R.: Multi-material Automotive Bodies and Dissimilar Joining Technology to Realize Multi-material, Kobelco Technology Review, 38, 2020, https://www.kobelco.co.jp/english/ktr/pdf/ktr_38/032-037.pdf

[11] Thomke, S.; Fujimoto, T.: The Effect of “Front-Loading” Problem-Solving on Product Development Performance, Journal of Product Innovation Management, 17(2), 2000, 128-142. https://doi.org/10.1111/1540-5885.1720128

[12] 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), 2014, 411-416. http://dx.doi.org/10.1080/16864360.2014.881183