



An Integrated Approach Supporting Design, Simulation, and Production Engineering of Connection Techniques in Automotive Body-in-white Development

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ABSTRACT

Today's automotive industry is characterized by increasingly shorter development times. This fact takes place in almost all areas of car development. The presented work is concerned with the automated support in BIW-design (body-in-white design). Presented is a method to support the design engineers in creating and processing data within the applied computer-aided design (CAD) environment. Through the implemented algorithm, a continuous process is provided, which closes the gap between the different design and simulation processes which are necessary for the preparation and verification of body-in-white connection technologies. Moreover, the presented method is used as a connection to computer-aided manufacturing (CAM). This linking also works in the reverse direction, so that changes in the course of simulation or manufacturing engineering can be responded in the CAD process with significantly reduced effort.

Keywords: body-in-white, connection techniques, design automation, CAD-CAE-CAM integration.

1. INTRODUCTION

To remain competitive in today's automotive industry, shorter development times are a must. In the last forty years the development time of a vehicle has been abbreviated from about seven to almost two years, [5]. Without the increased application of virtual product development in all fields of automotive engineering this improvement would not have been possible.

Fig. 1 shows exemplary the development process of a full-vehicle. This process is grouped into different phases. Nearly in all phases computer-aided (CA) programs are in use [6]. In the definition phase the styling process starts and new ideas are brought down to paper. The applied design tools are CAS (computer-aided styling) programs. These programs allow quick changes and can react easily to corrections. One main problem that results in connection to CAS systems is the relatively poor technology-oriented quality of the surfaces, which are difficult to handle within CAD systems during the further process [1]. In the concept phase the packaging layout starts, by the use of CAD programs. State of the art is parametric-associative CAD, in which the packaging of a full vehicle can be

developed. In the pre-development phase, ergonomic and legislative studies take place. For the support of functional development, verification and testing, CAE (computer-aided engineering) programs are applied. By the use of calculation and simulation programs the different CAD models are verified. Furthermore, the body structure is developed during the pre-series phase. For verification of the components regarding the manufacturability, CAM programs come to use. These programs are an integral part of computer integrated manufacturing to enable virtual production engineering. Finally, component design is finished in the course of the series development phase, and finally in the pre-series and series production, quality control takes place. All these phases are supported by CAD, CAE and CAM [3,7].

All phases described above engage each other, which results in the fact that all CA programs have to communicate with each other. The interdisciplinary application of different software environments in the course of automotive development is constantly faced with new challenges regarding data exchange, data integrity and process efficiency. The CA programs involved do not only interact with



horizontal couplings, which means that the different programs like CAD and CAE are connected via interfaces. They also need to interact in vertical direction which requires interactions between different CAD systems [2].

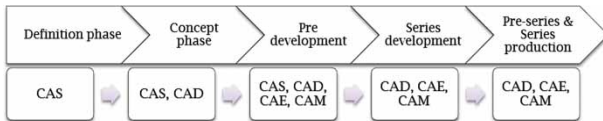


Fig. 1: Example of an entire-vehicle development process with the corresponding CAD systems.

2. VIRTUAL PRODUCT DEVELOPMENT IN BODY-IN-WHITE DESIGN

Data transfer in body-in-white development primarily occurs between CAS, CAD, CAE and CAM. In Fig. 2 the main steps of automotive body-in-white design are shown. An exemplary vehicle development starts with a rough product definition and an exterior styling proposal. In the next step the vehicle packaging development starts. For this phase, the CAS data are transferred into CAD environment.

In CAD the actual vehicle is designed under consideration of technical aspects, and is subsequently verified within different CAE systems. An example for a CAE-based verification is the simulation process in the course of vehicle or pedestrian crash analysis. 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 in regard of 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 [8].

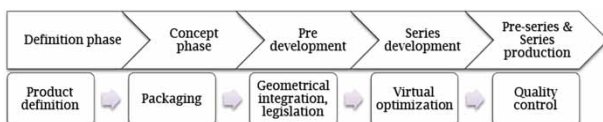


Fig. 2: Vehicle development with focus on body-in-white design.

A specific area in automotive BiW design represents the development of connection technology. These elements are used to join different components

of an automotive body, e.g. sheet metal parts. Connection technology is divided into different groups, according to the applied measures. In a standard automotive body, the most important connection technology consists of spot welds. Depending on the type and the size of the car, between about 4000 and 6000 spot welds are applied in an automotive body. This large number of spot welds requires a considerable effort in design as well as in simulation processes. In addition, production engineering of the welding process has to ensure the accessibility of weld robots and well-arranged configurations for automated welding. In a BiW development process, information regarding the applied connection technology is created in CAD by definition of the spot weld positions and dimensions as well as by the creation of the corresponding flanges at the sheet metal components. 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, e.g. the positions of spot welds and material information. Finally, production engineering is also supplied by the CAD-model with required information, e.g. positions and dimensions, the unambiguous definition of involved components, material information, etc.

During data transfer between these different disciplines of development, the CAD model, which includes the central information of the entire development process chain, already can reach its limits. Besides a considerable effort for the creation of spot welds, the definition of metadata, which cannot be provided geometrically, leads to an 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 points is of great importance, because they provide information about safety-relevant areas.

Asides from spot welding, additional technologies come into use in automotive body design, e.g. weld lines, bonding, bolts, and rivets. The tool described below deals with each of them.

3. INTEGRATED APPROACH SUPPORTING THE DESIGN OF CONNECTION TECHNIQUES

First and foremost implemented automatism in CAD systems support the design engineers in the creation of spot welds. As previously mentioned, up to 6000 spot welds are created in the body of a modern car. The present publication includes results of research work, which has the target to optimize the creation, verification, and data processing of connection technology from the beginning until production engineering, and quality management. In order to accelerate the design process of spot welding techniques, an algorithm was created that allows the semi-automated

definition of spot welds. The program requires a selection of one of the flanges onto the sheet metal parts, which has to be connected. After that, the center line of the flange is found with the help of an implemented algorithm. The geometry-oriented algorithm is based on the detection of parallel lines which are created along the entire flange length. These lines are aligned in parallel to the ends of the flange and serve as supporting elements to find the midpoints at every concerned flange section. Depending on the required number of spot welds, each midpoint serves as an anchor-point for the position of the corresponding spot weld. The space required for the welding guns (for production engineering) is ensured by predefined minimum distance values and the representation of the weld gun geometry by envelope models. On these welding points in turn, automated predetermined geometries and surface normals are created, which are relevant for subsequent data transfer. The creation of connection geometry for 2-sheet and 3-sheet metal parts is different, which is considered by a differing visualization. Fig. 3 exemplary shows the auxiliary construction which is in use for two sheet spot weld creation.

Within the CAD-model, all relevant connectivity information, as well as the created geometry are prepared for a satisfying visibility in a separate connection technique part. The connection technique part includes a specific model structure, which holds the entire data structure of geometry and additional metadata. This structure is used for better overview and also enables to distinguish between different types of connection. Fig. 4 gives an overview of the

geometrical parameters and the meta data which are handled. All these information can be read out and transferred into CAM and CAE programs. In this way, Figure 6 gives an overview of the data which are managed in the structure tree of the CAD model, exemplary for one welding point.

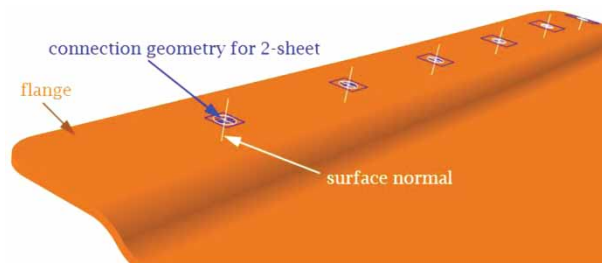


Fig. 3: Auxiliary construction spot welding.

The implemented tool supports design engineers further when processing data from existing sheet metal components. After the selection of the sheets to be joined, the material properties and the wall thickness of the respective sheets is analyzed and tracked as parameters in a designated area in the model structure. These values are taken into account in subsequent data discharging. In this way, the introduced tool is able to support the engineers not only during processing of existing (delivered) information; it also allows access to additional connection-technique related information. All metadata are handled with the help of a specific GUIs (graphical user interfaces),

geometrical parameters:

spot weld	position (coordinates) of each spot weld surface normal spot diameter
weld line	position (coordinates) of each discretization point surface normal of each discretization point throat thickness
bond line	position (coordinates) of each discretization point surface normal of each discretization point width of the bond line
bolts or rivets	position (coordinates) of each point where bolts or rivets are set surface normal shaft diameter bolt or rivet length

meta data:

spot weld	material, thickness and part number of the sheet pairing safety relevance
weld line	material, thickness and part number of the sheet pairing safety relevance procedure (arc welding, brazing or laser welding)
bond line	material, thickness and part number of the sheet pairing safety relevance bonding (adhesive structural, adhesive anti flutter, hemming or window adhesive)
bolts or rivets	material, thickness and part number of the sheet pairing safety relevance standard component

Fig. 4: Data management overview.

which is programmed within the applied CAD software and stored by use of a predefined parameter structure. These GUIs are prepared for the different connection types differently, so that all relevant information can be managed. Fig. 5 shows of the main window of the mentioned GUIs in which the type of connection technique can be selected.

In addition, the tool enables an unambiguous denotation and numbering of the various types of applied connection techniques. In case of spot welds a clearly defined nomination of each spot is required. The nomination is characterized by the specific components, which are combined in the welding process, the materials and other related aspects. In this way, the starting number of the welding point is determined by the design engineer. After that, the numbers for each spot weld are defined automatically for the subsequent points. This designation comes from the fact, that all components on the right side consist of even numbers and all parts on the left have odd numbers, or vice versa. 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 include the names (and numbers) of all connection elements.

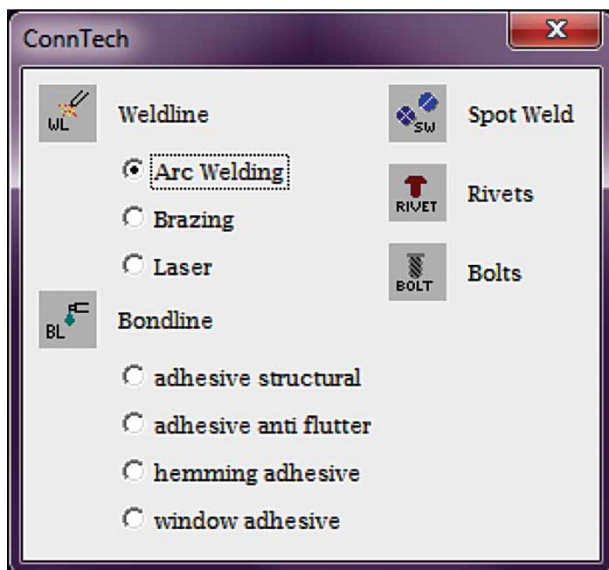


Fig. 5: ConnTech main GUI.

Finally, the previously created data are elected by an automated algorithm. This data monitoring takes place in a neutral format that can be transferred to the involved calculation programs. The data bundle not only includes the required parameters, but also the concerned geometry models. An important information includes all coordinates of each spot weld and the respective surface normals. This information is

saved in a predefined structure as it is exemplary shown for one spot weld in Fig. 6. For the transfer to the CAE environment for simulation purpose, a predefined format, called *CONN* is in use. 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 the point identification number (ID), the safety relevance, the material of the sheet pairings, the wall thickness as well as the part-IDs of the connected sheet metals and many more. The most important information that has to be transferred includes the point coordinates in x-, y- and z-direction and the surface-normal to the flange in each point. In addition, a *VIPS* format comes to use, which is a standard format for the transfer into CAM environments. In addition to the information content above, this format also includes the color of components and spot welds as well as the file name of the connection part. All these and other items are 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.

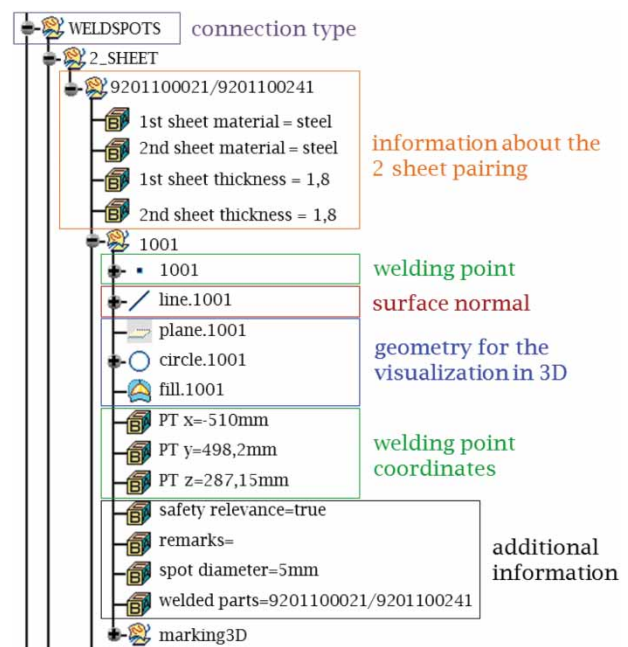


Fig. 6: Example model structure of one spot weld.

The respective changes that may arise during simulation-based investigations in calculation programs are discharged in a neutral format and can be transferred back into the CAD environment for further modifications of the design models. Through the data feedback to the CAD program, a uniform and consistent process results. In this way, the applied formats *CONN* and *VIPS* are used for this transfer, so that the data transfer from and to the CAD system

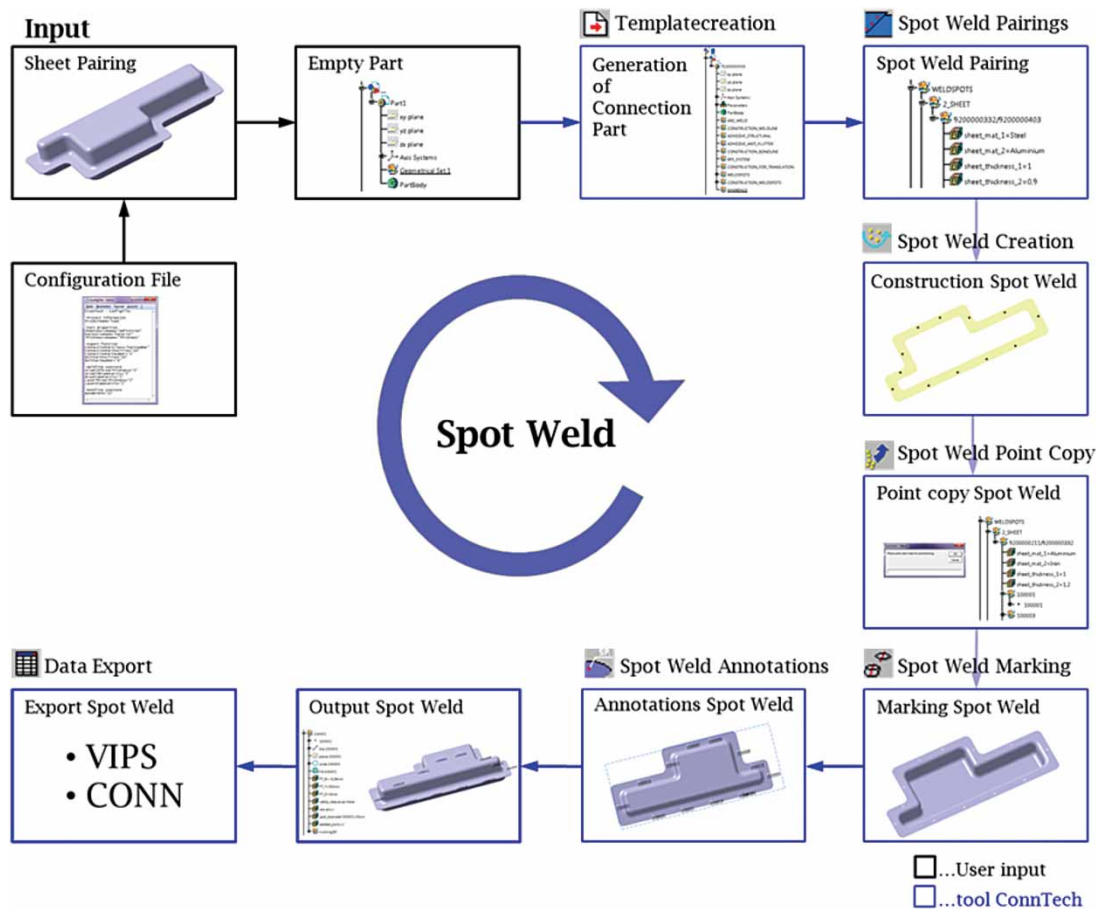


Fig. 7: Example process of spot welds creation, [9].

can be done effortlessly by comparing the individual entries.

4. EXAMPLE OF USE

The described approach has been implemented in a practical application, which supports the creation, optimization and verification of connection techniques in automotive body-in-white design. The tool is realized as a VBA (visual basic for applications) macro which is implemented in the commercial parametric associative 3D-CAD software CATIA V5, [4]. This 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 connection techniques. The tool includes several functions for each type of connection techniques. The present paper exemplary highlights the main features focused on the application and data transfer of spot welds.

In Fig. 7 an exemplary process of spot weld creation is shown. In order to this process an example of use of the VBA macro is given. Each shown icon, on the top of a process box, stands for an input for the automated routines.

For better handling, a configuration file is defined in advance. The marking for each connection technique part changes for each project, so this information must be defined in advance. Additionally, the default values in the given GUIs are set in advance depending on the specific project. The GUIs and the project name are always set by the project administration at the beginning of each project via a text file.

In the following, a sample of the subscribed tool is given, exemplary for the creation and data handling of spot welds. After having defined the general project-oriented configuration, a new connection technique part is created and placed in the product structure of the corresponding sheet pairings. In the next step, a structure of named sets is created in the connection part automatically. After selecting the sheet metal pairings, the macro reads out the desired data, e.g. material or wall thickness, and generates parameters in order to this information.

In the next step the described positioning points of the spot welds a created by the engineers automatically after selecting the concerning flanges. Then, all created points are renamed in double steps as a function of a start number, which is entered via the

graphical user interface. After renaming all relevant points, markings are set on each spot. With the help of a plane normal, lenses are created as geometrical representatives for two sheet and cylinders for three sheet pairings. Next, annotations are set on a user-selected plane with the former given point naming. After fulfilling all steps, the spot welds are marked in the 3D CAD model, which is shown in Fig. 8. In a final step, all relevant data is stored by a parameter set in the corresponding 3D model structure. Through this structure it is possible to read out all relevant data into neutral formats, like *CONN* and *VIPS*, which can supply CAE or CAM programs.



Fig. 8: An example of spot welding on a body-in-white.

Finally, all the changes are determined in the calculation programs to be recirculated back into the neutral format. This format can also be transferred into the CAD system. In this way, all relevant parameters are compared and all changes can be managed. In case changings, the involved point coordinates are modified automatically and the new entry is coloured red for a better visualization for the design engineers.

5. CONCLUSION

Taking into account the steady decreasing development time in the automobile industry, automated processes that support the design engineers in development and data transfer are becoming increasingly important. An implemented automation can significantly accelerate the development process, but also contribute to process reliability. Through the use of knowledge-based functionalities and structured geometry models in standard CAD systems, a method has been presented to produce and structure connection technique related geometry in automotive body-in-white design. The presented approach supports the

preparation of relevant data for subsequent simulation processes and production engineering. The data inputs for the creation and modification of different types of connection technique are supported by specific data handling within provided GUIs. Besides user-oriented support, the presented method also includes a new approach for the improvement of the entire development process of connection techniques by provision of a comprehensive data model, which is able to integrate styling, design, simulation and production engineering. In this way, the application leads to both, reduced development effort as well as increasing data quality.

Finally, it should be mentioned that the described new approach has been implemented into the development process of an automotive manufacturer successfully and finds its application in industrial projects.

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