

Using CAD, CAE, and CAM to Enhance Automotive Body Assembly Design, Analysis, and Fabrication

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ABSTRACT

Standards, processes, and software were developed to automate the process of creating the Body In White (BIW) fasteners, such as, spot welds and MIG welds. Enhancements were made to the previous process and software where the CAD data for fasteners was mostly geometric representations. The new method provides data that has complete embedded information, including actual connection properties, for the parts being welded. The key benefits include the ability to check geometry and design intent in 3D, quickly create and revise connections in finite element simulation models, and import data into weld offline teaching software to accelerate robot welding.

1. Introduction

In the late 80's to early 90's, automotive design engineers communicated weld information with symbols and annotations on drawings (Fig. 1). For spot welds, the symbols showed the location and quantity of parts connected while the annotations described the weld coordinates and the part numbers being connected. Such drawings were verified by visually contrasting the illustrations and annotations and comparing with the design intent. Once all errors were corrected, the drawing was issued and distributed. These drawings were used to create weld connections in Computer-Aided Engineering (CAE) models and welding templates for assembling prototype vehicles. In both cases, extensive labor and

time were necessary to read each drawing and either manually create a weld location in a CAE model or physically measure and mark a location on a weld template.

Once we moved to welds in 3D, the process was enhanced since weld locations could be extracted into CAE software. The source of communication was based on drawings. The 2D drawing contained the weld information for both the CAE world and Computer-Aided Manufacturing (CAM) environments. As CAD systems evolved (early 2000), we could embed knowledge in 3D. This provided us with the base for significant enhancements.

2. Developing the Body Fasteners Workbench

As shown in Fig. 2, we divided the flow of BIW assembly into four phases. In phase one, the design engineer provides the necessary inputs. In phase two, the program determines the parts that are being connected, gathers information about these parts, and creates the fasteners. Phase three involves checking the data. In phase four, the assembly is made available for simulation.

The Body Fasteners Workbench was developed to help with this process. The workbench concept was chosen because of the framework inherent to the base software. The workbench consists of a collection of functions that are arranged in toolbars and grouped based on the

Year 1980	1990	2000	2010
		Fasteners in 3D Annotations in 3D Embed Knowledge	
Fasteners in 2D Annotations in 2D	Fasteners in 3D Annotations in 2D		

Fig. 1 History of BIW assembly data

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following functions: fastener creation, operations, annotation, and reporting. The software algorithm is explained in a flowchart in Fig. 3.

During the initial stages of the software development, a worldwide team comprised of members from design, information systems, manufacturing, and tooling came together to define some common user requirements for 3D fasteners. Some of the standards that were developed, and used in the specifications for the software, include:

- A global unique identifier for each fastener
- 3D annotations for each fastener type
- A standard report format (CSV)

2.1. Design Phase

In the Design phase, the design engineer loads the parts that make the assembly and adds a part that will hold information about the assembly. Inputs depend on the type of fastener being created, for example, the input for a spot weld is a surface and points at which the welds have to be created. A MIG weld needs two surfaces and a curve. Sealers need two bounding surfaces while bolts need point, surface and a hole. The necessary inputs are referenced (copied in or referenced with a link) from the parts to be assembled. Once these inputs are acquired, the software starts to calculate connected parts.

2.2. Compute Phase

A key aspect of the Compute phase is calculating what parts are being fastened during the assembly process and

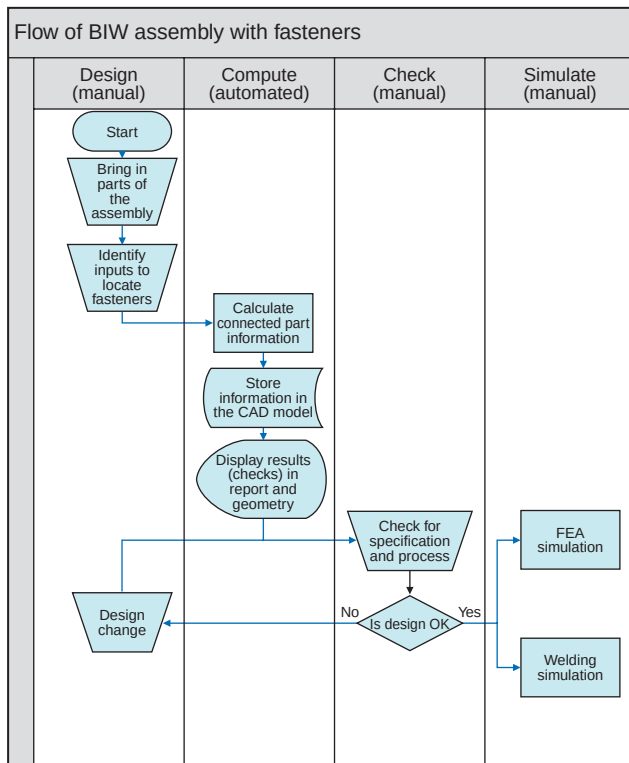


Fig. 2 BIW assembly phases

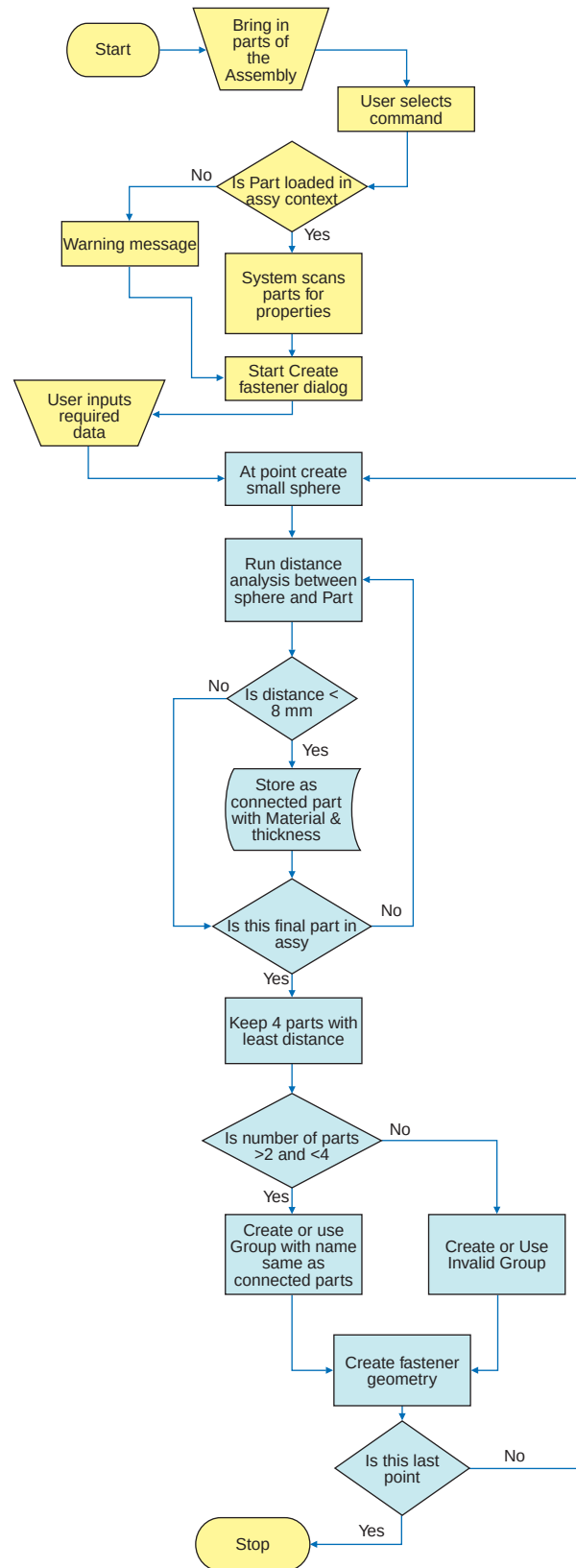


Fig. 3 Flowchart for software algorithm

acquiring their attributes. This could be done by asking the design engineer to select what parts are being connected, but impractical since one assembly might contain hundreds of spot welds. Furthermore, this process needs to be independent of the type of fastener being created. We investigated two methods to accomplish this.

2.2.1. Methods for calculating connected parts

Cylinder Method. At the location where a fastener is needed, a cylinder with 2 mm radius and 10 mm length is created along the normal to the input surface. These dimensions were selected balancing the need to capture the connected parts but remove false positives. The software computes the interference between the cylinder and all parts loaded in the assembly. Parts that interfere with the cylinder are assumed to be connected (Fig. 4).

Sphere Method. At the location where a fastener is needed, a 0.5 mm sphere is created. The software computes the distance between the sphere and all loaded parts. Parts that fall within 8 mm are assumed to be connected (Fig. 5).

Both methods return a list of parts that can be connected. However, the fastener type has to be considered to determine the relevant parts; for example, a MIG weld or sealer can connect two parts while a spot weld can connect up to four parts. Despite such restrictions, the software may still return more parts than expected (Fig. 6). In such cases, the user is prompted to select the relevant parts.

Based on our testing and the variety of fasteners that can be handled, we selected the sphere method for calculating connected parts.

After the connected parts are determined, properties

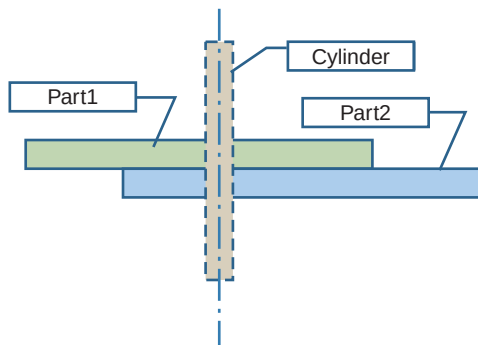


Fig. 4 Cylinder method

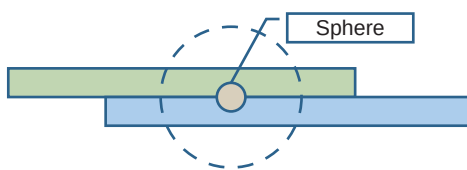


Fig. 5 Sphere method

are interrogated from the model and mapped from a Product Lifecycle Management (PLM) database. Part number, material, and thickness data are filtered and stored on the geometric feature.

2.2.2. Visualization

Each fastener is represented by geometry and annotations that are based on ISO and other standards. These representations have variations. A spot weld is represented based on the number of parts being connected while a MIG weld is based on the length of the weld. Additionally, the geometry has to be created with multiple visualizations, that is, Wire frame and Solids, which aid in downstream use of the data in visualization software or 2D drawing creation. Finally, the design engineer creates annotations for each fastener. Figure 7 shows an example of visualization and annotation on spot welds.

2.2.3. Data organization

A tree structure within the CAD model stores the geometry information. Good organization in the tree structure is important as it enables fast access to information. When the geometry is created, fasteners are

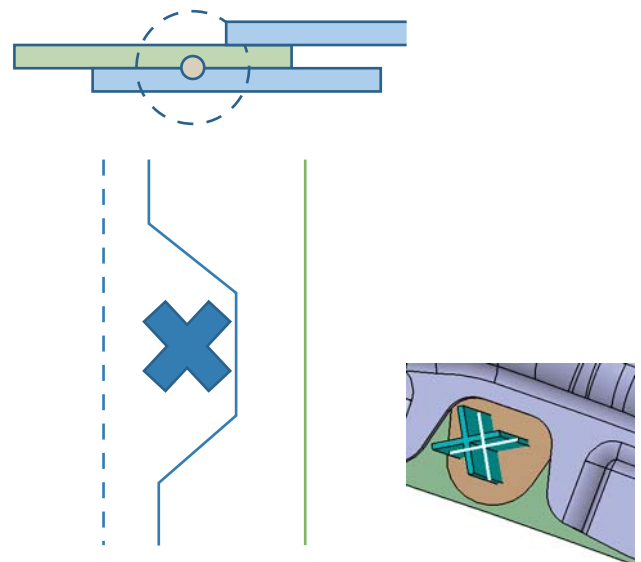


Fig. 6 Example of multiple parts identified to be connected

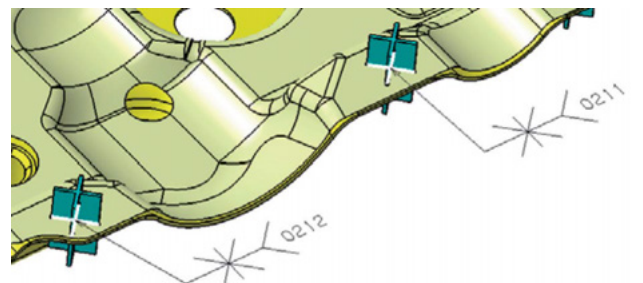


Fig. 7 Visualization and annotation on spot welds

organized in the tree by welds, sealants, bolts, etc. Welds are subdivided into Spot, MIG, and other weld types. Additionally, fasteners are grouped by the parts that are being connected as shown in Fig. 8 by the “PART2_SAE / PART3_SAE” label. All spot welds that connect these two parts are included in this group.

Once the connected parts are computed, the geometry, annotations and the organized tree is created then the data is ready for check phase.

2.3. Check Phase

Once an engineer completes creation of the fasteners, he/she uses a PLM workflow to promote the part’s workflow status and start the check process. The first check is automatic, and if successful, a manual second check is started.

2.3.1. Automated check

An automated program checks for invalid fastener definition, which could involve a mismatch between number of parts and the type of weld, a missing material or thickness, two spots created at the same location, or missing annotations. If problems are found, the part is demoted to the original workflow status and an e-mail sent to the design engineer with a link to the error report.

Errors can be corrected using edit functions provided for the fasteners. Individual fasteners can be modified by editing the inputs or by making corrections to the connected parts. Multiple fasteners can be modified by using a refresh function to re-compute connected parts and collect their modified properties. When there are no errors, the assembly is made available to the checker.

2.3.2. Manual check

To aid with the manual check, the information stored on fasteners can be displayed in several report formats to meet end users’ needs. Such reports contain fastener

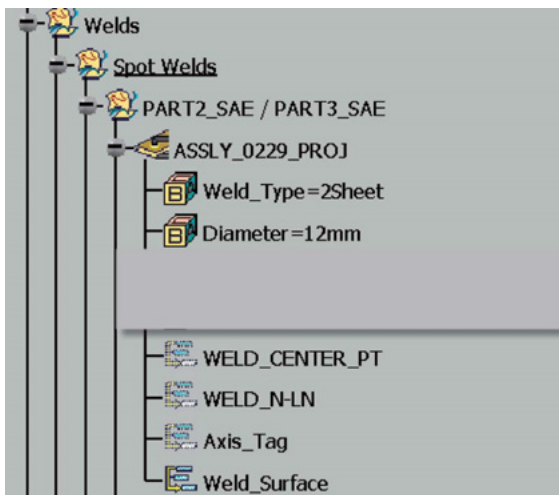


Fig. 8 Tree structure example

information, which includes a unique identifier, location, orientation, the parts being connected, and properties (material and thickness). This report can be saved as a file that can be read by spreadsheets or other applications.

Once the checker is satisfied with the assembly, he/she promotes the file to a locked status and a Spot Weld report file is generated in a comma-separated value (CSV) format (Fig. 9). This is the same information created with the report function. The data is now available for simulation engineers to build finite element models and to fabrication engineers to start offline programming.

2.4. Simulate Phase

2.4.1. Finite element (FE) analysis

Automotive manufacturers perform computer simulations throughout the vehicle development process. These simulations check and enhance overall vehicle performance in areas such as crashworthiness, durability, noise, vibration and handling. To perform these simulations, the engineers first create a computer model of the vehicle that is detailed enough to provide useful performance measurements. The computer model includes FE representations of each part and the corresponding connections. The most common structural connection is the spot weld. Since a typical vehicle contains approximately 4000 spot welds, it is important to have an automated process to create them.

The building of a full vehicle simulation model starts with creating FE part representations. A preprocessing software tool is used to import 3D CAD surface and solid data. As shown in Fig. 10, a mesh for each part is created in a batch process. Once all of the mesh files are created

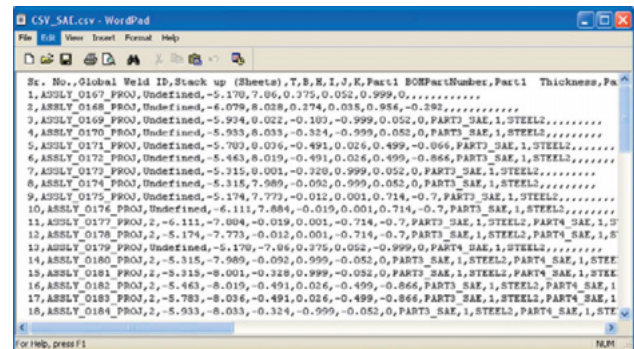


Fig. 9 Sample spot weld CSV file



Fig. 10 Finite element part meshes

for a sub-assembly, the preprocessor loads and places the individual meshes in the correct location and labels each mesh with its corresponding part number, material, and thickness information. In order to ensure simulation results it is important that these mesh properties are consistent with the properties used by the CAD program to define the fasteners. The sub-assembly is now ready to connect the mesh parts to each other.

The connection process for the simulation model starts with the spot weld CSV file, which contains all of the necessary data to build a FE representation of the spot weld. The FE spot weld creation tool reads and processes the unique weld identification number, the number of sheet metal layers connected, the 3D location of the center of the weld, and the part numbers for each of the sheet metal layers being welded. In the simulation model building process, the welds are created on a subassembly-by-subassembly basis (Fig. 11). Once sub-assemblies are complete, groups of sub-assemblies are connected with additional spot weld files. This process continues building

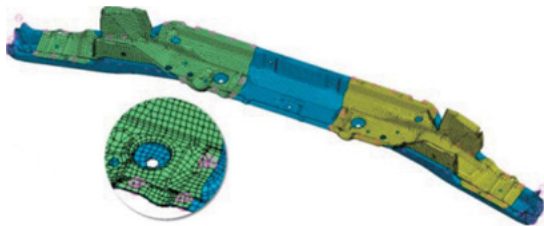


Fig. 11 Single assembly with FE connections

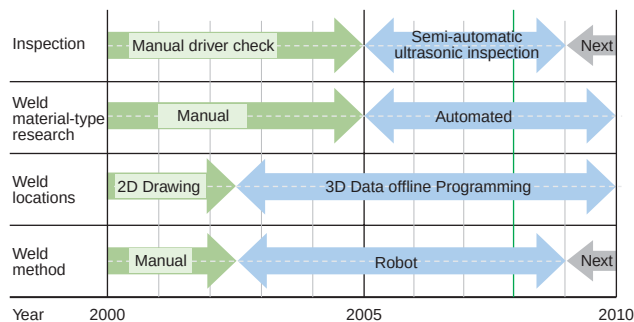


Fig. 12 Application evolutions in prototype processing

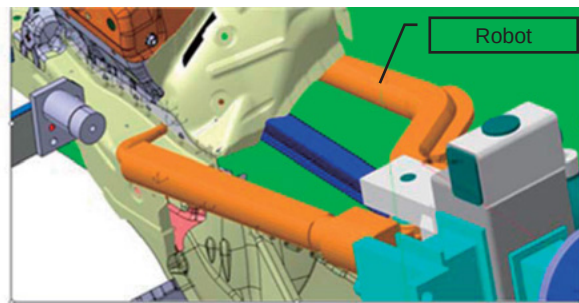


Fig. 13 Welding robot oriented based on imported weld points

until the final assembly is completed. Another method would be to combine all of the spot weld CSV files into one complete vehicle spot weld file and then create all of the FE spot welds at the same time.

2.4.2. Prototype fabrication

Prototype vehicles are built to confirm manufacturability and performance. Before implementing the 3D fastener environment, prototype welding was a manual process of reading individual drawings to build a weld table and printing drawings to create weld templates. The availability of the spot weld CSV file and the introduction of welding robots have reduced the overall preparation time for weld parameter development by approximately 50%. A timeline of the maturation of robotic welding processes is shown in Fig. 12.

The process starts by importing the weld information from the CSV file into the simulation environment. The result is a properly oriented weld tag for each spot weld, which allows for fast orientation and assignment of the welding robot (Fig. 13).

2.5. Software Maturation

The software has matured in multiple versions, leading up to the current version, V4. In the initial release, V1, an interface was developed to create the geometrical data. In this version, the step of creating a CSV file was a secondary process that didn't have any interaction with the design engineer. The next version, V2, implemented real-time information gathering from a PLM system while a design engineer created fasteners. This increased the accuracy of the CSV file as more checks were done before simulation or fabrication staff saw the data. The latest versions, V3 and V4, have support for more operations like symmetry, copy paste with links, and multiple PLM systems.

3. Conclusion

The development and implementation of BIW fasteners has advanced vehicle development in many ways:

- (1) Weld Design has advanced to a knowledge centric approach from the historical focus on geometry.
- (2) The software has shortened the time required for design engineers and checkers to collect and display information about the BIW assembly.
- (3) The task of building and updating simulation models has been simplified.
- (4) The lead time to weld prototype vehicles has been reduced.
- (5) The Body Fasteners software and associated standards have provided enterprise-level efficiency enhancements that benefit all facets of vehicle development.

The next step for BIW fasteners in the PLM environment is to detect changes in the assembly and manage the effect on assemblies.

References

- (1) ISO 16792: Technical Product Documentation Digital Product Definition data practices
- (2) JIS Z 3021: Symbolic representations of welds

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