Multi Material Modeling with ANSA: An Application in the Automated Assembly Process at FORD

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1 Abstract

The simulations of virtual models hold a key role during the design process of a vehicle. The numerus different components in a CAE model make its assembly one of the most demanding tasks during the model buildup.
Over the last years, the effort to achieve higher accuracy in crash test simulations has resulted in more detailed models. As a result, the FE representations used to connect the different parts vary a lot and get complex sometimes. To support effectively such time-consuming and error-prone modeling processes, the available tools should offer increased automation and standardization levels.
A commonly used method is to simulate the area of these connections by using different material properties representing effectively not only the material of the connecting flanges but also the heat affected zones in each flange. Ford-Werke GmbH in cooperation with BETA CAE Systems has come up with a fully automated process within ANSA pre-processor that reads the CAE and its connection file, assigning the proper connectivity to each connection. Additionally, with the use of external files assigns the needed materials in the area of each spotweld using the respective LS-DYNA keywords. Finally reports to the user the results of the assembly procedure and the final status of each connection.
The current paper explains the basic terms of the automated process mentioned above. Moreover, it presents the techniques used within ANSA to assembly a full analysis model in a fast and robust way combining different FE-representations and multi material assignment in the area of a connection.

2 Introduction

Crash and Safety CAE simulations become more and more demanding from year to year. The high level of detail has resulted in precise models that have captured a lot of different parameters of a real crash model. Throughout the simulation process of a crash model one of the most critical sub – processes is its assembly to a full analysis model. It is important how the different components will be connected to each other and more essential for an analyst to have the ability to tune as many different parameters as possible.
It became common practice to simulate the area of the connection between two components using multi material models. This way, real phenomena such as the heat-affected zones (HAZ) can be represented. The most appropriate FE-representation is the one that will enable the user to assign the desired characteristics to the area of a connection. Moreover it is important that the tools that one has at one's disposal offer automation and ensure a minimum of necessary human interaction.
Ford - Werke GmbH in cooperation with BETA CAE Systems SA set up an automated assembly process within ANSA for this new type of FE-representation. The specific process starts from the input of an LS-DYNA file, continues with the read of a connection (xml) file and with the given mesh parameters and quality criteria realizes all the connections of the model with multi material assignment

per connection area. Finally, a report is produced that informs the user which areas have passed a successful treatment and which ones need a further check of settings.

3 Solid Nugget – HAZ

The basis of the automated process explained in the current paper is the modelling technique that will be used in the connection area. At Ford a nugget of four LS-DYNA ***ELEMENT_SOLID HEXA** that are connected through a ***TIED_SHELL_EDGE_TO_SURFACE** contact to the flanges will be used. Around the projections of the solids on to the flanges, the HAZ area will be created with a desired dimension, see Fig. 1.

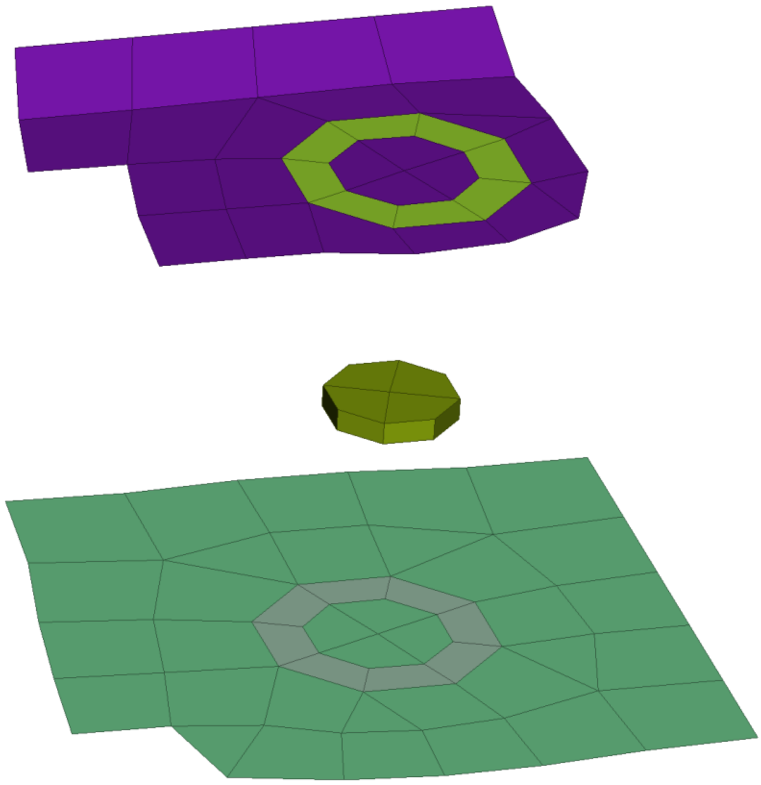

Fig.1: 2T Solid Nugget in ANSA.

The complete sub-assembly contains connections of two and three flanges (2T and 3T). According to the specific modelling, the HAZ has different material characteristics than the rest of the connecting flange. Apart from the Solid Nuggets there are connections where no HAZ is created and a cluster of **HEXA *ELEMENT_SOLID** will connect the two flanges using the mentioned ***CONTACT** type.

4 Scripted – automated process

To utilize the ANSA solid nugget generation, the next step that was needed was to set up a flexible process which offered the needed automation for a robust and fast assembly. The utmost goal was that it should run in batch mode avoiding launching the ANSA GUI at all. Another important aspect was that it should be interoperable and applicable not only for LS-DYNA but for other solvers as well.

During this procedure Ford would like to combine several steps. The user should be able to give a path for the LS-DYNA model that will be assembled. Also an xml file should be given that contains all the connection information. Then quality criteria and mesh parameters should be given for the mesh re-generation. For the potential HAZ creation an external ASCII file should be read that contains this information for a wide list of materials. Finally specific LS-DYNA **`*MATERIAL`** templates are read to be assigned in the HAZ properties (**`*SECTION_SHELL`**).

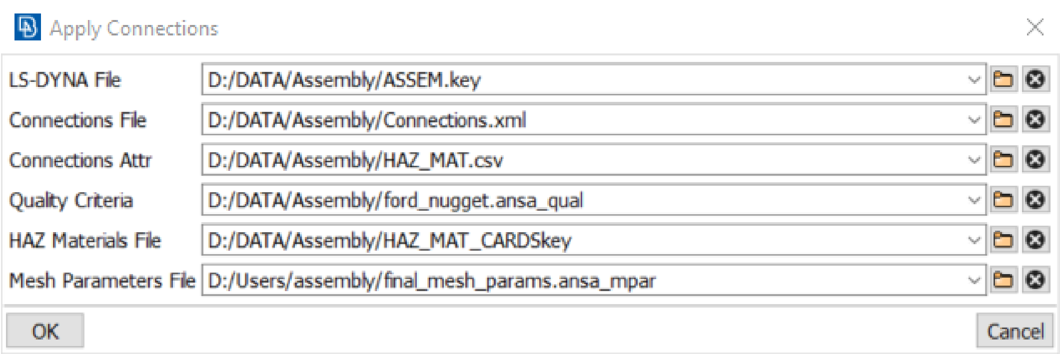

Fig.2: GUI of scripted automated process.

4.1 Input LS-DYNA file

The first step of the process is the LS-DYNA file input in ANSA. This LS-DYNA file is the subassembly that will have its internal components assembled. During this step, this file is read and all the desired input parameters that the user wants to assign, such as Ids offset values or any other miscellaneous LS-DYNA settings needed, are assigned.
When the file is read into ANSA, a preparation of the model for the application of these connections is made. According to FORD specifications, ANSA assigns the correct Module Ids for the ANSA parts hierarchy.

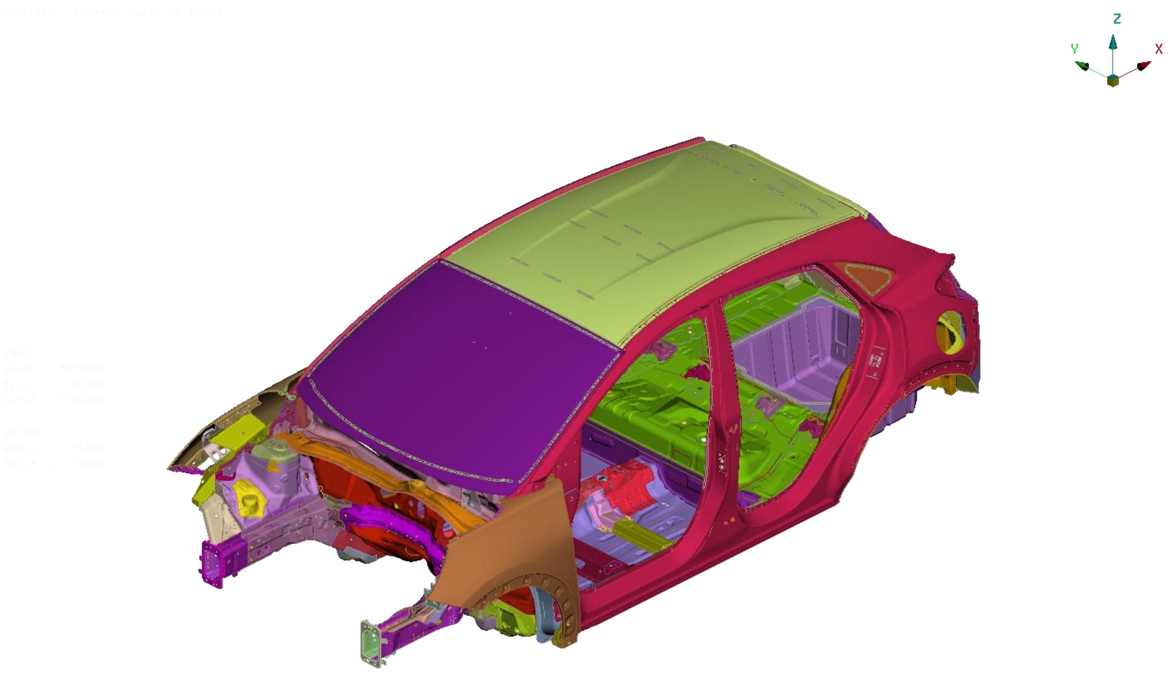

Fig.3: BiW in ANSA before the assembly process

4.2 Read attributes file

The attributes file is a csv file that contains a list of materials. This list contains the respective name for each material, the information if this material requires HAZ treatment and some numeric data for the corresponding material cards, see Fig. 4. ANSA reads this file and keeps in memory the corresponding material name and HAZ information. When the creation of the FE-representation takes place, it creates potential HAZ to the flanges including their respective material name.

	A	C	D	E
1	#Current	with HAZ	Parameter_1 [N/mm2]	Parameter_2 [N/mm2]
2	Material_1	yes	1050	1350
3	Material_2	no	210	410
4	Material_3	no	190	320
5	Material_4	yes	168	305
6	Material_5	no	160	300
7	Material_6	no	135	295
8	Material_7	no	295	385
9	Material_8	no	265	370
10	Material_9	yes	235	335
11	Material_10	no	220	325
12	Material_11	no	210	300
13	Material_12	yes	240	320
14	Material_13	yes	210	300
15	Material_14	no	240	320
16	Material_15	no	270	340

Fig.4: Attributes file

4.3 Material Template for HAZ

Ford needed to assign a specific material type with specific parameters in the HAZ area. A LS-DYNA file that contained the **`*MATERIAL`** templates and the relative material failure cards is read and creates the respective assignment during the realization.

4.4 Read the connections

After importing the desired subassembly in ANSA the process continues with the reading of the connections. A way to maintain, but also a possibility to make modifications is the xml file, see Fig. 7.

```
<version> 1.0.0 </version>
<connection_group>
  <id> 1 </id>
  <connected_to>
    <part>
      <base> part1 </base>
    </part>
    <part>
      <base> part2 </base>
    </part>
  </connected_to>
  <connection_list>
    <connection_0d>
      <id> 102584 </id>
      <type>spotweld</type>
      <loc> 3089.82  -75.  360.17 </loc>
      <label>Connection_1</label>
    </connection_0d>
    <connection_0d>
      <id> 102723 </id>
      <type>spotweld</type>
      <loc> 3141.82  -50.  349.91 </loc>
      <label>Connection_2</label>
    </connection_0d>
    <connection_0d>
      <id> 102724 </id>
      <type>spotweld</type>
      <loc> 3141.82  -100.  355.24 </loc>
      <label>Connection_3</label>
```

Fig.5: Connections file

The automated process at this point reads the xml file and automatically creates the ANSA connection entities. Each ANSA connection entity contains all the information for an area where two or more components are connected. So, one can access the ANSA connection card to get all the information existed in the xml file, see Fig. 6.

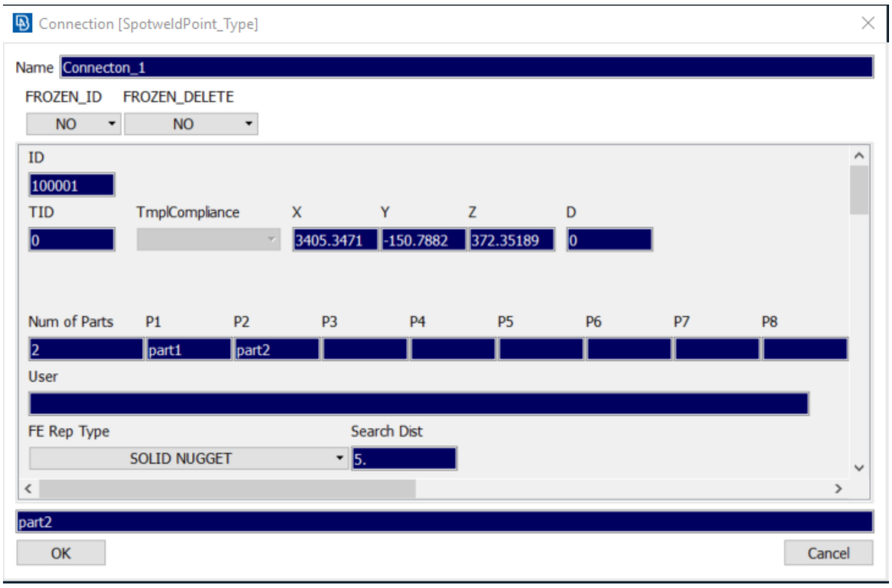

Fig.6: ANSA connection card

4.5 Connection Realization

The realization of a connection is the action in ANSA that produces the desired FE-representation to the coordinates between/among the different connecting parts that occur in the connection card. It is actually the solid nugget creation with the **`*CONTACT`**.

At this point the ANSA routine decides where it should create a HAZ, which materials to be used and to which property (*SECTION_SHELL and *SECTION_SOLID) they will be assigned.

Considering the above, the final result can end up with 2T connections that connect one flange with HAZ and one without. Moreover, the model can contain 3T connections where the upper flanges have HAZ but each one with different material, see Fig. 7.

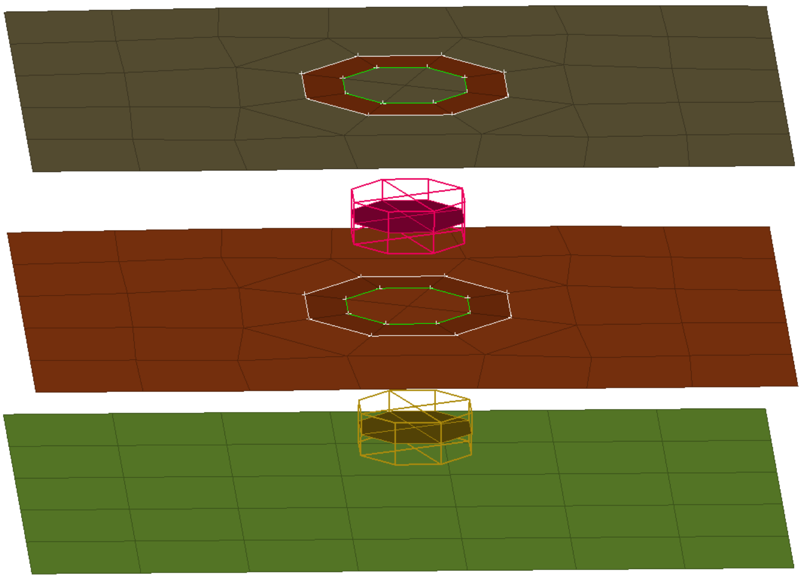

Fig.7: Multi Material and HAZ assignment

4.5.1 3 times realization

An important point is the exception handling during the realization of connections with HAZ. One major reason for this can be the fact that there is less space in the specific area for a HAZ due to the existence of a feature (fillet) or because of a closed boundary. During the automated process all these cases are collected and ANSA routines try to re-realize them with a small movement of the connection nearby. If there is still no space left for a HAZ to be created, then ANSA will realize them without HAZ just with a cluster of **HEXA *ELEMENT_SOLID** and a ***CONTACT *TIED_SHELL_EDGE_TO_SURFACE** in order to have connectivity there at least. Cases that fail for any other reason at the final stage are collected and reported in the final step of the automated process for the user for further investigation.

4.6 Mesh Parameters and Quality criteria

During the realization of the connections, the creation of HAZ changes the already existing mesh. There is a local reconstruction during the connections realization, but there are cases where the quality of the resulted mesh is not as expected. ANSA offers the ability to store a file with the mesh parameters that the mesh algorithm will follow during mesh generation, but also the quality criteria that have to be respected for a proper LS-DYNA (and any Solver) model. For that reason the automated process explained in the current paper offers the ability to load a quality criteria and a mesh parameters file. Apart from the fact that the creation of HAZ will follow some specific rules, a further mesh improvement will be applied after the realization of the connections in order to guarantee a high quality mesh of the complete model.

4.7 Report Generation

Generating a report is the last part of the automated process. ANSA creates an ASCII file that contains all the logged information regarding the complete HAZ generation run. Several steps were done automatically and in case that they have run in batch mode, a necessary report is generated.
ANSA checks the status of the connections and reports if and what is causing the difficulty for each connection that was not fulfilling the specification. Such difficulties can occur if there is incorrect/incomplete connectivity information on the connection cards (wrong Module Id) or if the material of a flange is not in the list of the attribute file (for HAZ consideration). Moreover, due to the fact that the realization of the connections is done in consecutive steps, with different settings, the report lists which connections have failed in the realization at each step and finally reports what is the status at the end of the run, see Fig. 8.
Following such a report the user will be informed what has happened during the process and knows where one needs to focus on and execute necessary adjustments or has a ‘green light’ for the specific sub-assembly.

```
Material  MAT-test_18-A33 does not exist in the csv file. Default settings will be applied.
Material  MAT-test_1-A33 does not exist in the csv file. Default settings will be applied.
Material  MAT-test_1-A33 does not exist in the csv file. Default settings will be applied.
Material  MAT-test_1-A33 does not exist in the csv file. Default settings will be applied.
Material  MAT-test_1-A33 does not exist in the csv file. Default settings will be applied.
Material  MAT-test_10-A33 does not exist in the csv file. Default settings will be applied.
Material  MAT-test_1-A33 does not exist in the csv file. Default settings will be applied.
27 Connections failed with error:
Missing parts/properties !
100412-100415,102584,102723-102732,102909-102920
WARNING: Optionally specify reconstruct flange script function in Connection Settings !
For 2767 Connections with Ids : 1-99,103,106-142,171,173-174,197-705,707-719,733-736,755-770,875-890,
The following 28 Connections have not been realized with default (strict) settings.
786 , Part_1-code_1-A , Part_1-code_2-A , Part_1-code_3-A
818 , Part_1-code_4-A , Part_1-code_5-A , Part_1-code_6-A
819 , Part_1-code_4-A , Part_1-code_5-A , Part_1-code_6-A
950 , Part_1-code_4-A , Part_1-code_7-A , Part_1-code_8-A
1340 , Part_1-code_3-A , Part_1-code_9-A ,
1345 , Part_1-code_6-A , Part_1-code_10-A ,
1441 , Part_1-code_11-A , Part_1-code_12-A , Part_1-code_2-A
1444 , Part_1-code_2-A , Part_1-code_3-A , Part_1-code_12-A
1445 , Part_1-code_5-A , Part_1-code_6-A , Part_1-code_13-A
3114 , Part_2-code_14-A , Part_1-code_13-A , Part_2-code_15-A
3121 , Part_2-code_14-A , Part_1-code_13-A , Part_2-code_15-A
3122 , Part_3 , Part_2-code_14-A , Part_1-code_12-A
3123 , Part_3 , Part_2-code_14-A , Part_1-code_12-A
3126 , Part_3 , Part_2-code_14-A , Part_1-code_12-A
3128 , Part_2-code_14-A , Part_2-code_16-A , Part_1-code_13-A
3130 , Part_2-code_14-A , Part_2-code_16-A , Part_1-code_12-A
3132 , Part_2-code_16-A , Part_1-code_12-A , Part_2-code_17-A
3167 , Part_2-code_16-A , Part_1-code_12-A ,
100426 , Part_1-code_18-A , Part_1-code_12-A ,
100430 , Part_1-code_19-A , Part_1-code_13-A ,
103671 , Part_1-code_3-A , Part_1-code_2-A ,
103677 , Part_1-code_6-A , Part_1-code_5-A ,
103773 , Part_1-code_20-A , Part_1-code_21-A ,
103778 , Part_1-code_20-A , Part_1-code_21-A ,
103779 , Part_1-code_20-A , Part_1-code_21-A ,
103803 , Part_1-code_22-A , Part_1-code_7-A ,
103808 , Part_1-code_22-A , Part_1-code_7-A ,
103809 , Part_1-code_22-A , Part_1-code_7-A ,
Try to Realize with "Do not move" released and "Zones in flatten areas deactivated"
The following 6 Connections have not been realized even with loosen settings.
786 , Part_1-code_1-A , Part_1-code_2-A , Part_1-code_3-A
819 , Part_1-code_4-A , Part_1-code_5-A , Part_1-code_6-A
3114 , Part_2-code_14-A , Part_1-code_13-A , Part_2-code_15-A
3122 , Part_3 , Part_2-code_14-A , Part_1-code_12-A
100426 , Part_1-code_18-A , Part_1-code_12-A ,
100430 , Part_1-code_19-A , Part_1-code_13-A ,
Try to Realize with NO HAZ"
All connections have been realized successfully!
```

Fig.8: Report file

5 Model Conversion

Another topic to be mentioned is that ANSA offers the ability of converting a FE-representation to a completely different realization. This means that a model that is connected with 1-D elements (**`*ELEMENT_BEAM`**) can be transformed into a model that is connected with solid nuggets (**`*ELEMENT_SOLID`**). The user can simply switch from one FE-representation to the desired one as long as ANSA connections are available. There is the migration process that ANSA connections have to be created. This migration process is done in ANSA through the '*Convert FE to Connection*' functionality where one can select massively the already existing connecting entities (pure LS-DYNA keywords) and get the respective ANSA connection entities. Then the next step is to select what is the desired FE-representation to apply.

6 Summary

A modern practice of simulating connections in CAE for a full vehicle model is the use of a multi-material modeling. This way one can not only represent the connecting entities but also the HAZ on each connecting flange. Ford-Werke GmbH in cooperation with BETA CAE Systems has come up with an automated process within ANSA for the assembly of LS-DYNA models that uses such a modelling technique. The specific process runs fully automated in batch mode. It starts with the input of the LS-DYNA subassembly within ANSA, continues with by reading the connections, proceeding to the realization of connections, improving the mesh quality and finally generating a full report of the completed assembly process. The current procedure results not only in higher quality models but also decreases the modelling time by avoiding user interactions.

7 Literature

[1] ANSA version 18.1.x User's Guide, BETA CAE Systems SA, January 2017

[2] Halquist, J.o., LS-DYNA Keyword Users Manula Version R7.x, Livermore Software Technology Corporation, Livermore 2014