

# PROCESS DEVELOPMENT FOR MULTI-DISCIPLINARY SPOT WELD OPTIMIZATION WITH CAX-LOCO, LS-OPT AND ANSA

<sup>1</sup>Dr. Gordon Geißler\*, <sup>2</sup>Thomas Hahn

<sup>1</sup>DYNAmore GmbH, Germany, <sup>2</sup>Audi AG, Germany

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ABSTRACT – The number of connection entities in modern car constructions is growing continuously. From that point of view, the identification of the most suitable structural behaviour of various car body configurations with respect to the number and the arrangement of connections becomes a challenge in automotive development. A standard simulation and optimization process was developed and established in a common project with the Audi AG and DYNAmore GmbH.

The simulation model assembly process consists of a car body without any connection entities, a structured data format that describe the connections in detail and an automated process that realizes the connections using ANSA.

All of these components are administrated and provided through the AUDI specific simulation data management tool CAX Load Case Composer (LoCo). This software is developed by DYNAmore and provides, among other innovative features, the possibility to parameterize components of the simulation model. With that ability at hand, it becomes possible to introduce parameters for the number of spot welds on a specified line. With the automated assembly process, the simulation engineer becomes able to investigate a number of spot weld configurations with a minimal amount of time and specific process knowledge.

Connecting this parameterized assembly process with a structural optimization software like LS-OPT, provides the possibility to set up a systematic investigation of spot weld configurations with respect to any simulation response representing structural performance. The reduction of the total amount of connections under consideration of constraints can be one goal of such an investigation. Also the adjustment of a desired structural stiffness or the control of the deformation behaviour by the connection setup might be possible objectives in that context.

## 1. INTRODUCTION

The importance of connection technology is growing in modern car constructions. To come up against the classical trade-off between minor weight and reliability of the structure, the connection of tailored components with complex shapes and different materials becomes necessary in an increasing amount. As shown in Figure 1, the equivalent number of all connection entities is more than 6000 units in an actual mid size sedan. The total number is expected to grow significant for prospective generations. All of these connection entities are related to direct and related production costs, therefore the aim is to reduce the amount of connections as far as possible.

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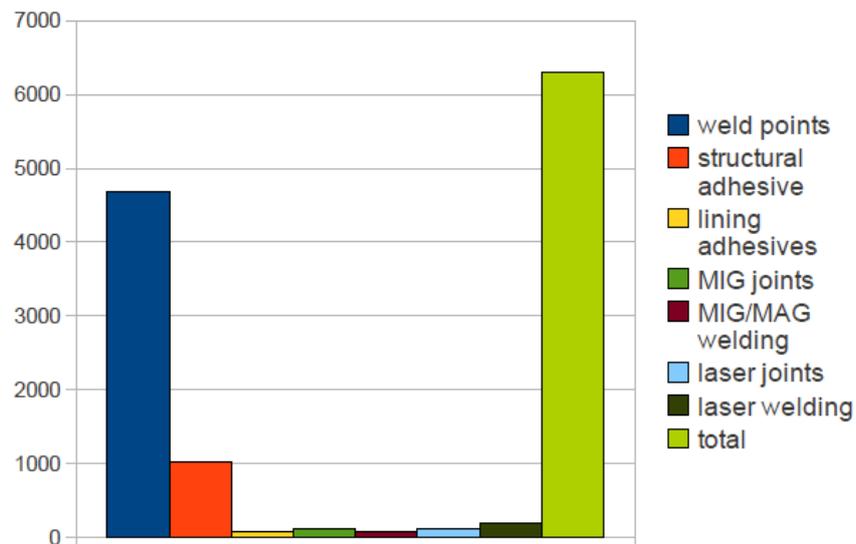


Figure 1 – Equivalent connection entities of an actual car body

With finite element simulations it becomes possible to assess the behaviour of different design variants with minimal effort. The parameterization of connection entities is rather complex compared to for instance the parameterization of sheet thicknesses. The development of an automated process that enables the simulation engineer to create variations of connections in number and position is the aim of this collaboration project with the Audi AG and DYNAMore GmbH. As shown in Figure 2, the different number of spot welds at a specific geometrical place should be accessible by only a scalar value. The process has to be compatible with the current simulation data management system and the model assembly process at Audi. Furthermore, the developed methods are applied for a discrete spot weld topology optimization with multidisciplinary load cases under consideration of constraints.

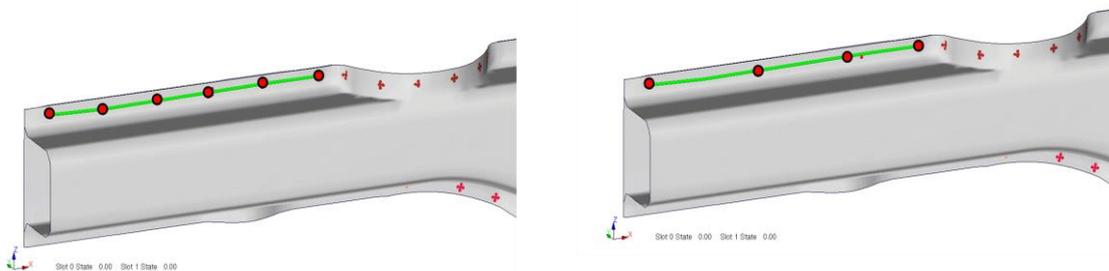


Figure 2 – Chassis beam with different number of connection entities

## 2. SIMULATION AND OPTIMIZATION PROCESS

The simulation model assembling process is assisted by the CAx Load Case Composer (LoCo) at Audi. This software is developed by DYNAMore and provides features for finite element component management and for collaboration work within a project team. The allocation of appropriate components for specific load cases is done by the tool through the relation of attributes. A first important capability of LoCo for the application in the current project is the parameterization of input files. Parameters for design changes of initial boundary conditions can be introduced in dependence on the considered load case. Exemplary, the definition of a project independent pool with barriers can be used in any project by introducing specific parameters for the barrier transformation and the initial velocity. Thus the use of redundant includes can be avoided or at least reduced by significant amounts. The second important point is the possibility to define an automated process and carry it out during the model assembly. With these two possibilities at hand, a process as shown in Figure 3 can be represented by the LoCo. The idea is to introduce the components without any connection technology and realize e.g. the spot welds and the adhesives in a

processing step after the model assembly. Therefore, a representation of the connections as well as the process for realization on the basis of ANSA scripting language has to be administered by LoCo too.

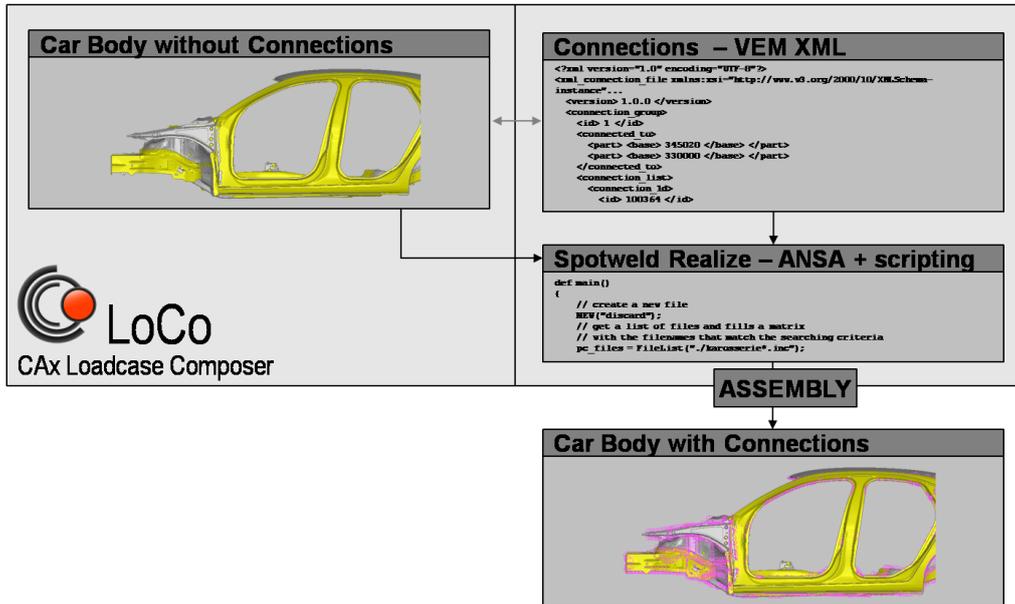


Figure 3 – Model assembly process with automated connection realization

The complete connection technology for a car body is represented within a specified extended markup language (VEM XML) format, which comes directly from the construction department in one single file. The parameterization is applied only to a selection of spot weld lines which are of interest. In a first processing step, the connection entities are separated by its type. The spot weld lines are further selected by a specific region of interest or a defined length of the geometrical lines, to keep the number of variables in a manageable size. Especially for the application of topology optimization the total number of considered splines has a huge influence on the complexity of the problem and the computational costs. Furthermore, symmetric geometrical places are identified to enable the consideration of the symmetry at spot weld realization, too. All of the described processing on the connection representation files are implemented in python scripting language, which enables a straightforward xml interpretation.

```
?xml version="1.0" encoding="UTF-8"?>
<xml_connection_file xmlns:xsi="http://www.w3.org/2000/10/XMLSchema-..."
  <version> 1.0.0 </version>
  <connection_group>
    <id> 1 </id>
    <connected_to>
      <part> <base> 345020 </base> </part>
      <part> <base> 330000 </base> </part>
    </connected_to>
    <connection_list>
      <connection_id>
        <id> 2964 </id>
        <type>spotline</type>
        <loc_list>
          <loc> 1551.566040 -782.815002 59.320831 </loc>
          ...
        </loc_list>
        <info> spacing 50.000000 </info>
        <info> margin 10.000000 </info>
      </connection_id>
      ...
    </connection_list>
  </connection_group>
```

Figure 4 – VEM XML description of a spot weld line (detail)

The exemplary xml-section of Figure 4 shows the definition of a spot weld connection line, which consists of a unique identification number <id>, an description of the connection type

<type>, the coordinates of the spline support points <loc> and information about the position of spot welds on the spline. The <spacing> defines the distance between connection points and <margin> enables the definition of an initial distance for the first spot weld at both ends of the spline. This xml Format can directly interpreted by ANSA, it is possible to open the file and realize all different types of connections. That functionality can also be used in combination with the ANSA scripting language, which enables the definition of a single processing script that contains all of the xml files and realizes the connections by the aid of ANSA.

The key for a variable number of spot welds on a spline is the introduction of a parameter and the substitution by LoCo for the model assembly process (compare Figure 5 and 6). With that functionality at hand the simulation engineer becomes able to create variations of the model with respect to the spacing and the number of spot welds on arbitrary splines in the assembled model.

```

...
  <info> spacing [% SWP_DIST_2964 %] </info>
  <info> margin 10.000000 </info>
</connection_ld>
...

```

Figure 5 – VEM XML description of a spot weld line (detail)

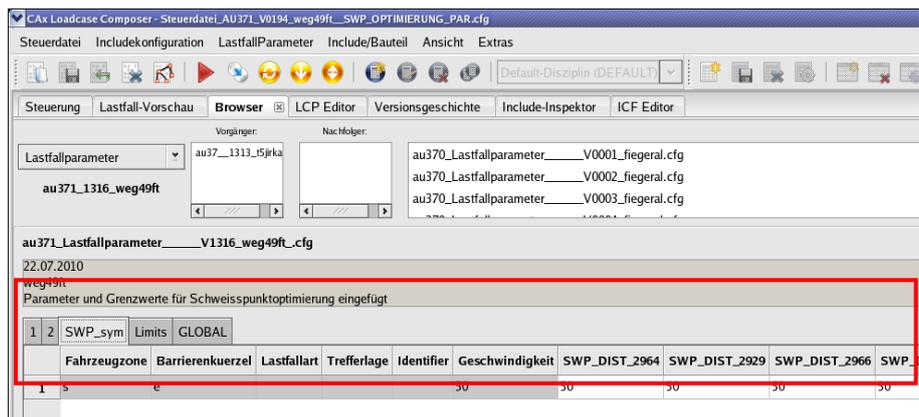


Figure 6 – LoCo GUI with parameters for the spot weld spacing on each spline

As a further possibility, the parameterization of the model enables the examination of parameter studies and numerical optimization by the utilisation of LS-OPT. The coupling of LoCo and the optimization tool is realized by a template engine, which enables a very flexible assembly definition. Similar to the standard assembly process, taking all the components of runs together to ready simulation decks, e.g. a special template for spot weld optimization is defined to assemble all necessary information and create a ready to use data structure for LS-OPT. This approach enables the access to such complex analysis for users without any detailed and specific knowledge about the underlying process.

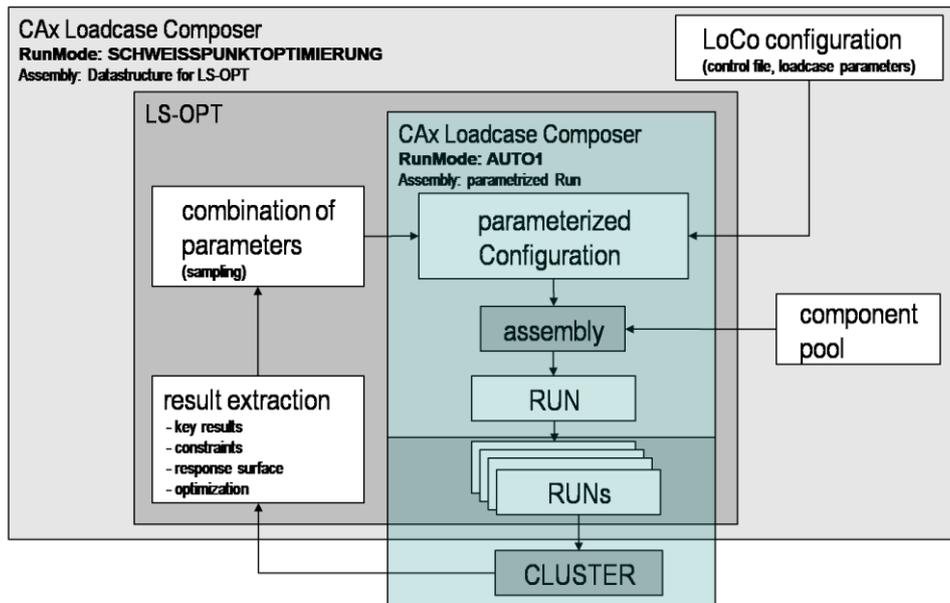


Figure 7 – Optimization Process

The whole optimization process, illustrated in Figure 7, starts with the selection of a subset of already introduced parameters and the considered load cases for the study. With these information at hand, LoCo is able to set up a data structure for the LS-OPT problem by the aid of the optimization template. Within that analysis, the optimization strategy and the distribution of parameters in the design space is in the range of LS-OPT. For each parameter set, a full simulation model is created by LoCo with the standard assembly template. The only variable components of this process are the LoCo load case parameters in a text file, that are given by the LS-OPT sampling algorithm. Together with the computation of the model and the specific evaluation of the results for each run, the assembly is carried out at the compute cluster node.

For the identification of effective spot weld configurations, a genetic algorithm is used. Due to the potentially large number of discrete variables, the strategy was applied instead of a meta-surface based method. A detailed introduction of the method and a description of all provided options, as shown in Figure 8, are given in the LS-OPT manual [3].

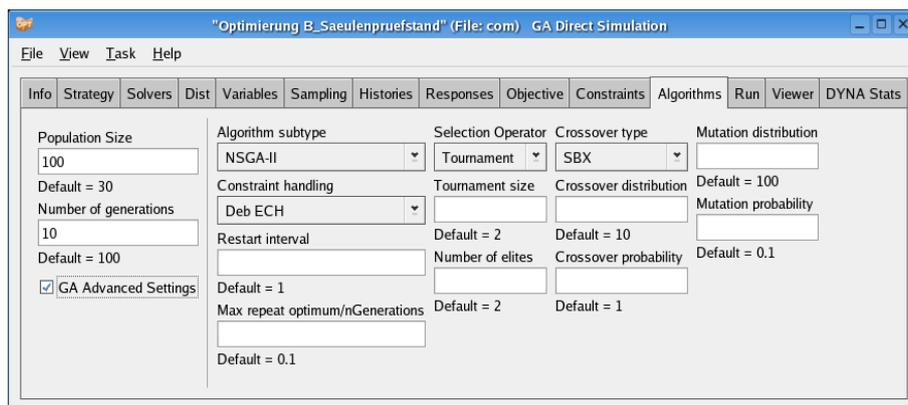


Figure 8 – Genetic algorithm advanced settings in LS-OPT

### 3. APPLICATIONS

#### Example 1

A first application of the presented methods is related to the spot weld reduction on a chassis beam of an actual development project. The section of the simulation model in Figure 9

shows the selected geometrical places where spot welds can be placed. A number of seven splines and a respective number of variables are defined for the optimization.

### Optimization Problem

Three front crash and a NVH load case with specific constraints were used to drive the optimization problem. A low speed crash for assurance purposes was carried out and the minimum number of spot welds was restricted by plastic strains and a minimum load level in the longitudinal member. In an US-NCAP crash test the occupant load criterion (OLC) and in EURO-NCAP the intrusions of the front wall were monitored. The NVH load case computes the stiffness response due to dynamic load at single points. These local dynamic stiffness values have to fulfil minimal requirements over a range of stimulation frequencies between 50 and 400 Hz.

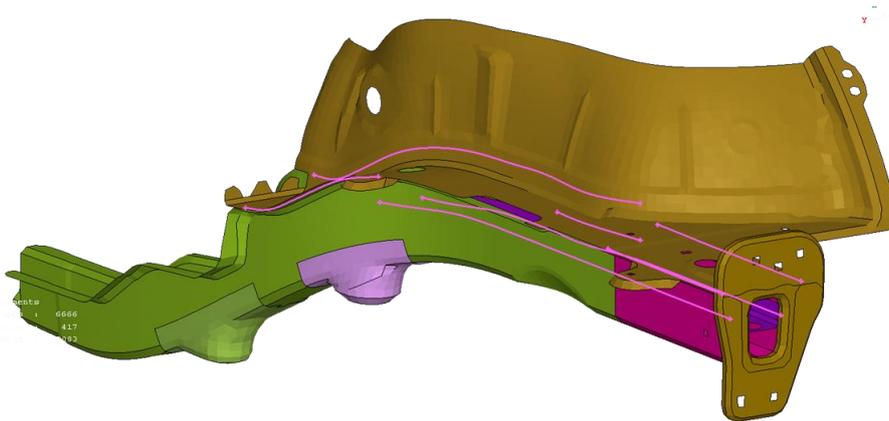


Figure 9 – Investigated chassis beam with splines for spot weld generation

### Optimization Results

After the computation of five generations the optimization was stopped due to the observation of a significant reduced number of spot welds in the investigated area under consideration of all specified boundary conditions. In summary, a number of hundred configurations were assembled and simulated for each load case. A subsequent evaluation of the spot weld forces shows no critical increase for the reduced configuration.

### Example 2

In a second investigation a single side crash load case was investigated and spot weld lines in the whole impact range of the barrier are selected for optimization. As shown in Figure 10, a total number of 14 variables are used for the problem definition. The capability to identify the symmetric counterpart for each spline in the car body was used here to couple the configuration on the left impact side with the right one. In that case, the number of necessary spot welds was restricted by the velocity of intrusion on three different points at the inside of the B-pillar. It was possible to identify configurations with less number of spot welds that fulfil this restriction. The optimization was stopped after seven generations and a number of 210 investigated variants.

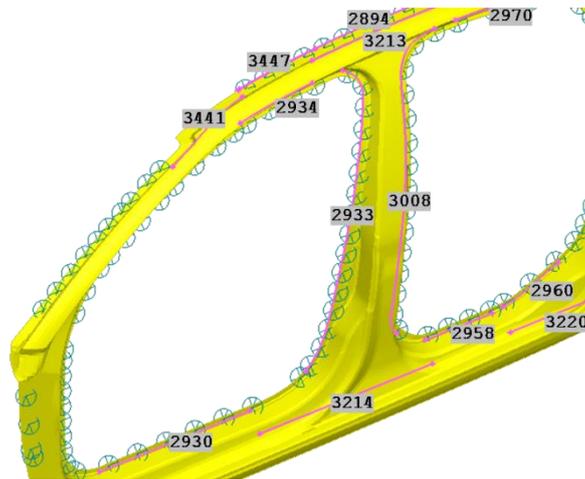


Figure 10 – Side panel frame and side impact related spot weld lines

## 5. CONCLUSIONS

In the presented project, ANSA is used to realize connections in an integrated simulation and optimization process. In combination with the simulation data management and model assembling tool CAx Load Case Composer, the general optimization tool LS-OPT and some customized process components, a standard solution for parameterized realization of connections in a vehicle simulation model was developed.

In two exemplary optimization problems, both with the aim to reduce the necessary number of spot welds, the capabilities of the proposed method are shown. In the first investigation, a local area with a small number of splines was selected for the evaluation with four different scenarios, simultaneously from the crash and the NVH discipline. The second example was related to a bigger number of variables from the whole side structure of the car. The suggested genetic algorithm was able to find a feasible configuration with a significant reduced number of spot welds for both cases.

Beside the application with the optimization focus to reduce the total number of connections under consideration of specified constraints, the parameterized definition of connection entities enables the simulation engineer to investigate different spot weld configurations with minimal costs. Also the tailored application of spot welds to control the stiffness and deformation behaviour of specific components becomes an accessible aim of investigation.

## REFERENCES

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