XMCF: A STANDARD FOR JOINT INFORMATION, COVERING PLM

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ABSTRACT

Complex systems consist of thousands of individual parts which need to be assembled by distinct kinds of joints. The increasing diversity of joining processes leads to a huge variety of attributes (geometry, joining partners, additional materials, processes, etc.) which are necessary for a qualified characterization of the joints.
This paper presents χMCF, which is introduced to standardize the description of joints needed for PLM.

KEYWORDS – Joints, connections, χMCF standard

1. INTRODUCTION

Motivation

Technical systems like passenger cars consist of thousands of individual parts which are connected by different kinds of joints (welding, gluing, riveting, screws etc.). The characteristics of a system and its components depend significantly on the used joints. Corresponding data must be available in the complete life cycle (design, simulation, testing, production, service, re-cycling).
The increasing diversity of joining processes leads to a huge variety of attributes (geometry, joining partners, additional materials, processes, etc.) which are necessary for a qualified characterization of the joints. Often several engineers are working simultaneously on the same part and joints. But, as a rule, everyone is interested only in a subset of attributes pertaining to a specific joint. Frequently, joint attributes are created and maintained decentralized. This leads often to incompleteness and inconsistency of the data and thus to inefficient processes.
X(chi)MCF (Extended Master Connection File) is a standard which has been developed by the working group 25 "Joining Technology" of FAT/VDA (The Research Association of German Automotive Union) and published as a detailed FAT report (cf. [6]).
By χMCF, the attributes of a joint element are described unambiguously in a neutral way. The definition of the attributes can begin with few attributes only and grow towards full description during the development process. χMCF is open for new joint technologies, is open for company or tool specific data which are currently not yet covered in the general standard, and new joint elements can easily be integrated. By χMCF, an efficient and reliable PLM process chain can be established with regard to the joint information. It is also a key enabler for further automations of all kind of virtual process steps.
χMCF 3.0 covers most of the joint elements which are commonly used in the automotive industry. The implementation of χMCF 3.0 in the finite element pre-processor Ansa of BETA CAE Systems International AG marks a milestone of the application of χMCF in the CAE process.

Design Principles

For the design of χMCF, different aspects need to be considered: Capability for distinct applications like CAD/CAE/CAM, easiness to integrate in different processes, openness for future developments, etc.:

1) χMCF is able to *completely* and *unambiguously* describe all relevant connections/joints used in the automotive industry. These include spot welds, seam welds, rivets and adhesives, and so on.
2) It is able to address all kind of processes, let it be in CAD, CAE and CAM, on the long run.
3) χMCF contains *only* information relevant to connections. Hierarchical product structure, assembly sequence, part variants etc. are *not* subject of χMCF. Such kind of information needs different vessels for propagation. However, χMCF may *refer* to such “external” information, e. g. part codes.
   This principle grants χMCF’s flexibility for application to any kind of process variants, established at different automotive OEMs.
4) The format is flexible and easy to extend to any future joint types and applications.
5) χMCF is built upon the industry standard XML.
6) The content of χMCF is intentionally allowed to be incomplete to a certain extend. This addresses the fact that new data is created and needs to be stored throughout the course of CAx processes, without changing its vessel.
7) χMCF follows the max-min principle: It contains information as much as necessary, at the same time, as little as possible.
8) At any certain stage of any involved process, connectors can be reconstructed from χMCF without loss of data or ambiguities.
9) The format description is kept compact. Elements are reused, whenever possible.
10) Application specific data can be stored in χMCF even without standardization: χMCF offers corresponding “empty” containers which can be assigned to any certain connector or to the complete collection / file.
11) Due to its simplicity and extensibility, χMCF forms a good candidate for long-term archiving connector information.

2. DETAILED FEATURES OF XMCF

<u>Description of topology</u>

A complex structure arises from assembling individual parts and sub-structures by joints. By assembling, a topology is introduced which makes a structure out of an amorphous system. Mathematically speaking, topology establishes a neighborhood relation in an amorphous set. In the present context the topology specifies which parts or sub-structures are connected by a specific joint like spot weld or seam weld or whatsoever, at which location, with which properties, etc. This can also be equivalently expressed as a specific joint (location, properties etc.) connecting certain parts or sub-structures ….

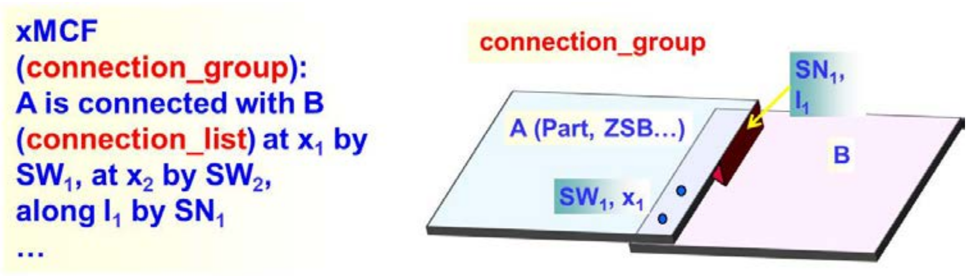

Figure 1 – Topological relation between parts or assemblies

In χMCF the topological relationship is mapped into XML by using an element tagged <connection_group/>, see Figure 1. A <connection_group/> comprises all joints connecting the same parts (or assemblies) which are specified in the node <connected_to/> either as string labels or integers (both are unique). The joints in the same <connection_group/> are grouped in the child node <connection_list/> (cf. [6]).

Idealization of joints

Each joint possesses individual properties and characteristics. Joints may differ from each other by their geometrical shapes, mechanical properties like strengths for different loadings, manufacturing processes etc.
To allow an efficient description of joints, some simplification and idealization are necessary. The way chosen by χMCF is to classify joints by their most basic and mandatory attributes, namely its geometrical dimensions. More precisely, there are 0-, 1- and 2-dimensional joints in χMCF, see Figure 2.

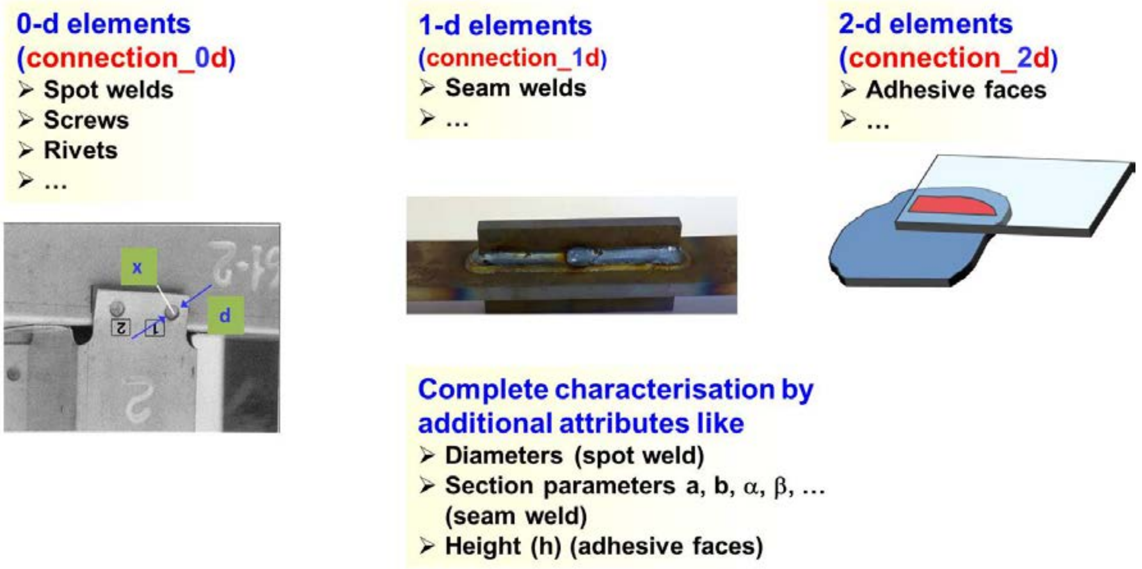

Figure 2 – Joints of different dimensions

E.g. a spot weld is a typical 0-dimensional joint in χMCF. It is geometrically described by its coordinate vector x (mapped to the xml-element <loc/>) and its diameter *d* as an additional attribute, see the following example:

```
<connection_0d label="Point.2872">
    <spotweld diameter="5.000"/>
    <loc>2382.359 536.151 260.272</loc>
    <custom_attributes_list>
        <custom_attributes owner="OEM_Car">
            <string key="WeldGR">5C6_800_709</string>
        </custom_attributes>
    </custom_attributes_list>
</connection_0d>
```

Listing 1 – Snippet of a χMCF for the definition of a spot weld

Screws, rivets, gum drops etc. are other examples for 0-dimensional joints.
A seam weld is a representative of 1-dimensional joints, see Figure 2. It is characterized by a polygon describing its spatial course and further parameters (attributes) determining its sectional shape perpendicular to the polygon. There are a dozen subtypes of seam welds (cf. [6]). The points of the polygon are <loc/>'s which are ordered in the xml node <loc_list/>.
Similarly, adhesives are often idealized as 2-dimensional joints (remember there are also 1-dimensional adhesive lines in χMCF). Two dimensional joints are geometrically specified by a surface and its height as attribute. The surfaces are composed of tri- or quadrangles. The vertices of the tri- or quadrangles are numbered <loc/>'s ordered in the xml node <loc_list/>. The tri- or quadrangles are defined by triples or quadruples (connectivity) of the numbers of the corresponding <loc/>'s which are grouped in a <face_list/> node.

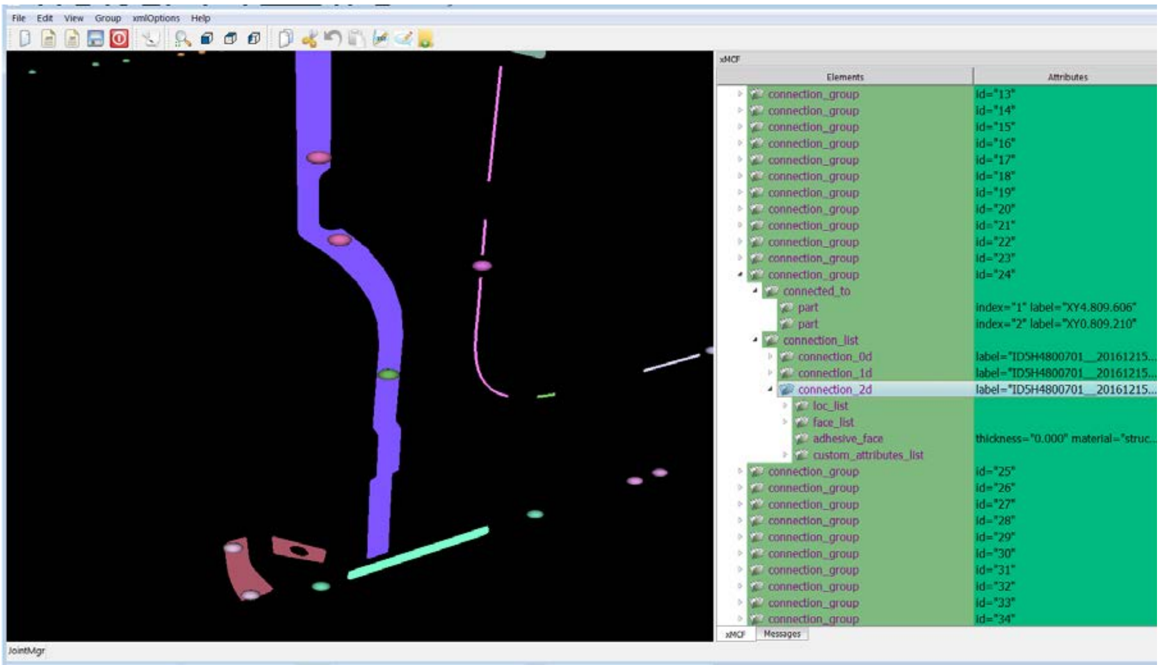

Figure 3 – Example of a χMCF file with 0-, 1- and 2-d joints

Usually the surfaces are constructed in a CAD-software (like CATIA). The tri- or quadrangles may be obtained by the tessellation of the surface geometry. Other than finite elements the connectivity of the tri- or quadrangles obtained by tessellation is usually incompatible (Gaps between neighbouring tri- or quadrangles of the same surface may exist. In ANSA, these tri- and quadrangles do not form a mesh-able macro). Of course, a compatible/conform (e.g. finite element) mesh can also be used for the representation of a 2-dimensional joint in χMCF.
In Figure 3 an example consisting of 0-, 1- and 2-d joints is shown. A χMCF file consists normally of several <connection_group/>'s which again contain more than one joint listed in the corresponding <connection_list/>.

<u>Joints considered in χMCF 3.0</u>

The current χMCF 3.0 (cf. [6]) covers the following joints:

1) 0-d joints:
   Spot welds, robscans, rivets, bolts and screws, gum drops, clinches, heat stakes/ thermal stakes, clips/snap joints, nails.
2) 1-d joints:
   Seam welds, adhesive lines, hemming flanges, sequence connections.
3) 2-d joints:
   Adhesive faces.

<u>User and application specific data</u>

χMCF makes a distinction between data which are generally standardized and data which are user and application specific. General data like geometrical parameters (e.g. diameter, location for spot welds) are standardized, either as attributes (like "technology" for seam welds) or as elements (like <loc/> for coordinates).
There are also many data which are user or application specific. A user, user group or company may need additional attributes for joints which have meanings only for him/them. Similarly, some software tools need the possibility to store parameters (e.g. meshing-parameters for a pre-processor) which is not relevant for other software tools. It is not necessary and often impossible, to standardize such data.
χMCF provides several elements where software, users and companies can place their data. The element <appdata/> can be e.g. used by software to store parameters (in case for

ANSA, these could be parameters for a special realization of a joint). <femdata/> can be used in the context of finite element applications for storing references to nodes, elements, properties etc. For more general usages, χMCF provides another element <custom_attributes_list/> which holds a list of <custom_attributes/>'s. Each element <custom_attributes/> is a container for arbitrary key-value-pairs of different kinds (similar to maps of C++ STL, dictionaries of python). As values the following data types are supported:

1) string or list of strings (<string/>, <string_list/>),
2) real or list of reals (<real/>, <real_list/>),
3) integer or list of integers (<int/>, <int_list/>).

The ownership (user/process/application) of a <custom_attributes/> element is specified by the attribute "owner=xxxx".
The introduction of owner specific data simplifies the integration of χMCF in an arbitrary, existing process. A simple example for <custom_attributes/> is given in Listing 1.

XMCF in the real processes

In real processes, joints and their attributes are defined by different responsible persons at different stages in the development process. Frequently, this is an iterative process. The joints are defined, modified, optimized.

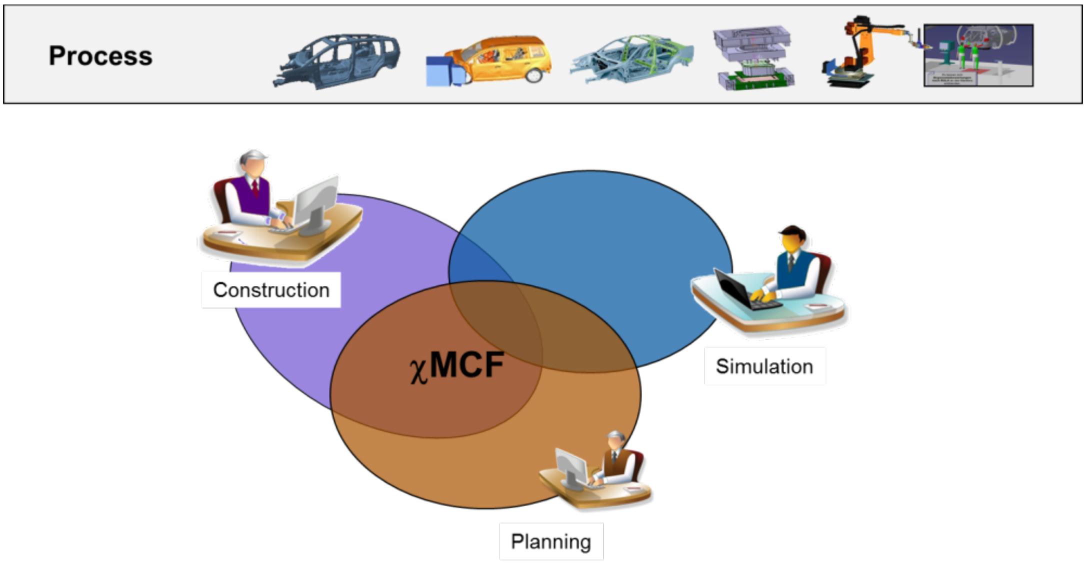

Figure 4 – χMCF in real processes

As mentioned before, the content of a χMCF file may be incomplete to a certain degree. This enables a flexible process which is illustrated by Figure 4. Accordingly, connection data may be created or modified at any stage of any CAx-process by all participating fractions: construction, simulation or planning. The available data are shared by all stakeholders in the process. By using the same database, redundancy and inconsistency is avoided. No additional interfaces between different applications are necessary.

Connection data and χMCF in PLM

In computer-aided (CAx-) processes, two major data tracks like CAD and product structure & meta data are well established and widely in use. As for connection data, the situation is less satisfying. In order to handle connections, each OEM creates own CATIA macros or buys proprietary software. Only few techniques are supported with only a fraction of their attributes. Inventing new techniques or adding new parameters results in excessive costs and process threats. Changing software vendors implies high investments. This is due to the fact that there did not exist any standard for connection data for long time.

Introducing and using χMCF remedy this unsatisfactory situation. With χMCF, a third data track parallel to CAD and product structure & meta data becomes obvious (see Figure 5). Figure 4 and Figure 6 show how a seamless process can be established using χMCF.

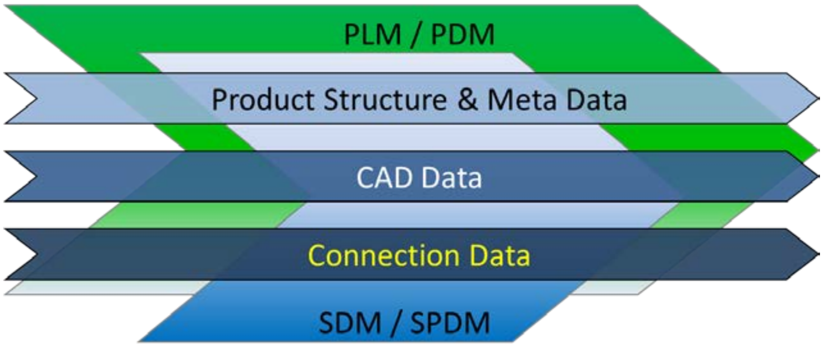

Figure 5 – Data tracks in CAx-process chain: CAD, product structure & meta data plus connection data

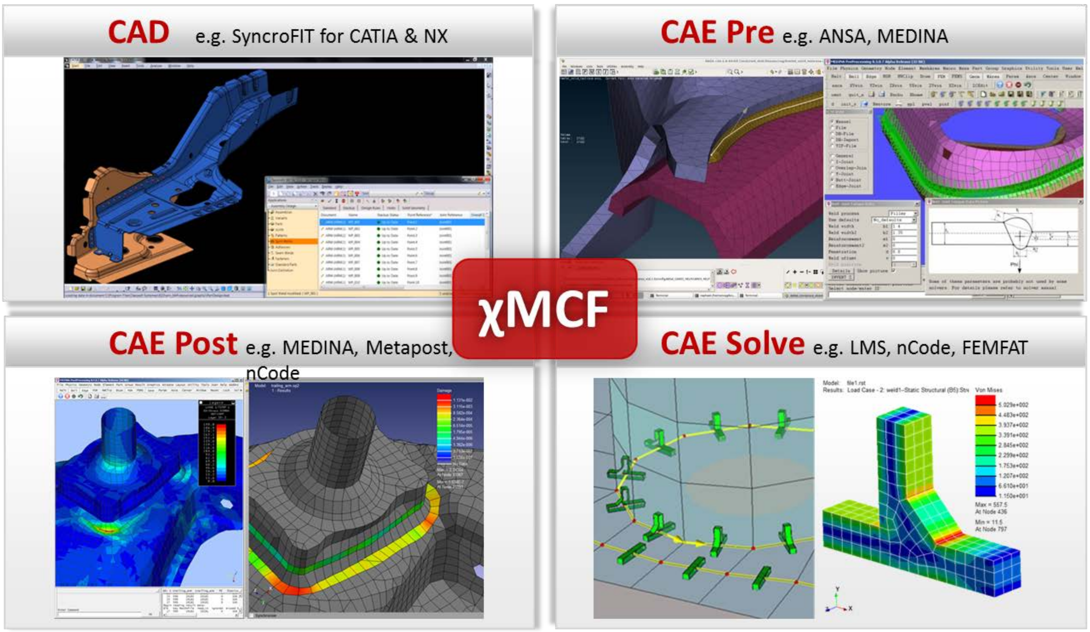

Figure 6 – Living and working with connection data and χMCF

3. IMPLEMENTAION OF XMCF IN SOFTWARE AND APPLICATION

<u>Implementation of early χMCF versions</u>

The very first implementation of χMCF (cf. [1]) was carried out in ANSA. It was then followed by the implementation of χMCF 1.1 (cf. [4]) in the pre-processor MEDINA and the fatigue solvers Virtual.Lab (Siemens/LMS), FEMFAT (Magna Powertrain ECS) and nCode DesignLife (HBM Prenscia).

<u>Implementation of χMCF 3.0</u> [6]

The implementation of χMCF 3.0 is already realized in the pre-processor HyperMesh (Altair). Its implementation in ANSA is realized partly and is still in progress.
It is to expect that the implementation of χMCF 3.0 in the CAD-systems CATIA (Dassault Systèmes) and NX (Siemens PLM) will follow.

Example application of χMCF in an in-house fatigue tool of Audi/Volkswagen

From the viewpoint of a structural analyst, the use of a standardized format for defining the characteristics of model components of any kind is very attractive. Special attention is devoted to connecting elements, since on the one hand their modelling is comparatively complex, and on the other hand they play an important role in almost all disciplines of simulation.
The application described in the following refers to the numerical fatigue analysis of welded chassis parts. Here seam welds (1d connections in χMCF) are used extensively. The properties of seam welds are complex. E.g. the material is inhomogeneous in the welding zones. There is often high residual stress in the complete structure. The weld geometry is irregular, etc. Thus the numerical fatigue evaluation of seam welds is still a big challenge. For the sake of comparison, different software products based on different fatigue concepts are frequently used side by side. Unfortunately, these often make a complete redefinition of the connection information necessary. It is obvious that the use of a standard for connection like χMCF helps to save time and gain data security.
For the fatigue analysis of seam welds at Volkswagen, the commercial software FEMFAT-Weld and the in-house tool SuperTools (based on the super-elements and developed at Audi) are used in parallel. ANSA was chosen as the pre-processor due to the support of χMCF on the one hand and the use of Python as a macro language on the other hand. In the current ANSA releases, χMCF 3.0 is not yet available, so the version 1.1 is used instead. However this is barely of significance since our aim is to depict a process that supports these two completely different procedures.
The crucial point is the separation of joint specific data from software (application) specific data. The joint specific data are independent from and thus common to all applications. Figure 7 shows how the joint specific (common) data can be defined in ANSA for seamline connections. Application data are specified as user attributes in dependence on the individual software (Femfat, SuperTools). The ANSA Python macro language in connection with the BC-GUI interface is well suited to provide a user interface to set the specific data for both approaches. All additional data is mapped on user attributes that are stored automatically in χMCF.

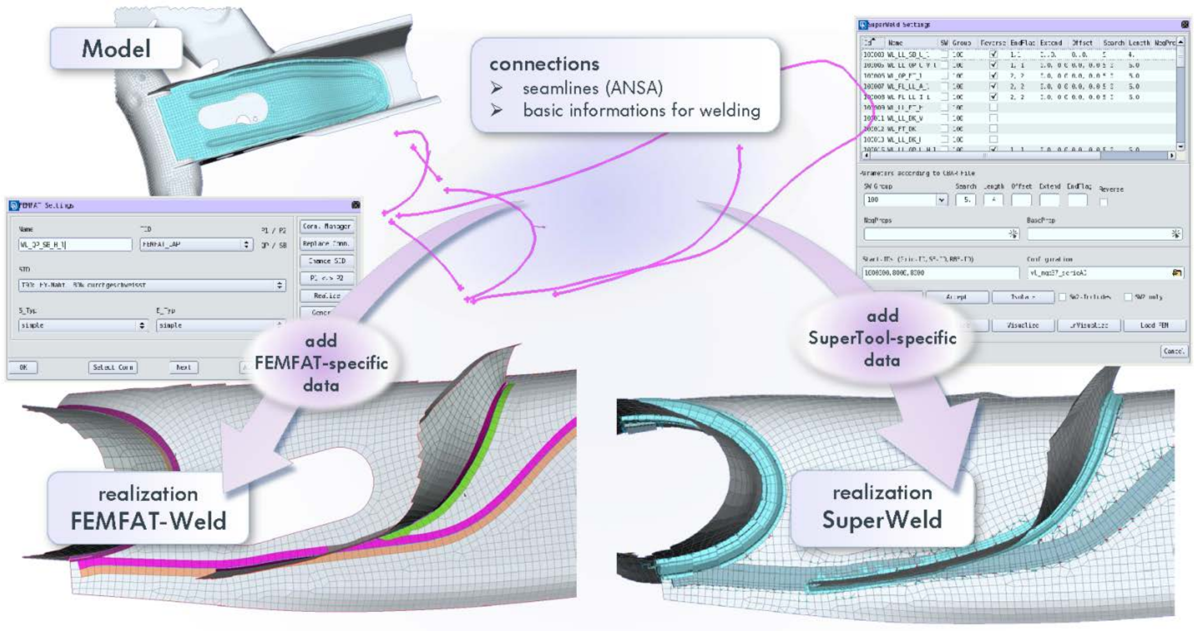

Figure 7 – The connection in ANSA forms the base for different approaches

Depending on this data, the calculation process passes different steps. A look at Figure 8 shows that both approaches are very similar and, in principle, only a few steps are really different. In both cases, FEMFAT's basic functionality is used to calculate the FE models for

the solver Abaqus and the accumulation of damage. The underlying stresses in the seamlines, on the other hand, are calculated by different methods.
In fact, the two calculation approaches differ only by adding three additional positions (drawn cyan in the figure) when using SuperTools. These are applications of the in-house programs WLPre and WLPost for the handling of special data, which are required in the context of the SuperTools. MacsPre and MacsPost are in-house tools for modeling and evaluating vehicle-specific FE models.
The experiences that have been made with χMCF in the implementation of the described process can be summarized as follows: χMCF proves to be very flexible with its XML format. Due to the fact that numerous parsers are available for different programming languages, access to the stored data in the user program is very convenient and reliable. However, the potential of χMCF can only be fully exploited if all the tools used in the process chain that convert the connection information are able to read χMCF. It is very important that this is accompanied by the ability to work in batch mode. This is the only way to ensure that interaction with the user is restricted to pre-processing and post-processing, as in the process outlined, and thus the process can also function as a loop in an optimization process.

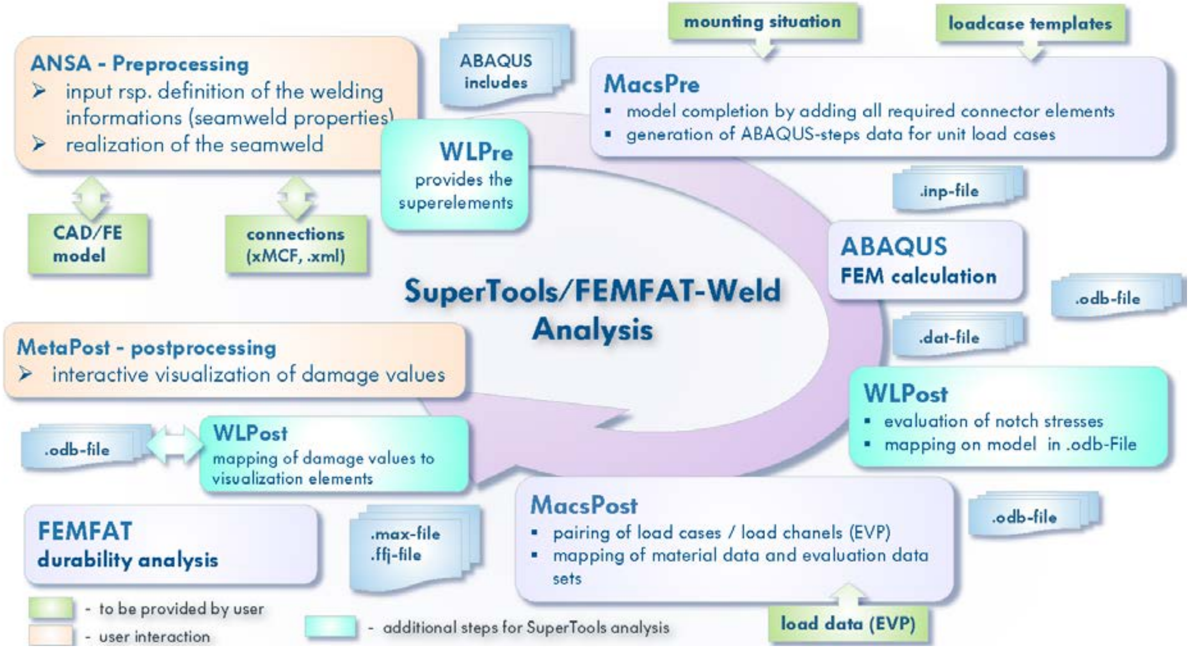

Figure 8 – Working process involving FEMFAT-Weld and SuperTools as well

As soon as the new standard (χMCF 3.0) is available for all process steps, it is planned to adapt the process chain accordingly.

4. FUTURE DEVELOPMENT

χMCF 3.0 covers joints which find consideration in the current CAE-processes in the automotive industry. For the upcoming version χMCF 3.1, further joint types will be incorporated. With increasing use of χMCF by OEMs it is expected that more and more attributes will arise which will be integrated in χMCF as continuous extension.

5. CONCLUSIONS

With χMCF 3.0, a new version of the standard for connection data is introduced. Using χMCF, an important data track for connection data parallel to the existing data tracks can easily be established. This will enable more efficient CAx-processes at all automotive OEMs.

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