χMCF (xMCF)

Extended Master Connection File

A Standard for Describing Connections and Joints in the Automotive Industry

FAT Forschungsvereinigung Automobiltechnik

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1 Introduction

1.1 Motivation

An automobile is a complex system like many other technical systems. It consists typically of thousands of individual parts which are assembled by joints. Depending on the involved materials and the manufacturing process, different joint types are often necessary in order to obtain an economical and reliable complete structure.

A wide range of joints are used in the automotive industry: From welded joints to screws, adhesives and mechanical joints like clinching etc. They differ from each other not only in their physical and mechanical properties but also in their geometrical shapes and manufacturing processes.

The development of a new car typically passes through the stages of design, simulation and testing until it reaches SOP (start of production) at the end. The information concerning the joints arises peu à peu during the progress of the development. The types of the required information may vary. For designers and CAE-engineers, geometrical information may be of primary interest whereas additional information like fillers etc. is important for prototyping and production, and so on.

An effective development process relies on the efficient management of connection information, which is extensive for a system like an automobile. This is only possible, if the involved information is standardized and mapped into a database or file. The advantage of a standard is evident: Typically, different systems like CAD, CAE and CAM are employed in the developing process. Based on a standard, there is no necessity to convert the same information from one system to the others which are often interested in only a part of the joint information. This prevents possible errors and reduces the development effort of the involved systems.

1.2 MCF

Up to the present day, there is still no standard which is capable to describe all the joint information needed in the development process. The companies use internal file formats to hold the joint information, which is typically in-house and incomplete. The Master Connection File (MCF) by Ford is one of these formats. The MCF format is based on the XML-standard and covers only few joint types (cf. [1]).

1.3 From MCF to χMCF - The Scope of the Document

Facing the difficulty that joints are represented or realized quite differently in different CAE tools, FAT-AK 25[1] made the proposal to develop a standard for connections and joints in cooperation with the vendors of CAE-software.

The evaluation of existing formats revealed that the MCF format by Ford was the most suitable basis for further developments and extensions. In order to distinguish it from the original Ford-MCF, the FAT-format was named the E<u>x</u>tended <u>M</u>aster <u>C</u>onnection <u>F</u>ile, abbreviated as χMCF (read: chi-M-C-F) or xMCF (read: x-M-C-F).

[1] Working group 25 for joining technologies of the German Research Association of Automotive Technologies. By the way, all major automotive manufacturers and suppliers resident in Germany are represented in AK 25.

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In 2005, the consortium decided to begin with the extension of MCF to seam welds. There were several reasons for this decision. First of all, the demand for the fatigue evaluation of seam welds was increasing rapidly. Furthermore, there are a wide variety of weld types with partly complex geometrical shapes. The proper description of these welds meant a big challenge. The successful treatment of seam welds would lay the foundation for the integration of any other joint type.

The current document provides a complete documentation of the spot weld and welded seams after some basic properties and features of χMCF are explained. Further joints like rivets and adhesives etc. will be treated in the near future.

The current version of χMCF does not cover all information relevant for the joints treated here. Thanks to the simple extensibility of χMCF, additional information can be integrated on demand.

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2 Design Principles and Basic Features of χMCF

The Extended Master Connection File (χMCF) is a container for connection information of a complex structure (here the focus is put on automobiles).

Typically, a complex structure consists of a lot of individual parts which are joined together. Unconnected parts are amorphous. Connections establish a topology between the parts. It is thus evident that any efficient database or container designed to gather connection information should be equipped with structures which are able to map this kind of topology between the parts.

Real development processes are complicated. The amount of connection information is huge. It is intended to promote χMCF to become an industry standard in the long term. This demands certain rigorousness of χMCF. On the other hand, some flexibility is desired in order to enable an easy integration of χMCF into different processes. This makes clear that χMCF needs a sophisticated design.

This chapter explains the design principles and some basic features of χMCF, which are important for a proper understanding and straight-forward future extensions.

2.1 Design Principles

The design of χMCF is guided by the following principles:

1) χMCF should be 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 should be 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 has to be flexible and easy to extend to any future joint types and applications.
5) χMCF is built upon the industry standard XML.
6) Connection data are unique.
7) The content of χMCF may 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.
8) χMCF follows the max-min principle: It contains information as much as necessary, at the same time, as little as possible.
9) At any certain stage of any involved process, connectors can be reconstructed from χMCF without loss of data or ambiguities.
10) The format description is kept compact. Elements are reused, whenever possible.
11) 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.
12) Due to its simplicity and extensibility, χMCF forms a good candidate for long-term archiving connector information.

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Using XML deserves some comments. XML is by itself an industry standard and human readable. XML allows for contents getting certain structure which is the precondition to easily map the topology of connectivity of complex structures like automobiles.

2.2 Idealization of Joints

Different joints possess different characteristics. They 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 simplifications and idealizations are necessary. The way chosen by χMCF is to classify joints by their most basic and mandatory attribute, namely its geometrical dimensions. Thus, there are 0-, 1- and 2-dimensional joints in χMCF.

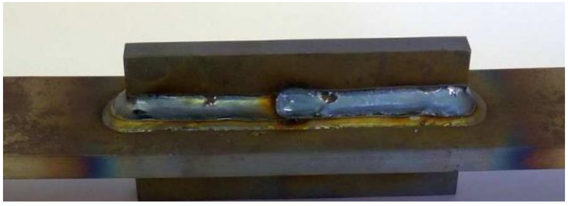

Figure 1: Seam weld as 1-dimensional joint

A spot weld is treated as a 0-dimensional joint in χMCF. In this way, a (an idealized) spot weld is geometrically described by its coordinate vector ***x*** and its diameter *d* as an additional attribute. Besides spot welds, there are more joints which can be treated as 0-dimensional.

A seam weld is a representative of 1-dimensional joints, see Figure 1. It is characterized by a curve describing its spatial course and additional parameters (attributes) determining its sectional shape perpendicular to the curve. Details are referred to later chapters.

Similarly, adhesive joints are idealized as 2-dimensional surfaces. Details are subjects of future extensions.

2.3 Reconstruction of Joints from χMCF

An important topic worthwhile to mention is the *reconstruction* of the joints. It is crucial that it is possible to reconstruct the corresponding joint in its idealized form uniquely by means of the introduced parameters and attributes. In case of spot weld, a unique reconstruction is possible by the coordinate vector **x** and the diameter d, plus the sheet thicknesses which by themselves are not a constituent of χMCF (recall χMCF contains only information relevant to joints), but of the corresponding CAD or CAE model.

2.4 Description of Topology

As mentioned before, a complex structure arises by connection of parts and sub-structures (assemblies). The connections introduce a topology between the individuals. In the present context, the description of the topological relations is not necessarily unique, a-priori. For example, the structure shown in Figure 2 could be described by the following sentences (alternatives)

1) Part (or Assembly) A is joined to Part B by the seam weld 1 along the curve l_1 and the spot weld 1 at the position x_1 …

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and
Part (or Assembly) A is connected to Part C by the adhesive AD_x in the area A_x, etc..

2) The seam weld 1 joins Part (or Assembly) A to Part B along the curve l_1
and
spot weld 1 connects Part (or Assembly) A to Part B at the position x_1 etc..

3) …

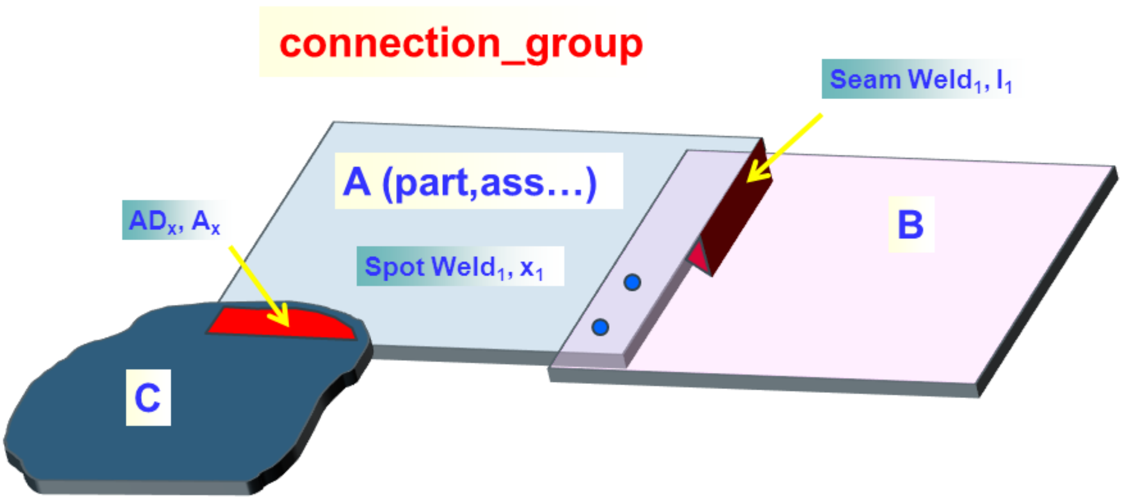

Figure 2: Topological Relations Between Parts and Assemblies

The alternative 1) is adopted by χMCF. The description is mapped into XML by using an element tagged ***<connection_group>***. A ***<connection_group>*** comprises all joints which connect the same parts (or assemblies). Details are referred to later chapters. Here one of the merits of employing XML becomes apparent.

It is to mention that frequently more than two parts are joined together. A spot weld can e.g. join three sheets, a screw even more. Such situations have to be taken into account, too.

According to design principle 3), overall product structure cannot be reproduced from χMCF. For example, any of the following product structures would equally fit to Figure 2:

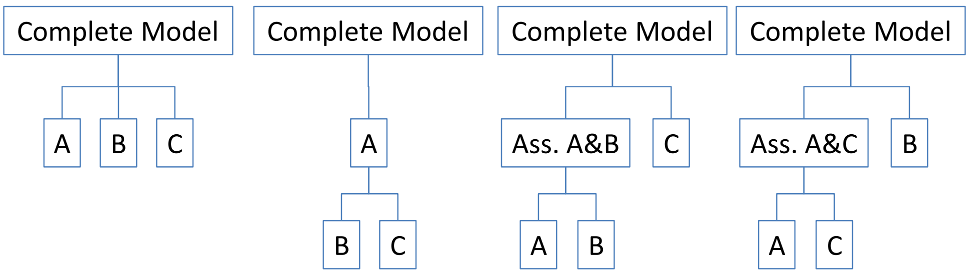

Figure 3: Product Structures Fitting to Previous Figure.

And this list is far from being complete.

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2.5 χMCF in the Development Processes

The typical development process is a long chain involving many (maybe overlapping) single steps like design, construction, prototyping, simulation, testing, production planning, etc., see Figure 4. Depending on the individual manufacturer considered, information of connections and joints arises at different stages of the process and comes from different parties (Figure 5). An efficient handling and management of this information can only be guaranteed by a (common) database/container which contains the information *uniquely*. This shall be guaranteed by a standard like χMCF.

Figure 4: The Development Process

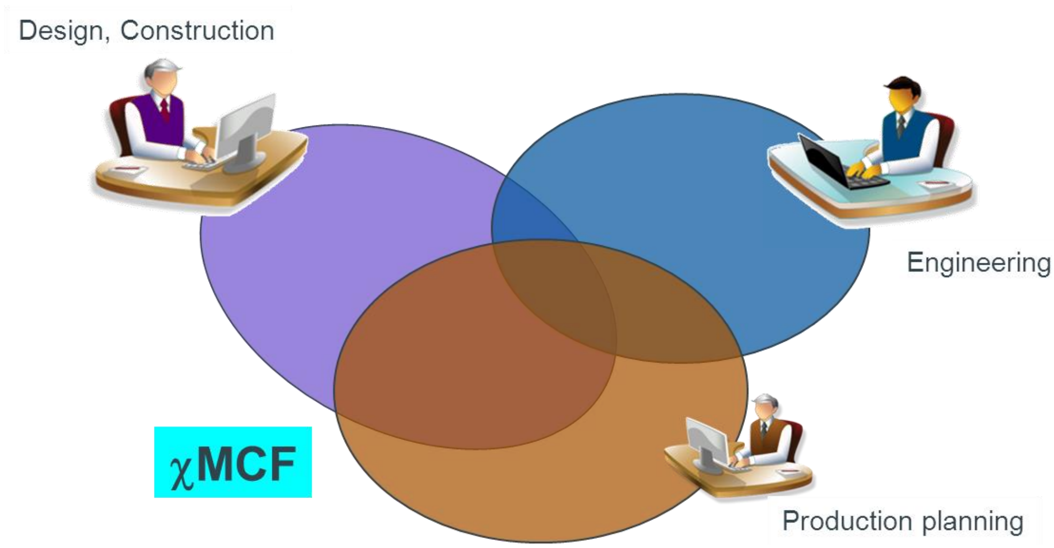

Figure 5: χMCF as a Platform for Connection Information in the Complete Development Process

A careful examination of Figure 5 enables one to get more feeling and understanding about how the work with χMCF in a real process could look like: χMCF is a structured set which can be divided into several overlapping subsets. Each subset contains a part of connection information which is of interest for a certain party, e.g., simulation or planning. The intersection of all subsets contains information which is of interest for all other parties involved, e. g. coordinates and flange partners.

As mentioned before, the information contained in χMCF is not necessarily complete, at least not at an early stage of the development process. Rather its content grows while the process is advancing. Defining the individual joint and filling up the container thus build up a continuous process. As shown in Figure 5, connection information could be created by any of the involved parties (design, construction, engineering, planning, etc.). The common situation is that each party contributes part of information (geometrical, technological etc.) defining a specific joint. Merging of the partial

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information leads to the complete characterization of the joint. Therefore, χMCF is an ideal tool to enable this dynamic process since filling up χMCF means merging information.

Figure 5 makes also clear that connection information (full or partial) is available to everyone once it is defined and stored in χMCF. Thus, unnecessary duplication of effort is avoided automatically. Typically different parties work in different environments using different software tools. Provided all systems support χMCF, transfer of data from one format to another will be not necessary any more. This will save development cost and avoid loss of data caused by the transfer.

Information contained in χMCF can be used to automate many tasks in the development and thus to enhance efficiency:

- **Automatic CAE assembly**
  Meanwhile most FE-preprocessors are able to mesh parts automatically in the batch-meshing mode. An automated assembly can be realized by the connection information contained in χMCF.
- **Automatic Programming of Welding Robot**
  Based on χMCF, welding robots can be programmed automatically.

An essential feature of χMCF is that it contains only information relevant to the joints. No data are included which are dependent on the process. Hence it is relatively easy to implement χMCF into any real process. Depending on the application, it is possible to use χMCF as a stand-alone database or integrate χMCF into an even more comprehensive database.

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3 Key-words of XML specification

3.1 Key-words

The carrier of information in a χMCF file is an element which can be equipped with some attributes and child elements. Elements and attributes are defined by their names (identifiers) and values (information).

By the XML standard, values assumed by elements can be distinguished by their types like boolean, float, double, string, date, etc. The same applies to attributes. The user can determine how elements and attributes are used (optional, required or prohibited). If necessary, the frequency of occurrence of elements with the given name (i.e., number of siblings of identical names) can be restricted (in XML schema, this is specified by the attributes *minOccurs* and *maxOccurs*).

In accordance with the XML standard (version 1.0[2]), the following key-words are used in the current document to characterize the elements and attributes:

- Type
- Value Space
- Default
- Use
- Multiplicity (corresponds to the attributes *minOccurs* and *maxOccurs* of the element ***<xs:element>*** of XML schema)
- Restrictions (corresponds to the element *restriction* of XML schema)

The type of the value of an element or attribute is specified by the key-word *Type*. The numerical ID of a property (attribute "pid") of a ***<part>*** opening tag is typically an integer which is a built-in type of XML standard. However, only positive integers are usually used in this context. That means, the possible value of ID of the type integer is restricted. To specify the values which are assumable by an element or an attribute, the key-word *Value Space* (a set) is used. The Value Space can be given as an enumeration (a finite set) or a set defined explicitly. E.g. positive integer is symbolized by > 0 whereas a float between 0.0 and 1.0 is given by [0.0, 1.0], similar to mathematics.

Some elements and attributes obtain default values if they are not given explicitly in the χMCF file. The default values adopted are specified by the keyword *Default*.

In this document, the special type "alphanumeric" is frequently used for labels of parts and assemblies, which deserve a careful discussion. In the CAD world, a label is synonymous with the name of a part, a geometric object etc. Not only letters "[A-Za-z]", but also numbers "[0-9]" and other special characters like "[-_.$#±]" and more are used for labels. Sometimes, first character is restricted to "[A-Za-z]". Thus, it is difficult to give an exact definition for the type "alphanumeric" which would fit to the individual need. Fortunately, using XML's "encoding" attribute, even non-ASCII characters can be handled easily, e. g. Arabic, Chinese, Cyrillic, Greek, Hebrew, etc. Nevertheless, as sort of general recommendation, labels should not start or end with white space.

[2] Up to now, only versions 1.0 and 1.1 of XML exist, where 1.1 is *not* widely used. Hence, most systems still create XML 1.0 files. (For differences see http://www.w3.org/TR/xml11/#sec-xml11.)

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The key-word `Use` specifies, whether an element or an attribute is optional, required or prohibited. The frequency of the occurrence of an element or attribute is defined by `Multiplicity` e.g. in the form: `minOccurs ≤ Multiplicity ≤ maxOccurs`. Any additional restrictions imposed on an element or an attribute are specified by the key-word `Restrictions`.

3.2 Operators

As explained above, the individual use of some elements or attributes may be optional. But some of them are coherent (thus in certain sense redundant). An important example is the label and pid of a part or an assembly. They represent the same part (except for e. g. tailored blanks). One can use the one or the other or both to identify a part. To express this fact, the logical operator || (OR) will be used as follows:

label || pid = 1 (true)

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4 Parts, Properties and Assemblies

χMCF describes, how parts, properties and assemblies are connected by joints in a pre-defined way. Hence, we need a clear understanding about what a part, property or assembly actually is in our context.

4.1 Parts

Parts are logical groupings of 3D objects, on first hand. Their objective is to provide a general nomenclature of the pieces which form a certain product. This nomenclature allows communications between all stake holders of all involved processes.

Typically, it is assumed that parts do not disintegrate into several physical compounds.

Parts can be instantiated at different locations of a product, e. g. wheels in a car etc.

Parts can be mirrored at a symmetry plane of the model, e. g. front doors of a car.

Parts can contain other parts (sub-parts): A car, for instance is made of body in white, power train, doors and claps etc. A door is made of an outer sheet, an inner sheet, a windows with its mechanics, some crash enforcements etc. The mechanics of a window are made of some guiding rails, an electric motor and so on.

Hence, in sense of graph theory, parts form a tree (if their instances are considered) or a directed, cycle free graph. Parts without sub-parts are called the “leaves” of this tree or graph.

If a part is mentioned in a list, not only its own content (e. g. finite elements) is addressed, but also all contents of its sub-parts and their children, down to the lowest level (leaves) of the part graph.

4.1.1 Part Labels

A part is uniquely identified by its *label*, up to ditto-parts. Connectors within a connection group that refers to ditto parts must be able to “detect” the “correct” part instance according to their respective geometrical location.

We assume that mirror parts have other part labels than their “base” parts.

Note: In most CAx processes, parts actually have two string attributes: One label describing the name and/or usage of a part in a human readable form, and another one used for indexing this item in the OEM’s “part store”. The latter one typically consists of only few characters (some 8 to 12, e. g.), resembles more to a number than to a name, and hence is not human readable. In our context, we refer to the latter one, if we say “part label”.

4.2 Properties

In CAE, properties are a concept for assigning physical behavior to a number of finite elements. Hence, any finite element can have at most one property. However, there frequently are elements without such properties (RBEs, masses, etc.). In most solvers, properties are uniquely identified by positive integers, so called property IDs or short: PIDs.

Even, if finite elements of different parts have same physical behavior (let’s say, left and right wing of a car), they usually have assigned different PIDs. This can be considered as reminiscence to ancient

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times, when parts just have not been invented. PIDs were also used for administrative purposes, then.

However, for χMCF, PIDs are just alternative, non-recursive means for addressing collections of elements.

One specific part frequently consists of one specific property (PID), only. However, there are important exceptions:

- A tailored blank is a metal sheet which consists of several pieces of simple sheets joined together. Both, the thicknesses and the materials of the individual sheets, may differ. Nevertheless, a tailored blank is one single part from the χMCF point of view. Since one PID would not provide a name for the *complete* part, the part label has to be used, or else an assembly of several PIDs.
- Sometimes, a cast part can be treated with shell formulation in its thin areas, whereas solid elements (with different PIDs) are used in other areas.
- Due to e. g. stamping processes, physical behavior and thickness may vary even within one originally homogeneous sheet metal, requiring several PIDs for correct simulation.
- Occasionally, CAD parts containing several smart pieces with their PIDs are aggregated to one single CAE part, consequently still containing several PIDs.

4.3 Assemblies

In many CAx systems, parts containing sub-parts are called assemblies. The notion distinguishes them from leaves of the part tree or graph.

However, in χMCF, an assembly is just a set of parts and/or properties, denoted by their part labels and PIDs. They do not need to possess any special relation respective to the part graph. The opposite is true: χMCF-assemblies address situations, where specifying a single PID would address not enough, a high level part would address way too many elements and medium-size parts would not make the job.

On the other hand, this does not happen too often: If a weld line e. g. crosses property boundaries, these properties usually belong to the same tailored blank, hence the same part. If there would be a physical gap between the properties, welding would be applied to a single sheet across this gap, which causes new questions to the welding process:

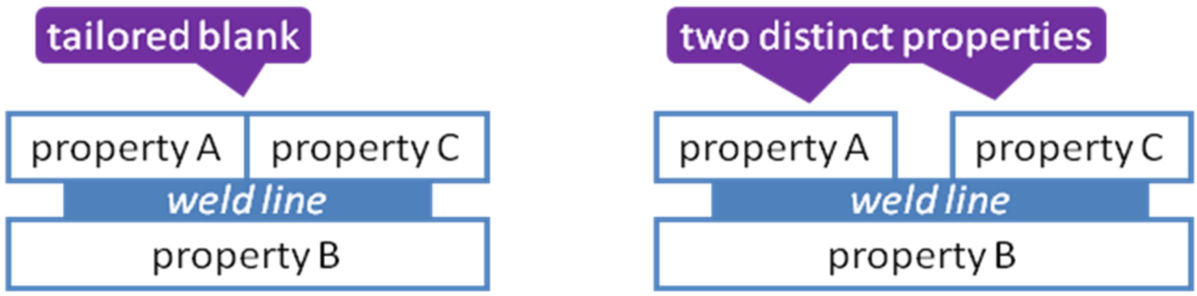

Figure 6: Weld line crossing tailored blank vs. weld line crossing physical gap

And even then: Due to geometrical proximity and usual assembly processes, it is very likely that properties A and C belong to the same part just one level above in part graph.

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5 File Structure of χMCF

As mentioned before, χMCF is built upon XML. This eases χMCF to possess a clear logical structure.

The root/document element of χMCF is mandatorily named ***<xmcf>*** [3]. The root element may contain the following types of child elements

1) Comments following the usual XML standard; hence not further discussed here.
2) Elements containing general information.
3) Variant declaration
4) Groups of connection specific elements ***<connection_group>*** of arbitrary number.
5) Elements ***<appdata>*** containing data specific for individual applications

5.1 Elements containing general information

χMCF is equipped with the following elements for general information:

- ***<date>*** optional
- ***<version>*** mandatory
- ***<units>*** optional

The root element ***<xmcf>*** contains the following nested elements:

Nested Elements	***Multiplicity***	***Status***	***Constraint***
date	1	Optional	-
version	1	Required	-
units	1	Optional	-

5.1.1 Date

The element ***<date>*** of the format “yyyy-mm-dd” specifies the date on which of the file is created. It follows norm ISO 8601, cf. http://en.wikipedia.org/wiki/ISO_8601.

Example A:

```
<?xml version="1.0" encoding="UTF-8" ?>
<xmcf xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="mcf_2_0.xsd">
    <date> 2014-08-07 </date>
    <version> 2.0.0 </version>
    <units length=”mm” angle=”rad” mass=”kg” force=”N” time=”s”/>
    ...
</xmcf>
```

[3] Since V2.0 introduces significant changes, root element has been renamed from "mcf" to "xmcf" in order to avoid confusion with the "old" MCF-Format.

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5.1.2 Version

The version code of the χMCF standard upon which the current file is built must be specified by the element ***<version>***.

The version code of χMCF files following this document is 2.0.

Example A:

```
<?xml version="1.0" encoding="UTF-8" ?>
<xmcf xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="mcf_2_0.xsd">
    <date> 2014-08-07 </date>
    <version> 2.0.0 </version>
    <units length="mm" angle="rad" mass="kg" force="N" time="s"/>
    ...
</xmcf>
```

5.1.3 Unit System

The unit system used by χMCF is based upon the International System of Units (SI[4]) and specified by the element ***<units>***. Both the base and the derived units are supported, including decimal prefixes.

Following non-SI units are allowed, additionally: Length [in] and [ft]; Mass [lb].

The following units are default of χMCF:

- Length [mm]
- Angle [deg]
- Mass [kg]
- Force [N]
- Time [s]

XML-specification of ***<units>***:

Attribute	***Use***	***Value Space***
length	Optional	"mm", "m", "in", "ft"
angle	Optional	"deg", "rad"
mass	Optional	"g", "kg", "t", "lb"
force	Optional	"kN", "N"
time	Optional	"s", "min", "h"

Example A:

```
<?xml version="1.0" encoding="UTF-8" ?>
<xmcf xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="mcf_2_0.xsd">
    <date> 2014-08-07 </date>
    <version> 2.0.0 </version>
    <units length="mm" angle="rad" mass="kg" force="N" time="s"/>
    ...
</xmcf>
```

[4] Cf. http://en.wikipedia.org/wiki/SI.

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5.2 Application, User and Process Specific Data

The user/application software can store additional information into a χMCF file. In this way, flexibility is introduced which enables an easy integration of χMCF into an existing development process.

The current χMCF definition allows two such data elements:

- ***<appdata>***
  Contents has to be documented by the corresponding application or user. It is *no* official part of the χMCF standard.
- ***<femdata>***
  Contents is documented in FATXML [7] and hence does not need to be described, here.

5.2.1 User Specific Data <appdata>

<appdata> is suitable for any user/application specific information and can be placed on root level (directly within ***<xMCF/>*** tag) and within any single connector (tags ***<connection_0d/>***, ***<connection_1d/>***, and ***<connection_2d/>***). Additionally it is also allowed to define directly under element ***<connection_group>***.

<appdata> must contain at least one nested element named after the application or user that is intended to interpret the data. It is recommended, but not required, to place application specific tags into a separate namespace and to provide a XML schema for its content.

As of September 2014, the following applications (in alphabetical order) have been registered:

- ANSA
- FEMFAT
- LMS Virtual.Lab
- MEDINA
- nCode

Note: ANSA is listed as proposal only. Beta CAE Systems S.A. should approve it.

XML-specification of ***<appdata>***:

Nested Elements	*Multiplicity*	*Status*	*Constraint*
ANSA	1	Optional	-
FEMFAT	1	Optional	-
LMSVirtualLAB	1	Optional	-
MEDINA	1	Optional	-
NCODE	1	Optional	-

Example A (*appdata* for MEDINA at <u>root</u> level):

```
<?xml version="1.0" encoding="iso-8859-1" standalone="no"?>
<xmcf xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:MEDINA="http://servicenet.t-systems.com/medina/xMCF"
xsi:schemaLocation="http://servicenet.t-systems.com/medina/xMCF mcf_MEDINA.xsd"
xsi:noNamespaceSchemaLocation="xmcf.xsd">
    <date> 2014-08-07 </date>
    <version> 2.0.0 </version>
    <units length="mm" angle="rad" mass="kg" force="N" time="s"/>
```

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```
    <appdata>
        <MEDINA xmlns="http://servicenet.t-systems.com/medina/xMCF">
            <data_at_root>
                <version MEDINA="MEDINA 8.4.2 Maintenance Release (64 Bit)"/>
                ...
            </data_at_root>
        </MEDINA>
    </appdata>
    ...
</xmcf>
```

Example B (*appdata* for MEDINA at connection level):

```
<?xml version="1.0" encoding="iso-8859-1" standalone="no"?>
<xmcf xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:MEDINA="http://servicenet.t-systems.com/medina/xMCF"
xsi:schemaLocation="http://servicenet.t-systems.com/medina/xMCF mcf_MEDINA.xsd"
xsi:noNamespaceSchemaLocation="xmcf.xsd">
    <date> 2014-08-07 </date>
    <version> 2.0.0 </version>
    <units length="mm" angle="rad" mass="kg" force="N" time="s"/>
    ...
    <connection_group id="1">
        <connected_to>
            ...
        </connected_to>
        <connection_list>
            <connection_1d label="1000032">
                <loc_list>
                    ...
                </loc_list>
                <seamweld>
                    ...
                </seamweld>
                <appdata>
                    <MEDINA xmlns="http://servicenet.t-systems.com/medina/xMCF">
                        <data_at_connector>
                            ....
                        </data_at_connector>
                    </MEDINA>
                </appdata>
            </connection_1d>
        </connection_list>
    </connection_group>
</xmcf>
```

Example C (*appdata* for MEDINA at connection level):

```
<?xml version="1.0" encoding="iso-8859-1" standalone="no"?>
<xmcf xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:MEDINA="http://servicenet.t-systems.com/medina/xMCF"
xsi:schemaLocation="http://servicenet.t-systems.com/medina/xMCF mcf_MEDINA.xsd"
xsi:noNamespaceSchemaLocation="xmcf.xsd">
    <date> 2014-08-07 </date>
    <version> 2.0.0 </version>
    <units length="mm" angle="rad" mass="kg" force="N" time="s"/>
    ...
    <connection_group id="1">
        <connected_to>
            ...
        </connected_to>
        <connection_list>
            <connection_1d label="1000032">
                <loc_list>
                    ...
                </loc_list>
                <seamweld>
                    ...
                </seamweld>
```

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```
                <appdata>
                    <MEDINA xmlns="http://servicenet.t-systems.com/medina/xMCF">
                        <data_at_connector>
                            ....
                        </data_at_connector>
                    </MEDINA>
                </appdata>
            </connection_1d>
        </connection_list>
    </connection_group>
</xmcf>
```

5.2.2 Finite Element Specific Data <femdata>

For the numerical simulation by finite element method, a joint can be discretized (realized) in different kinds and ways depending on the focus of the simulation (crash, fatigue etc.). It is thus frequently necessary to switch from one realization to another one. For this purpose, details of a specific realization may be of interest.

The optional ***<femdata>*** can be placed within any single connector [5](relevant tags are ***<connection_0d/>, <connection_1d/> and <connection_2d/>***).

<femdata> references FEM-entities that are related to the connector in which it is placed. Its content, i.e. nested elements are specific to a single solver.

This solver naming should be taken from FATXML version 1.1 (as current version) which are the followings:

- PAM-CRASH
- LS-DYNA
- Permas
- ABAQUS
- RADIOSS
- Optistruct

And these should be extended by other also required solver names to enable wide usage of the standard:

- NASTRAN
- FEMFAT

XML-specification of ***<femdata>***:

Nested Elements	***Multiplicity***	***Status***	***Constraint***
PAMCRASH	1	Optional	-
LSDYNA	1	Optional	-
PERMAS	1	Optional	-
ABAQUS	1	Optional	-
RADIOSS	1	Optional	-
OPTISTRUCT	1	Optional	-

[5] Future χMCF versions may include <femdata/> at root level or <connection_group> elements, but this is not allowed in V 2.0.

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NASTRAN	1	Optional	-
FEMFAT	1	Optional	-

Only the ***<CAE_DATA>*** tag, defined and documented in FATXML [7], is allowed as nested element of the child element of ***<femdata>***.

Nested Elements	*Multiplicity*	*Status*	*Constraint*
CAE_DATA	0-*	Required	As defined in [7].

The *CAE_DATA* element has only one attribute as defined in FATXML document version v1.1.0. This is the following:

Attributes	*Type*	*Status*	*Constraint*
VERSION	Numeric	Required	-

Attribute "VERSION"

It represents the CAE Variant in the xml code. The 0 value stands for original data from PDM System. If the CAE Part is being modified in a preprocessor then this attribute will be incremented.

The *CAE_DATA* element can have nested elements as defined in FATXML document version v1.1.0. These are the followings:

Nested Elements	*Multiplicity*	*Status*	*Constraint*
REPRESENTATION	1	Optional	-
COMMENT	1	Optional	-
CAE_PART_MEMBER	1-*	Required	-

Element "REPRESENTATION"

This element describes by text content within its nested element value the same PDM Part which is being represented by a specific FE modeling technique. E.g. for CRASH or NVH different mesh quality or used FE Element can be assumed.

Element "COMMENT"

This element can be used to make some comments regarding to the applied CAE data.

Element "CAE_PART_MEMBER"

To describe the cae part members involved in the connection this element can be used to identify it by defining an *ID* and *ENTITY* elements. For further definition of *CAE_PART_MEMBER* see the document source website for FATXML [7][6].

[6] http://www.vda.de/de/publikationen/publikationen_downloads/detail.php?id=955

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Example A (example of ***femdata*** within a ***connection_0d*** element**):**

```
<connection_0d label="My0dConnection_id_100000">
    ...
    <femdata>
        <NASTRAN>
            <CAE_DATA VERSION="1">
                <REPRESENTATION>
                    ...
                </REPRESENTATION>
                <COMMENT>
                    ...
                </COMMENT>
                <CAE_PART_MEMBER ID="1">
                    <ENTITY>
                        <TYPE>
                            CQUAD
                        </TYPE>
                        <ID>
                            12345-12356
                        </ID>
                    </ENTITY>
                </CAE_PART_MEMBER>
            </CAE_DATA>
        </NASTRAN>
    </femdata>
    ...
</connection_0d>
```

Similar to FATXML, χMCF data can be imbedded into solver decks by this means: Any receiving system can easily detect and remove discretization objects, created by a sending system, in order to substitute them by its own new discretization objects.

5.3 Connection Data <connection_group>

<connection_group> comprises the topological information about the involved parts and assemblies (Chapter 4), respectively. As explained in Section 2.4, joints are grouped together by the parts or assemblies which they commonly connect.

The topological relation (relation of neighbors) is defined by the child element ***<connected_to>*** whereas all involved joints are listed in the child element ***<connection_list>*** according to their types (see Section 2.2).

Each ***<connection_group>*** is uniquely identified by a numeric identifier (id).

Note: From this, it follows that χMCF files *cannot* be simply "pasted together" by use of a standard text editor.

XML-specification of ***<connection_group>***:

Attributes	***Type***	Status	***Constraint***
id	Numeric (integer)	Required	unique within a χMCF file

Nested Elements	***Multiplicity***	***Status***	***Constraint***
connected_to	1	Required	-
connection_list	1	Required	-

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5.3.1 Connected Objects

The basic objects which can be jointed together are parts and assemblies (see Chapter 4) which appear as nested elements ***<part>*** and ***<assy>*** of ***<connected_to>***.

XML-specification of ***<connected_to>***:

Nested Elements	*Multiplicity*	*Status*	*Constraint*
part	1 - *	At least *one* of these elements is required	-
assy	1 - *		-

5.3.1.1 Part *<part>*

In χMCF, a part may refer to one CAx part or one CAE property, as well. However, if both attributes "label" and "pid" are present, the label governs.

It is described by the element ***<part>*** and a numeric *index*, a *label* or a *pid* (property id), all provided as attributes.

The *index* needs to be unique only within the parent element ***<connected_to>***. For specific connections, it is used as the matching index for the base sheet.

The attribute *index* of *part* element is required only if the *part* element is being used as nested element under element *connected_to*. In case if the *part* element is used within the element *assy* then NO *index* is allowed to be present as attribute of the *part* element.

XML-specification of ***<part>***:

Attributes	*Type*	*Value Space*	*Status*	*Constraint*
index	Integer	> 0	Required	Unique and required only within the parent element ***connected_to***
label	Alphanumeric	Alphanumeric	Optional	Optional, if pid is present.
pid	Integer	> 0	Optional	Optional, if label is present.

Example A (only required attributes**):**

```
<connected_to>
    <part index="1" label="PART_7000400"/>
</connected_to>
```

Example B (within optional attributes**):**

```
<connected_to>
    <part index="1" label="PART_7000400" pid="3202132"/>
</connected_to>
```

5.3.1.2 Assembly *<assy>*:

An assembly represents a sub-structure consisting of at least two ***<part>*** elements. It is described by the element ***<assy>*** with only the mandatory attribute *index*.

XML-specification of ***<assy>***:

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Attributes	*Type*	*Status*	*Constraint*
index	Integer	Required	Unique within the parent element

Example A (only ***assy*** element within ***connected_to*** - full definition**):**

```
<connected_to>
    <assy index="42">
        <part label=”sheet_steel_in_door_left_30_thickness2.70” pid="110013"/>
        <part label=”sheet_steel_in_door_left_31_thickness2.75” pid="110099"/>
    </assy>
</connected_to>
```

Example B (*part* and ***assy*** elements within ***connected_to*** - full definition**):**

```
<connected_to>
    <part index=”1” label=”sheet_steel_in_door_left_32_thickness3.2” pid=”3202132”/>
    <assy index="42">
        <part label=”sheet_steel_in_door_left_30_thickness2.70” pid="110013"/>
        <part label=”sheet_steel_in_door_left_31_thickness2.75” pid="110099"/>
    </assy>
</connected_to>
```

Example C (*part* and ***assy*** elements within ***connected_to*** - minimum definition**):**

```
<connected_to>
    <part index=”1”/>
    <assy index="42">
        <part label=”sheet_steel_in_door_left_30_thickness2.70”/>
        <part label=”sheet_steel_in_door_left_31_thickness2.75”/>
    </assy>
</connected_to>

OR

<connected_to>
    <part index=”1”/>
    <assy index="42">
        <part pid="110013"/>
        <part pid="110099"/>
    </assy>
</connected_to>
```

The body of an ***<assy>*** tag equals that of a ***<connected_to>*** tag. But the meaning is different: All parts within one ***<assy>*** tag are meant to constitute *the same* side/layer/partner of a flange, whereas all members of a ***<connected_to>*** tag are *different* sides/layers/partners of a flange.

Recursion, i. e. an ***<assy>*** tag nested within another ***<assy>*** tag, is not allowed.

5.3.2 Joints

All the joints which connect the same set of objects (order does not matter) described in the element ***<connected_to>*** are listed in the element ***<connection_list>***. There should be *only one* connection group for any distinct set of objects in a χMCF file.

As discussed in Sect. 2.2, χMCF differs between 0-, 1- and 2-dimensional joints which will be specified in detail in the following chapters. Thus, an element ***<connection_list>*** can comprise child elements ***<connection_0d>***, ***<connection_1d>*** and ***<connection_2d>*** of arbitrary repetitions.

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XML-specification of ***<connection_list>***:

Nested Elements	***Multiplicity***	***Status***	***Constraint***
connection_0d	*	optional	-
connection_1d	*	optional	-
connection_2d	*	optional	-

A ***<connection_list>*** must not be empty. That means at least 1 connection has to be defined.

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5.4 A Minimalistic Example of a χMCF file

In the following an example shows how the xMCF xml file should look like:

Example:

```
<?xml version="1.0" encoding="iso-8859-1" standalone="no"?>
<xmcf xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:MEDINA="http://servicenet.t-systems.com/medina/xMCF"
xsi:schemaLocation="http://servicenet.t-systems.com/medina/xMCF mcf_MEDINA.xsd"
xsi:noNamespaceSchemaLocation="xmcf.xsd">
<!-- File Name: new_car.xml -->
<xmcf>
    <!-- some comments -->
    <date> 2014-08-07 </date>
    <version> 2.0.0 </version>
    <units length="mm" angle="rad" mass="kg" force="N" time="s"/>
    <appdata> <!—appdata at root level -->
        <MEDINA xmlns="http://servicenet.t-systems.com/medina/xMCF">
            <data_at_root>
                <version MEDINA="MEDINA 8.4.2 Maintenance Release (64 Bit)"/>
                ...
            </data_at_root>
        </MEDINA>
    </appdata>
        ...
    <connection_group>
        <connected_to>
            <part index="1", label="sheet_leftdoor__front_t=3", pid="20123213"/>
            <part index="2", label="assembly_ leftdoor _hinge", pid="90123213"/>
        </connected_to>
        <appdata> <!—appdata at connection_group level -->
            <MEDINA xmlns="http://servicenet.t-systems.com/medina/xMCF">
                <data_at_connection_group>
                            ....
                </data_at_connection_group>
            </MEDINA>
        </appdata>
        <connection_list>
            <connection_0d>
                <femdata>
                    <NASTRAN>
                        <CAE_DATA xmlns="FATXML"7>
                           ...
                        </CAE_DATA>
                    </NASTRAN>
                </femdata>

               ...
            </connection_0d>
            <connection_1d>
               <loc_list>
                    ...
                </loc_list>
                <seamweld>
                    ...
                </seamweld>
                <appdata>
                    <MEDINA xmlns="http://servicenet.t-systems.com/medina/xMCF">
                        <data_at_connector>
                            ....
                        </data_at_connector>
                    </MEDINA>
                </appdata>
               ...
            </connection_1d>
            <connection_2d>
               ...
```

[7] *xmlns="FATXML"* is just an example. Usually, an XML namespace is determined by providing an URL.

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```
            </connection_2d>
            ...
        </connection_list >
    </connection_group>
    <connection_group>
        ...
    </connection_group>
    ...
</xmcf>
```

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5.5 XML Schema Definition

XML-Schema definition (XSD) will be created after the release of V 2.0 and published on VDA web server.

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6 Data Common to any Connection

Any connection must have an attribute called ***label***, which identifies it throughout the entire CAE process. It is not necessary that these labels are unique: For instance, if a weld line is split into different parts at a certain step in the process (e.g.: when crossing holes in the structure), its components shall keep the ***label*** attribute. A system "way down" in the process (i.e. detached from any centralized naming authority) may create new connections with all the same label, e.g.: "0" or empty string.

The ***label*** may be composed of digits only, but it should not be confused with e.g.: a finite element's ID. If desired, finite element IDs would have to be placed within some ***appdata*** element.

Any connection must have an attribute type.

Connections may come in three different dimensions: ***<connection_0d>***, ***<connection_1d>*** and ***<connection_2d>***.

Any connection must have *coordinates*. How many they are and how they are described depends on the connection's dimension. Details are described in the following sections.

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7 0D connections

7.1 Generic Definitions

7.1.1 Identification

Each point connection is optionally identified by its ***label***. This identification can be made at the element called ***connection_0d***.

The XML definitions of all 0D connections i.e. ***connection_0d*** elements are containing the following attributes:

Attributes	*Type*	*Status*	*Constraint*
label	Alphanumeric	Optional	-

Attribute "label"

The label defines the human readable identification of connection. It might contain a description of the connection or simply an index as an integer.

Example A (minimum definition**):**

```
<connection_list>
    <connection_0d>
        <loc>
            ...
        </loc>
        <spotweld>
            ...
        </spotweld>
    </connection_0d>
</connection_list>
```

Example B (within assigned text to ***label*****):**

```
<connection_list>
    <connection_0d label="MySpotWeld">
        <loc>
            ...
        </loc>
        <spotweld>
            ...
        </spotweld>
    </connection_0d>
</connection_list>
```

7.1.2 Location

The definition of the connection location is described by the element ***loc***. This element is nested below the parent element ***connection_0d***. It contains three values specifying the x, y and z coordinates of the location as text content.

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Text	***Type***	***Value Space***	***Status***	***Constraint***
x	Floating point	(-∞, ∞)	Required	-
y	Floating point	(-∞, ∞)	Required	-
z	Floating point	(-∞, ∞)	Required	-

Example A (with minimum definition for ***connection_0d*****):**

```
<connection_0d>
    <loc> 2581.21 -708.408 31.6532 </loc>
    ...
</connection_0d>
```

7.1.3 Type Specification

Each connection is identified by its type. The XML definitions of all 0D connections are containing the following elements:

Nested Elements	***Multiplicity***	***Status***	***Constraint***
spotweld	1	Optional	-

Note: Additional 0D connections types (bolt, screw, rivet, etc.) are planned to be introduced in the next version of the standard documentation which will be V3.0.

7.2 Spot welds

A spot weld is denoted by an element ***spotweld***. This element is described completely by its attribute and nested elements.

XML specification of ***<connection_0d>*** with attribute ***label:***

Attributes	***Type***	***Value Space***	***Status***	***Constraint***
label	Alphanumeric	Alphanumeric	Optional	-

Nested Elements	***Multiplicity***	***Status***	***Constraint***
spotweld	1	Optional	-

XML specification of ***<spotweld>*** with element ***diameter:***

Attributes	***Type***	***Value Space***	***Status***	***Constraint***
diameter	Floating point	> 0.0	Optional	-

The diameter of a spotweld is specified by the attribute *diameter* for the child element of ***<connection_0d>***.

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Example A:

```
<connection_0d label="SW_left_Gh_2123921">
    <spotweld diameter="5.0"/>
    <loc> 1645.83 821.145 616.585 </loc>
    <appdata>
        ...
    </appdata>
</connection_0d>
```

7.3 Robscans

It is referred to Section 10.2.

7.4 Rivets

It is referred to Section 10.2.

7.5 Screws

It is referred to Section 10.2.

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8 1D connections

8.1 Seam Welds

8.1.1 Description and Modeling Parameters

To be able to use the χMCF file as a description for seam welds in the process it is necessary to use the modeling described in this document.

The description of seam welds made up from different modeling types is handled in the way that these welds are split up into separate seam welds each of them containing the specific information representing the intended modeling.

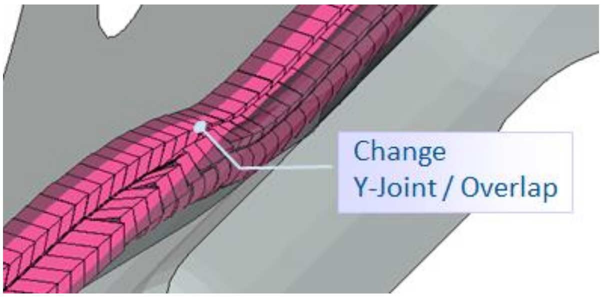

Figure 7: Weld Line Changing from Y-Joint to Overlap-Joint

This assures that a seam weld definition only represents one cross section with the welding parameters for all the welded sides.

8.1.2 Seam Weld Definition Overview

The weld definition depends on the type of the weld. For each of the different types the parameters and their meaning can be different. The detailed description can be found in the next sections describing each weld type separately.

The table shown below provides an overview over the current seam weld types and their parameters.

For each of the weld types it provides the following information:

- Type of the weld
- Number of weld positions for the type
- Supported technology
- Valid weld sections
- Required parameters
- Optional parameters with their default values
- Section drawing related to the weld type

For the given combinations of weld type, technology and section the parameters and the section drawings are provided. The section drawings do not show the specific sections possible for a technology.

The sheet parameters describing the sheet thickness in the following document sections are not part of the χMCF file contents. They are used in the weld specific sections to describe parameters stored in the χMCF file and their relations.

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The variety is to be handled by the application using the χMCF file inside the process. All the information stored for the weld together with the model is sufficient to determine the specific type of connection.

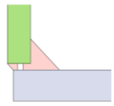
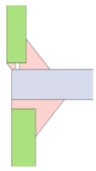
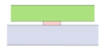
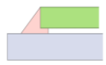
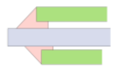
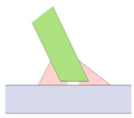
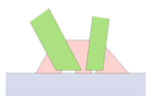
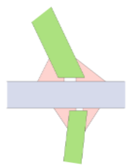
Weld Type	# of Weld Positions	Welding Technology	Section	Weld Parameter			Layout
				Required	Optional	Fixed	
Butt Joint	1	Arc	I	width	-	-	
	1		V	width	-	-	
	1		U	width	-	-	
	2		X	width	-	-	
	1		Y	width	-	-	
	1		Radius	width	-	-	
Corner Weld	1-2	Arc	Fillet	thickness i.e. throat	penetration=0 gap=0 angle=45	-	
	1-2		HV	thickness i.e. throat	gap=0 angle=45	penetration=1	
	1-2		U	thickness i.e. throat	penetration=0 gap=0 angle=45	-	
Double Corner Weld	2-4	Arc	Fillet	thickness i.e. throat	penetration=0 gap=0 angle=45	-	
	2-4		HV	thickness i.e. throat	gap=0 angle=45	penetration=1	
	2-4		U	thickness i.e. throat	penetration=0 gap=0 angle=45	-	
Edge Weld	1	Arc	I	width	gap=0	-	
	1		V	width	gap=0	-	
	1		U	width	gap=0	-	
I-Weld	1	Laser	-	width	gap=0	-	
	1	Arc	U	width	gap=0	-	
Overlap Weld	1	Arc	-	thickness i.e. throat	penetration=0 gap=0 angle=45	-	
	2	Arc	-	thickness i.e. throat	penetration=0 gap=0 angle=45	-	
	2	Arc	-	thickness i.e. throat	penetration=0 gap=0 angle=45	-	
Y-Joint	1-2	Arc	Fillet	thickness i.e. throat	penetration=0 gap=0 angle=45	-	
	1-2		HV	thickness i.e. throat	gap=0 angle=45	penetration=1	
	1-2		HY	thickness i.e. throat	penetration=0 gap=0 angle=45	-	
K-Joint	2-3	Arc	Fillet	thickness i.e. throat	penetration=0 gap=0 angle=45	-	
	2-3		HV	thickness i.e. throat	gap=0 angle=45	penetration=1	
	2-3		HY	thickness i.e. throat	penetration=0 gap=0 angle=45	-	
Cruciform-Joint	2-4	Arc	Fillet	thickness i.e. throat	penetration=0 gap=0 angle=45	-	
	2-4		HV	thickness i.e. throat	gap=0 angle=45	penetration=1	
	2-4		HY	thickness i.e. throat	penetration=0 gap=0 angle=45	-	

Figure 8: Seam weld types and attributes

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8.1.3 Specific XML Realization

This part of the XML structure describes the data stored for each of the seam welds. This includes the details necessary to describe each connection in depth.

Inside the XML definition of the seam weld each of the welds related to a connection is stored in a separate weld position inside the specific subtype definition.

```
- <connection_list>
  - <connection_1d label="1000032">
    - <loc_list>
        <loc v="0">68 0 0</loc>
        <loc v="1">88 0 0</loc>
      </loc_list>
    - <seamweld>
      - <butt_joint base="1" technology="resistance" section="Y" filler="yes">
          <weld_position u="1" x="0" y="6.12323e-17" z="1" width="3" />
        </butt_joint>
      </seamweld>
    - <appdata>
      - <MEDINA xmlns="http://servicenet.t-systems.com/medina/xMCF">
        - <data_at_connector>
          - <original_loc_list>
              <loc u="0">68 4 10</loc>
              <loc u="1">88 4 10</loc>
            </original_loc_list>
            <connection_data adjust_limit="1" weld_position_id="1" max_projection_distance="10" />
            <administrative_data element_label="Weldline_Overlap-Join" part_tree_position="fixed" connector_property_id="1000032" />
          </data_at_connector>
        </MEDINA>
      </appdata>
    </connection_1d>
  </connection_list>
```

Figure 8: χMCF Structure of a Seam Weld (`connection_1d`)

8.1.4 Generic Seam Weld Definition

8.1.4.1 Identification

Each seam weld is optionally identified by its `label`. The XML definition at ***connection_1d*** level contains the following attributes:

Attributes	*Type*	*Status*	*Constraint*
label	Alphanumeric	Optional	-

Attribute "label"

The label defines the human readable identification of the seam weld connection.

Example A:

```
<connection_list>
    <connection_1d label="MyWeldLine">
        <loc_list>
            ...
        </loc_list>
        <seamweld>
            ...
        </seamweld>
        <appdata>
            ...
        </appdata>
    </connection_1d>
</connection_list>
```

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8.1.4.2 Connection Line

The definition of the connection line is described as a series of points and thus split into segments. All other curves can also be represented with this type of representation by adding necessary points and thus approximating to the needed accuracy.

Start point of the connection line is the first location specified in the line definition. All other points are taken in the provided order inside the χMCF file.

Element "loc_list"

The list of locations for the definition of the connection line is stored in the element ***loc_list***. This element contains nested elements ***loc*** defining the location of a point of the connection line in space. These locations have to be ordered so that the line defined by the ordered list of locations specifies the connection line.

No additional attributes are associated to the element ***loc_list***.

The loc_list element has the following nested elements:

Nested Elements	*Multiplicity*	*Status*	*Constraint*
loc	1-*	Required	-

Element "loc"

Each location specified by the element ***loc*** contains three values specifying the x, y and z coordinates of the location.

The attributes associated to the element ***loc*** are:

Attributes	*Type*	*Status*	*Constraint*
v	Numeric	Required	-

The attribute ***v*** is used as surrogate index to ensure proper ordering. The values are NOT related to the attribute ***u*** used in the ***weld_position*** element.

The ***<loc>*** with the minimum value of "v" marks the start of a seam weld and max(v) is used to mark the end. The reason for that is some manufacturing techniques are not "symmetric" regarding both ends of a seam weld.

Example A:

```
<loc_list>
    <loc v="0">
            2581.21 -708.408 31.6532
    </loc>
    <loc v="0.1">
            2581.42 -708.357 35.2816
    </loc>
    <loc v="2.22">
            2581.05 -708.302 39.0643
    </loc>
</loc_list>
```

8.1.4.3 Type Specification

Each seam weld is identified by main type of the weld and described more precisely by its subtype. This means there is a general category that includes several subcases. Detailed information can be seen under definition of element main type and subtype.

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Definition of main type

The element main type for seam welding always has the value ***seamweld***. This is located directly below the ***connection_1d*** element. It is used to define the connection as general as it can be.

The XML definition of seam weld main type contains the following nested elements:

Nested Elements	*Multiplicity*	*Status*	*Constraint*
butt_joint	1	Optional	-
corner_weld	1	Optional	-
edge_weld	1	Optional	-
i_weld	1	Optional	-
overlap_weld	1	Optional	-
y_joint	1	Optional	-
k_joint	1	Optional	-
cruciform_joint	1	Optional	-

Example A (main type as ***seamweld*****):**

```
<connection_1d>
    <seamweld>
       ...
    </seamweld>
</connection_1d>
```

Note: The differentiator for the specific seam weld is stored as value in the subtype element which is described below.

Definition of subtype

Different kinds of welds are distinguished through the definition of a subtype of the seam weld.

Valid values for the subtype element are:

- ***butt_joint***
- ***corner_weld***
- ***edge_weld***
- ***i_weld***
- ***overlap_weld***
- ***y_joint***
- ***k_joint***
- ***cruciform_joint***

Each subtype element can contain the following attributes:

Attributes	*Type*	*Status*	*Constraint*
base	Numeric	Optional	-
technology	Selection	Optional	-

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Each subtype element contains the following nested elements:

Nested Elements	***Multiplicity***	***Status***	***Constraint***
weld_position	1 - *	Optional	-
sheet_parameter	1 - *	Optional	-

Note: The number of elements of ***weld_position*** is dependent on the specific subtype.

Attribute "base"

The attribute ***base*** defines the index of the base sheet for the weld. It references the attribute ***index*** inside the element ***<part>*** of the ***<connected_to>*** element. This could be useful when the angle of the weld itself is not symmetrical between the welded sheet and the base sheet. That means it is crucial to be identified to which sheet part the angle is being measured.

Attribute "technology"

The technology used to weld the connection can be specified for each of the welds of a connection separately.

This technology can be one of

- Resistance welding
- Arc welding
- Energy beam welding (e.g. laser)

Additionally to the technology there is a specification for each of the weld positions whether the welding introduces additional material (attribute ***filler***).

The attribute ***technology*** defines the welding technology used for its subtype.

Possible values are:

- ***resistance***
- ***arc***
- ***laser*** (Energy beam / Laser)

Example A (main type as ***seamweld*** and subtype as ***butt_joint*****):**

```
<connection_1d>
    <seamweld>
        <butt_joint base="1" technology="resistance">
            ...
            <weld_position ... />
            <sheet_parameter ... />
            ...
        </butt_joint>
    </seamweld>
</connection_1d>
```

8.1.4.4 Weld Position and Sheet Metal Parameters

We have to collect and put into separate groups the parameters that can be observed in terms of welding processes. Some of the used and measured parameters are related to the involved sheet metal parts, describing the thickness of the sheet and the applied sheet angle between to sheet metal parts.

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On the other hand, we can distinguish the parameters that are mentioned in terms of the welding process has been made i.e. the weld itself is present. The detailed description of these parameters can be seen for Sheet Parameters in chapter 8.1.4.4.1 and for Weld Position Parameters in chapter 8.1.4.4.2.

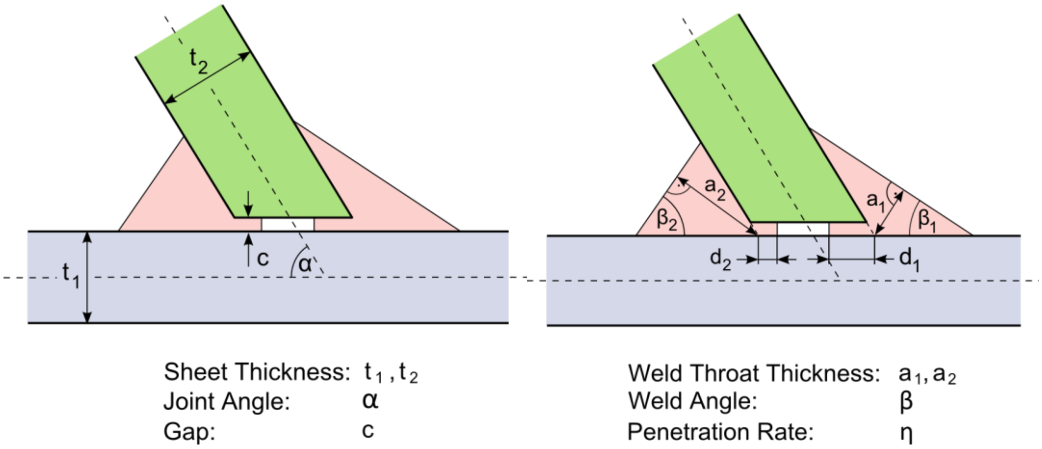

Figure 9: Sheet Parameters vs. Weld Position Parameters

8.1.4.4.1 Parameters Assigned to a Specific Sheet of the Flange

In a welded connection there are different kinds of parameters that have to be assigned to either welded sheet metal or the created weld itself. Thus we can group and put all those parameters under two elements directly under the parent subtype element. These are the ***sheet_parameter*** and the ***weld_position***.

Element "sheet_parameter"

The element ***sheet_parameter*** describes the sheet in order to identify the correct sheet when multiple sheets are connected. Furthermore it defines as attributes the corresponding gap applied between the welded sheet and the base sheet, i.e. in general the applied gap between the welded sheets involved in the welding process.

It is defined using the following attributes:

Attributes	***Type***	***Status***	***Constraint***
index	Numeric	Required	It must be referenced to ***<part>*** index attribute
gap	Numeric	Optional	Default value is 0
sheet_thickness	Numeric	Optional	-
sheet_angle	Numeric	Optional	-

Attribute "index"

The value of the attribute ***index*** must be referenced to the Part index. The *index* needs to be unique only within the parent element ***<connected_to>***. For specific connections, it is used as the matching index for the subjected welded sheet.

Attribute "gap"

The value of the attribute ***gap*** is numerical in the range (0, ∞). It defines the distance between the base and the connected sheet.

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Attribute “sheet_thickness”

The value of the attribute ***sheet_thickness*** is numerical in the range (0, ∞). It defines the CAD related input for the thickness measure of the connected sheet (in the example in Figure 9 this is t_2). In case of more than 1 welded sheet exist see the definition example in 8.1.11.5.

Attribute “sheet_angle”

The value of the attribute ***sheet_angle*** is numerical in the range [0, 360). It defines the angle between the base sheet and the connected sheet middle lines.

Example A (within each ***attribute***):

```
<connection_1d>
    <seamweld>
        <corner_weld base="1" technology="resistance">
            <weld_position .../>
            <sheet_parameter index="2" gap="1.0" sheet_thickness="1.5" sheet_angle="90"/>
        </corner_weld>
    </seamweld>
</connection_1d>
```

8.1.4.4.2 Welding Position

The position of the welding on the seam weld is specified by an orientation vector pointing from the weld root into the side where the welding takes place (see Figure 10).

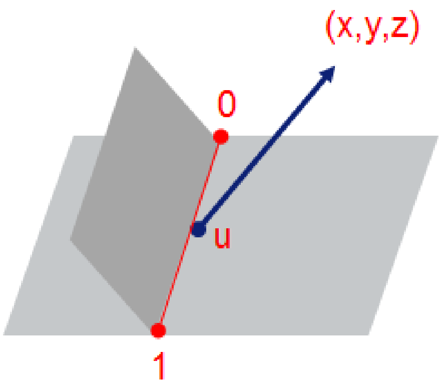

Figure 10: Welding Position of a Y-Joint

The origin of this orientation vector is located directly on the connection line. The position on the connection line is determined by a fraction in the range [0, 1] of the complete line. The fraction is applied to the length of the connection line measured as sum of all segment lengths in space.

A connection can be welded at different positions. This is depending on the seam weld type and can be between two and five positions (by combing K-Joint with a Y-Joint). Each position represents a welding performed from one side of the structure.

Details for each seam weld type are described inside the specific chapter (e.g. see 8.1.5).

Primary and Secondary Sides

For weld definitions needing a specific side the orientation vector defines the primary side. All other sides are named secondary side not specifying any precedence on them.

Element “weld_position”

The element ***weld_position*** describes the location of the weld relative to the connection line specified in ***loc_list***. It is defined using the following attributes:

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Attributes	*Type*	*Status*	*Constraint*
u	Numeric	Required	0 ≤ u ≤ 1
x	Numeric	Required	-
y	Numeric	Required	-
z	Numeric	Required	-
reference	Boolean	Optional	“false”
section	Selection	Optional	-
thickness	Numeric	Optional	Value only for specific weld types
width	Numeric	Optional	Value only for specific weld types
angle	Numeric	Optional	-
filler	Selection	Optional	-
shape	Selection	Optional	-
penetration	Numeric	Optional	0 ≤ penetration ≤ 1

Depending on subtype the attributes of the element ***weld_position*** are different. Each of the subtype is supporting its specific combination of attributes. Description of the specific combination can be found in the specific weld section below.

Example A (within each ***attribute*****):**

```
<connection_1d>
    <seamweld>
        <corner_weld base="1" technology="resistance">
            <weld_position u="0.2" x="1" y="0" z="1"
                           reference="true"
                           section="HY"
                           thickness="0.5"
                           width="3.0"
                           angle="45"
                           filler="yes"
                           shape="straight"
                           penetration="0.6"/>
            <sheet_parameter index="2" gap="1.0"/>
        </corner_weld>
    </seamweld>
</connection_1d>
```

Attributes “u”, “x”, “y”, “z”

The attribute ***u*** specifies the relative location on the connection line defined in ***loc_list***. Value ***u=0*** represents the first location of the connection line matching the element ***loc*** specified with the lowest value for the attribute ***u***. Value ***u=1*** represents the last location of this line matching the element ***loc*** with highest value for the attribute value ***u***. Values in between are specifying the point located at the specified fraction of the line measure in summed up lengths of the segments of the connection line in space.

The attributes ***x, y, z*** are specifying the direction vector in global coordinate system into the quadrant of the welding. The origin of this vector is defined by ***u*** and the ***loc_list***.

The length of the vector has no specific meaning, only the direction is used. However, it should be sufficiently long to be unambiguous as it is presented in Figure 11.

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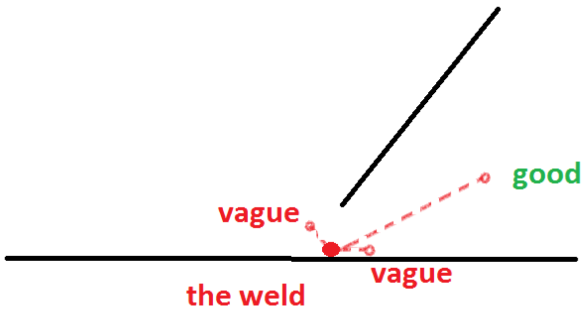

Figure 11: Welding Position vector direction and length

Attribute "reference"

The attribute ***reference*** specifies this weld position to be the reference for welds that need such a reference. In case of butt-welds or cruciform joints this is needed to specify a specific side for one of the attributes (see there).

Attribute "section"

The attribute ***section*** defines the geometry section of the weld. The different section types that can be used inside the definition of seam welds are listed here. The description here denotes the principles of the sections. Details of the interpretation on the different weld type can be found in the corresponding section for each of the weld types.

In most cases the sections "Fillet", "HV" and "HY" are used in seam weld connections when the head of a sheet is welded on a base sheet. Connections putting two sheet heads together are mostly using the section types "I", "V", "X" and "Y".

Allowed values are:

- ***I***
- ***V***
- ***U***
- ***X***
- ***Y***
- ***HV***
- ***HY***
- ***Fillet***
- ***Radius***

Section "I"

The section "I" describes the filling of the weld normally on the head sides of a connection. The section is filled completely and may be welded from one or two sides.

Section "V"

The section "V" describes the one-sided filling of the weld with welding material looking like a "V". The weld filling provides full penetration.

Section "U"

The section "U" describes the one-sided filling of the weld with welding material looking like a "U". The penetration in most cases is less than full penetration.

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Section "X"

The section "X" describes the filling of a two-side weld with welding material looking like an "X". The weld filling provides full penetration.

Section "Y"

The section "Y" describes the one-sided filling of the weld with welding material looking like a "v". Only a part of the gap between the welded sheets is filled thus there is no full penetration.

Section "HV"

The section "HV" describes the filling of a one-sided weld with a full penetration. The welded sheet is normally be phased to take full advantage of the full penetration.

Section "HY"

The section "HY" describes again a filling of a one-side weld but the penetration is only partial. In common cases the welded sheet is phased partially to take again advantage of the penetration at that area.

Section "Fillet"

The section "Fillet" describes a one-sided welding placed on the outside of the welded sheets. Depending on the sheet thicknesses there might be a penetration.

Section "Radius"

The section "Radius" describes a special case where the welding material looks like a circle but not filling the complete gap between the welded sheets. In most cases there is no full penetration.

Section "Laser"

The section "Laser" describes the filling of a laser welding affected zone. The result can be a complete weld-through on one sheet or the filling of a gap due to laser heating influence.

Attribute "thickness"

The value of the attribute ***thickness*** is a numerical value in the range of (0, ∞). It describes the distance between the weld root and the weld surface. It is used for to describe the throat thickness of the weld.

Attribute "width"

The value of the attribute ***width*** is a numerical value in the range of (0, ∞).

Attribute "angle"

The value of the attribute ***angle*** is a numerical value. This attribute of the ***weld_position*** element describes the angle between the weld face and the base sheet face.

Attribute "filler"

The attribute ***filler*** specifies whether the welding is performed using filling material. This is the case for resistance or arc welding but not for laser welding.
The allowed values are:

- ***yes***
- ***no***

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According to above rule on filling material the default values are depending on the attribute value of ***technology*** of the element subtype:

Attribute value "technology"	***Default value "filler"***
resistant	yes
arc	yes
laser	no

Attribute "shape"

The attribute ***shape*** defines the shape of the weld throat. Allowed values are:

- ***straight***
- ***convex***
- ***concave***

Attribute "penetration"

The value of the attribute ***penetration*** is a numerical value in the range [0; 1]. The value describes the ratio between the thickness and the penetration of the sheets. Value of 0 means no penetration, value of 1 represents complete penetration.

Note: *The attribute* **penetration** *of a* **<weld_position>** *holds for all sheets connected by this* **<weld_position>** *(e.g. important for K-joints).*
Note: If all **weld_position** at the same welded sheet have a sum of penetration ≥ 1 there is no open (unfilled) gap between the base sheet and the welded sheet.

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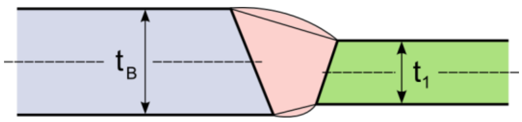
8.1.5 Butt Joint

The principles of the modeling of Butt Joints for χMCF are described in this section. A Butt Joint describes a connection between two sheets welded at their forehead side.

The XML definition of a Butt Joint supports up to two weld positions. Each of the weld positions is specified using the element ***weld_position*** with the corresponding attributes and nested elements inside the subtype definition.

8.1.5.1 Sheet Parameters

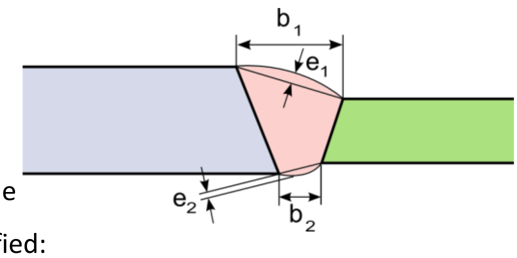
The parameters to describe the connection are:



- t_B Thickness of base sheet
- t_1 Thickness of welded sheet

8.1.5.2 Weld Parameters

The parameters of the weld are described below:



- b_1 Width of the weld at primary side
- b_2 Width of the weld at secondary side
- e_1 Reinforcement of the weld at primary side
- e_2 Reinforcement of the weld at secondary side

Inside the χMCF File the following parameters can be specified:

Parameter	***χMCF-Key***	***Multiplicity***	***Value Range***	***Status***	***Default Value***
b	width	1 – 2	≥ 0	Optional	-
e	-	(1 – 2)	(≥ 0)	(Optional)	(0)

Note: The reinforcement is currently not defined as ***attribute*** in the version 2.0 document!

8.1.5.3 Attributes

Attribute "base"

The index for the base sheet is specified using the attribute ***base***.

Attribute "technology"

The value for the attribute ***technology*** can be specified using the following values:

- ***resistance***
- ***arc***
- ***laser*** (Energy beam / Laser)

8.1.5.4 Element "weld_position"

For the element ***weld_position***, the following attributes can be specified for the Butt Joint:

Attributes	***Type***	***Status***	***Constraint***
u	Numeric	Required	0 ≤ u ≤ 1
x	Numeric	Required	-
y	Numeric	Required	-

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z	Numeric	Required	-
reference	Boolean	Optional	“false”
section	Selection	Optional	-
width	Numeric	Optional	-
filler	Selection	Optional	-

Attributes “u, x, y, z, reference”

Detailed definition can be found in section 8.1.4.4.2 Welding Position.

Attribute “section”

Valid values for the attribute ***section*** of a Butt Joint are:

- ***I***
- ***U***
- ***V***
- ***X***
- ***Y***
- ***Radius***

Attribute “width”

The attribute value ***width*** specifies the width of the weld.

Attribute “filler”

Valid values for the attribute filler can be:

- ***yes***
- ***no***

Note: *Depending on the technology the default value can different (see in Generic Seam Weld Definition section under attribute filler).*

Example A (within only necessary ***attributes*****):**

```
<seamweld>
    <butt_joint base="1" technology="arc">
        <weld_position u="0.2" x="1" y="0" z="1"
                       section="X"
                       width="1.5"/>
        <sheet_parameter ... />
    </butt_joint>
</seamweld>
```

Example B (within every ***attribute*****):**

```
<seamweld>
    <butt_joint base="1" technology="arc">
        <weld_position u="0.2" x="1" y="0" z="1"
                       reference="true"
                       section="X"
                       width="1.5"
                       filler="yes"/>
        <sheet_parameter ... />
    </butt_joint>
</seamweld>
```

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8.1.5.5 Element “sheet_parameter”

For the element ***sheet_parameter***, the following attributes can be specified for the Butt Joint:

Attributes	***Type***	***Status***	***Constraint***
index	Numeric	Required	It must be referenced to ***<part>*** index attribute
gap	Numeric	Optional	Default value is 0
sheet_thickness	Numeric	Optional	-
sheet_angle	Numeric	Optional	-

Example A (within only required ***attributes*****):**

```
<seamweld>
    <butt_joint base=”1” technology="arc”>
        <weld_position u="0.2" x="1" y="0" z="1" ... />
        <sheet_parameter index="2" gap="0" sheet_thickness=”1.5” sheet_angle=”180” />
    </butt_joint>
</seamweld>
```

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8.1.6 Corner Weld

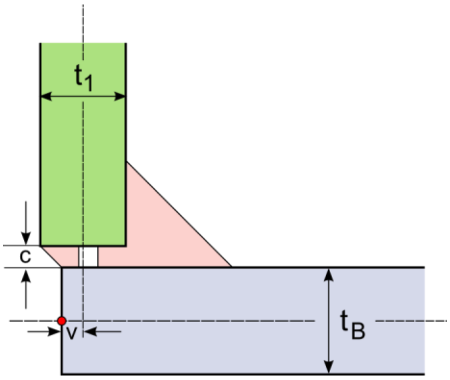
The principles of the modeling of corner welds for χMCF are described in this section. A corner weld describes a connection between two or three sheets welded together.

The XML definition of a Corner Weld supports up to four positions. Each of the weld positions is specified using the element ***weld_position*** with the corresponding attributes and nested elements inside the subtype definition.

8.1.6.1 Sheet Parameters

The parameters to describe the connection are:

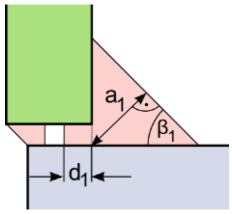
- t_B Thickness of base sheet
- t_1 Thickness of welded sheet
- c Gap between base sheet and welded sheet
- v Misalignment of welded sheet



8.1.6.2 Weld Parameters

The parameters of the welds are the same for all of the potential welds on the connection:

- a_i Thickness of the weld (a-value, throat)
- d_i Depth of the penetration
- β_i Weld angle



For the penetration the ratio η_i of the penetration depth to the sheet thickness is specified inside the χMCF file.

This is computed by $\eta_i = \frac{d_i}{t_j} \sin \alpha_j$ where variable *i* is specifying the weld index and variable *j* is defined by the sheet index of the welded sheet related to the weld. (α_j in case of a Corner Weld is 90° and therefore $\sin\alpha_j$=1.)

Inside the χMCF File the following parameters can be specified:

Parameter	*χMCF-Key*	*Multiplicity*	*Value Range*	*Status*	*Default Value*
a	thickness	1 – 2	≥ 0	Optional	
β	angle	0 – 2	≥ 0	Optional	45 [deg]
η	penetration	0 – 2	0 ≤ η ≤ 1	Optional	0

All other parameters are provided by the model itself.

8.1.6.3 Attributes

Attribute "base"

The index for the base sheet is specified using the attribute ***base***.

Attribute "technology"

The value for the attribute ***technology*** can be specified using the following values:

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- ***resistance***
- ***arc***
- ***laser*** (Energy beam / Laser)

8.1.6.4 Element “weld_position”

For the element ***weld_position*** the following attributes can be specified for the Corner Weld:

Attributes	*Type*	*Status*
u	Numeric	Required
x	Numeric	Required
y	Numeric	Required
z	Numeric	Required
reference	Boolean	Optional
section	Selection	Optional
thickness	Numeric	Optional
angle	Numeric	Optional
shape	Selection	Optional
penetration	Numeric	Optional
filler	Selection	Optional

Attributes “u, x, y, z, reference”

Detailed definition can be found in section 8.1.4.4.2 Welding Position.

Attribute “section”

Valid values for the attribute ***section*** of a corner weld are:

- ***HV***
- ***U***
- ***Fillet***

Attribute “thickness”

The attribute ***thickness*** specifies the thickness (a-value, throat) of the weld. Depending on the section this is required, optional or not allowed:

Attribute value “section”	*Attribute “thickness”*
HV	Optional
U	Not allowed
Fillet	Required

Attribute “angle”

The attribute ***angle*** specifies the angle of the weld relative to the base sheet. Depending on the section this is optional or not allowed:

Attribute value “section”	*Attribute “angle”*
HV	Optional

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U	Not allowed
Fillet	Required

Attribute "shape"

The attribute ***shape*** defines the shape of the weld throat.

Attribute "penetration"

The attribute ***penetration*** specifies the degree of penetration resulting from the welding.

Attribute "filler"

Valid values for the attribute filler can be:

- ***yes***
- ***no***

Note: *Depending on the technology the default value can different (see in Generic Seam Weld Definition section under attribute filler).*

Example A (within each ***attribute*****):**

```
<seamweld>
    <corner_weld base="1" technology="resistance">
        <weld_position u="0" x="0" y="1" z="0"
                       reference="no"
                       section="Fillet"
                       thickness="1.5"
                       angle="30"
                       shape="concave"
                       penetration="0.5"
                       filler="yes"/>
        <sheet_parameter ... />
    </corner_weld>
</seamweld>
```

8.1.6.5 Element "sheet_parameter"

For the element ***sheet_parameter***, the following attributes can be specified for the Corner Weld:

Attributes	***Type***	***Status***	***Constraint***
index	Numeric	Required	It must be referenced to ***<part>*** index attribute
gap	Numeric	Optional	Default value is 0
sheet_thickness	Numeric	Optional	-
sheet_angle	Numeric	Optional	-

Example A (within only required ***attributes*****):**

```
<seamweld>
    <corner_weld base="1" technology="resistance">
        <weld_position u="0" x="0" y="1" z="0" ... />
        <sheet_parameter index="2" gap="0" sheet_thickness="1.5" sheet_angle="90" />
    </corner_weld>
</seamweld>
```

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8.1.7 Edge Weld

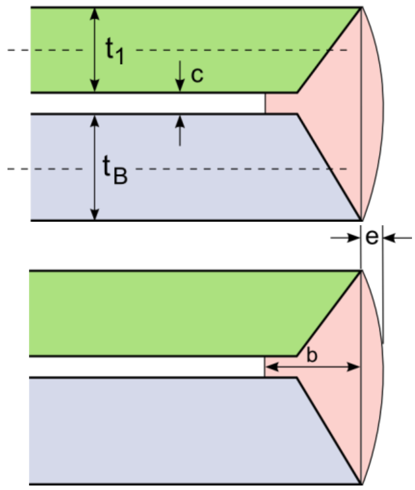
The principles of the modeling of edge welds for χMCF are described in this section. An Edge Weld describes a connection between two sheets welded at their forehead side.

The XML definition of an Edge Weld supports one position. The weld position is specified using the element ***weld_position*** with the corresponding attributes and nested elements inside the subtype definition.

8.1.7.1 Sheet Parameters

The parameters to describe the connection are:

- t_B Thickness of base sheet
- t_1 Thickness of welded sheet
- c Gap between base and welded sheet



8.1.7.2 Weld Parameters

The parameters of the weld are described below:

- b Width of the weld
- e Reinforcement

The following parameters can be specified for the edge weld:

Parameter	***χMCF-Key***	***Multiplicity***	***Value Range***	***Status***	***Default Value***
b	width	1	≥ 0	Optional	
c	gap	0 – 1	≥ 0	Optional	0
e	-	0 – 1	≥ 0	Optional	0

Note: The reinforcement is currently not defined as ***attribute*** in the version 2.0 document!

8.1.7.3 Attributes

Attribute "base"

The index for the base sheet is specified using the attribute ***base***.

Attribute "technology"

The value for the attribute ***technology*** can be specified using the following values:

- ***resistance***
- ***arc***
- ***laser*** (Energy beam / Laser)

8.1.7.4 Element "weld_position"

For the element ***weld_position*** the following attributes can be specified for the Edge Weld:

Attributes	***Type***	***Status***
u	Numeric	Required
x	Numeric	Required

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y	Numeric	Required
z	Numeric	Required
reference	Boolean	Optional
section	Selection	Optional
width	Numeric	Optional
filler	Selection	Optional

Attributes "u, x, y, z, reference"

Detailed definition can be found in section 8.1.4.4.2 Welding Position.

Attribute "section"

Valid values for the attribute ***section*** of a edge weld are:

- ***I***
- ***V***
- ***U***

Attribute "width"

The attribute ***width*** specifies the width of the weld.

Attribute "filler"

Valid values for the attribute filler can be:

- ***yes***
- ***no***

Note: *Depending on the technology the default value can different (see in Generic Seam Weld Definition section under attribute filler).*

Example A (within each optional ***attribute*****):**

```
<seamweld>
    <edge_weld base="1" technology="arc">
        <weld_position u="1" x="1" y="1" z="0"
                       reference="no"
                       section="V"
                       width="2"
                       filler="yes" />
        <sheet_parameter ... />
    </edge_weld>
</seamweld>
```

8.1.7.5 Element "sheet_parameter"

For the element ***sheet_parameter***, the following attributes can be specified for the Corner Weld:

Attributes	***Type***	***Status***	***Constraint***
index	Numeric	Required	It must be referenced to ***<part>*** index attribute
gap	Numeric	Optional	Default value is 0
sheet_thickness	Numeric	Optional	-
sheet_angle	Numeric	Optional	-

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Example A (within only required ***attributes*****):**

```
<seamweld>
    <edge_weld base=”1” technology="resistance”>
        <weld_position u="1" x="1" y="1" z="0" ... />
        <sheet_parameter index="2" gap="0" sheet_thickness=”1.5” sheet_angle=”90” />
    </edge_weld>
</seamweld>
```

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8.1.8 I-Weld

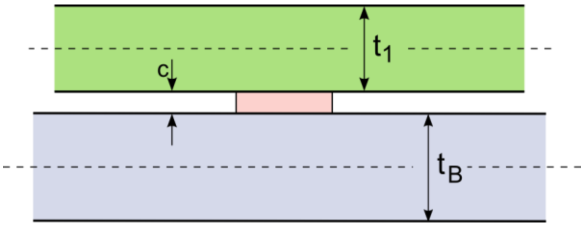
The principles of the modeling of I-welds for χMCF are described in this section. An I-Weld describes a connection between two sheets welded together.

The XML definition of an I-Weld supports one weld position. The weld position is specified using the element ***weld_position*** with the corresponding attributes and nested elements inside the subtype definition.

8.1.8.1 Sheet Parameters

The parameters to describe the connection are:

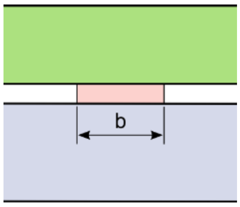
- t_B Thickness of base sheet
- t_1 Thickness of welded sheet
- c Gap between base and welded sheet



8.1.8.2 Weld Parameters

The parameters of the weld are described below:

- b Width of the weld



The following parameter can be specified for the I-weld:

Parameter	*χMCF-Key*	*Multiplicity*	*Value Range*	*Status*	*Default Value*
b	width	1	≥ 0	Optional	

All other parameters are provided by the model itself and are partially used to specify parameters of the weld.

8.1.8.3 Attributes

Attribute "base"

The index for the base sheet is specified using the attribute ***base***.

Attribute "technology"

The value for the attribute ***technology*** can be specified using the following values:

- ***resistance***
- ***arc***
- ***laser*** (Energy beam / Laser)

8.1.8.4 Element "weld_position"

For the element ***weld_position*** the following attributes can be specified for the I-Weld:

Attributes	*Type*	*Status*
u	Numeric	Required
x	Numeric	Required
y	Numeric	Required
z	Numeric	Required
reference	Boolean	Optional

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width	Numeric	Optional
filler	Selection	Optional

Attributes "u, x, y, z, reference"

Detailed definition can be found in section 8.1.4.4.2 Welding Position.

Attribute "width"

The attribute ***width*** specifies the width of the weld.

Attribute "filler"

Valid values for the attribute ***filler*** can be:

- ***yes***
- ***no***

Note: *Depending on the technology the default value can different (see in Generic Seam Weld Definition section under attribute filler).*

Example A (within each ***attribute*****):**

```
<seamweld>
    <i_weld base="1" technology="laser">
        <weld_position u="0" x="1" y="1" z="1"
                       reference="no"
                       width="1.0"
                       filler="no" />
        <sheet_parameter ... />
    </i_weld>
</seamweld>
```

8.1.8.5 Element "sheet_parameter"

For the element ***sheet_parameter***, the following attributes can be specified for the Corner Weld:

Attributes	*Type*	*Status*	*Constraint*
index	Numeric	Required	It must be referenced to ***<part>*** index attribute
gap	Numeric	Optional	Default value is 0
sheet_thickness	Numeric	Optional	-
sheet_angle	Numeric	Optional	-

Example A (within only required ***attributes*****):**

```
<seamweld>
    <i_weld base="1" technology="laser">
        <weld_position u="0" x="1" y="1" z="1" ... "/>
        <sheet_parameter index="2" gap="0" sheet_thickness="1.5" sheet_angle="0"/>
    </i_weld>
</seamweld>
```

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8.1.9 Overlap Weld

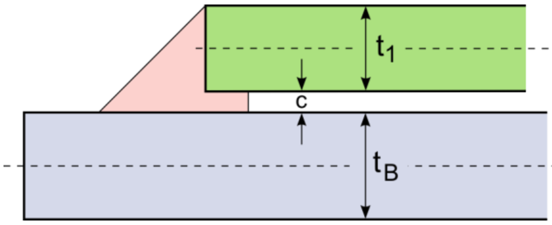
The principles of the modeling of overlap welds for χMCF are described in this section. An Overlap Weld describes a connection between two or three sheets welded together.

The XML definition of an Overlap Weld supports up to three weld positions. Each of the weld positions is specified using the element ***weld_position*** with the corresponding attributes and nested elements inside the subtype definition.

8.1.9.1 Simple Overlap Weld

Sheet Parameters

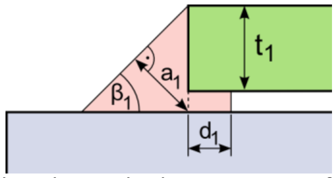
The parameters to describe the connection are:



- t_B Thickness of base sheet
- t_1 Thickness of welded sheet
- c Gap between base and welded sheet

Weld Parameters

The parameters of the welds are the same for all of the potential welds on the connection:



- a_1 Thickness of the weld (a-value, throat)
- d_1 Depth of the penetration
- β_1 Weld angle

For the penetration, the ratio η_1 of the penetration depth to the sheet thickness is specified inside the χMCF file.

This is computed by $\eta_1 = \frac{d_1}{t_1}$, where t_1 is the thickness of the attached sheet (green in above figure), *not* of the base sheet.

Inside the χMCF File the following parameters can be specified:

Parameter	***χMCF-Key***	***Multiplicity***	***Value Range***	***Status***	***Default Value***
a	thickness	1	≥ 0	Optional	
β	angle	0 – 1	≥ 0	Optional	45 [deg]
η	penetration	0 – 1	0 ≤ η ≤ 1	Optional	0

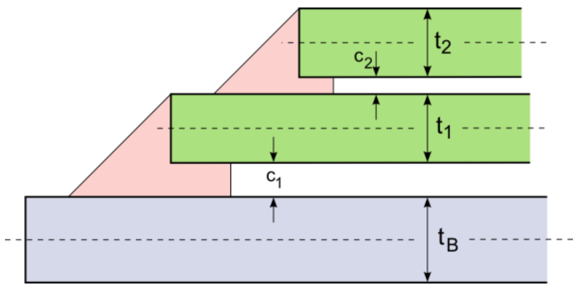
All other parameters are provided by the model itself and are partially used to specify parameters of the weld.

8.1.9.2 Single Sided Double Overlap Weld

The Single Sided Double Overlap Weld is represented by a stacked welding.

Sheet Parameters

The parameters to describe the connection are:



- t_B Thickness of base sheet
- t_1, t_2 Thicknesses of welded sheets
- c_1, c_2 Gaps between base and welded sheets

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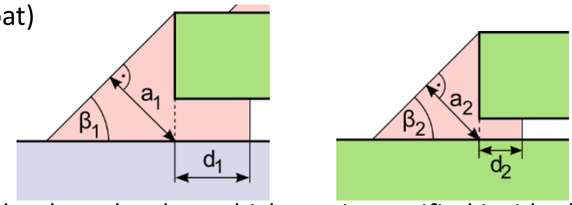
Weld Parameters

The parameters of the welds are the same for all of the welds on the connection:

- a_i Thickness of the weld (a-value, throat)
- d_i Depth of the penetration
- β_i Weld angle



For the penetration the ratio η_i of the penetration depth to the sheet thickness is specified inside the χMCF file.

This is computed by $\eta_i = \frac{d_i}{t_j} \sin \alpha_j$ where index *i* is specifying the weld index and index *j* is defined by the sheet index of the welded sheet related to the weld.

Inside the χMCF File the following parameters can be specified:

Parameter	*χMCF-Key*	*Multiplicity*	*Value Range*	*Status*	*Default Value*
a	thickness	2	≥ 0	Optional	
β	angle	0 – 2	≥ 0	Optional	45 [deg]
η	penetration	0 – 2	0 ≤ η ≤ 1	Optional	0

All other parameters are provided by the model itself and are partially used to specify parameters of the weld.

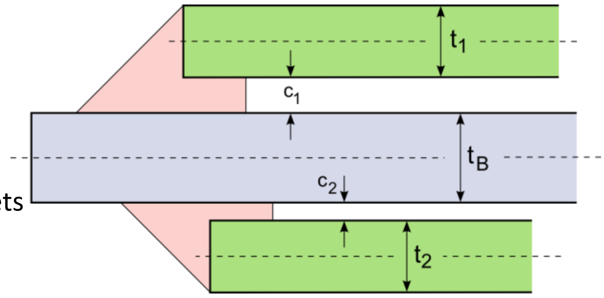
8.1.9.3 Double Sided Double Overlap Weld

A Double Sided Double Overlap Weld can have the welds on both sides of the base sheet.

Sheet Parameters

The parameters to describe the connection are:

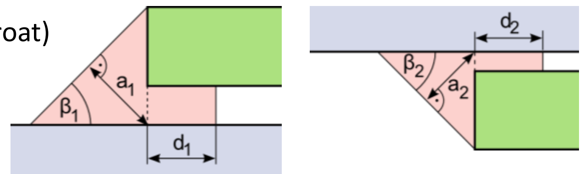
- t_B Thickness of base sheet
- t_1, t_2 Thicknesses of welded sheets
- c_1, c_2 Gaps between base and welded sheets



Weld Parameters

The parameters of the welds are the same for all of the welds on the connection:

- a_i Thickness of the weld (a-value, throat)
- d_i Depth of the penetration
- β_i Weld angle



For the penetration the ratio η_i of the penetration depth to the sheet thickness is specified inside the χMCF file.

This is computed by $\eta_i = \frac{d_i}{t_j} \sin \alpha_j$ where index *i* is specifying the weld index and index *j* is defined by the sheet index of the welded sheet related to the weld.

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Inside the χMCF File the following parameters can be specified:

Parameter	*χMCF-Key*	*Multiplicity*	*Value Range*	*Status*	*Default Value*
a	thickness	2	≥ 0	Optional	
β	angle	0 – 2	≥ 0	Optional	45 [deg]
η	penetration	0 – 2	0 ≤ η ≤ 1	Optional	0

All other parameters are provided by the model itself and are partially used to specify parameters of the weld.

8.1.9.4 Attributes

Attribute "base"

The index for the base sheet is specified using the attribute ***base***.

Attribute "technology"

The value for the attribute ***technology*** can be specified using the following values:

- ***resistance***
- ***arc***
- ***laser*** (Energy beam / Laser)

8.1.9.5 Element "weld_position"

For the element ***weld_position*** the following attributes can be specified for the Overlap Weld:

Attributes	*Type*	*Status*
base	Numeric	Optional
u	Numeric	Required
x	Numeric	Required
y	Numeric	Required
z	Numeric	Required
reference	Boolean	Optional
section	Selection	Optional
thickness	Numeric	Optional
angle	Numeric	Optional
shape	Selection	Optional
penetration	Numeric	Optional
filler	Selection	Optional

Attributes "u, x, y, z, reference"

Detailed definition can be found in section 8.1.4.4.2 Welding Position.

Attribute "base"

For this type of weld the ***base*** sheet can be specified also inside the element ***weld_position***. This is necessary in the case of a stacked welding with two welded sheets.

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Attribute "section"

The only valid value currently for the attribute ***section*** of an Overlap Weld is:

- ***Fillet***

Note: This value is the default if the ***section*** attribute is not specified.

Attribute "thickness"

The attribute ***thickness*** specifies the thickness (a-value, throat) of the weld.

Attribute "angle"

The attribute ***angle*** specifies the angle of the weld relative to the base sheet.

Attribute "shape"

The attribute ***shape*** defines the shape of the weld throat.

Attribute "penetration"

The attribute ***penetration*** specifies the degree of penetration resulting from the welding.

Attribute "filler"

Valid values for the attribute filler can be:

- ***yes***
- ***no***

Note: *Depending on the technology the default value can different (see in Generic Seam Weld Definition section under attribute filler).*

Example A (within each ***attribute***, except ***base*** within ***weld_position*****):**

```
<seamweld>
    <overlap_weld base="1" technology="resistance">
        <weld_position u="0" x="0" y="0" z="1"
                   reference="no"
                   section="Fillet"
                   thickness="1.5"
                   angle="30"
                   shape="concave"
                   penetration="0.5"
                   filler="yes" />
        <sheet_parameter ... />
    </overlap_weld>
</seamweld>
```

8.1.9.6 Element "sheet_parameter"

For the element ***sheet_parameter***, the following attributes can be specified for the Corner Weld:

Attributes	*Type*	*Status*	*Constraint*
index	Numeric	Required	It must be referenced to ***<part>*** index attribute
gap	Numeric	Optional	Default value is 0
sheet_thickness	Numeric	Optional	-
sheet_angle	Numeric	Optional	-

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Example A (within only required ***attributes*****):**

```
<seamweld>
    <overlap_weld base=”1” technology="resistance”>
        <weld_position u="0" x="0" y="0" z="1" .../>
        <sheet_parameter index="2" gap="1.0" sheet_thickness=”1.5” sheet_angle=”0”/>
    </overlap_weld>
</seamweld>
```

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8.1.10 Y-Joint

The principles of the modeling of Y-joints for χMCF are described in this section. A Y-Joint describes a connection between two or three sheets.

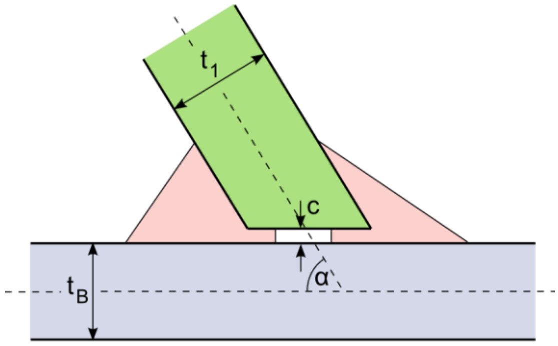
The Y-Joint defines a connection between a welded sheet and a base sheet. There are two potential welds that can be specified for this type of connection. The parameters for each of the welds can be described separately.

The XML definition of a Y-Joint supports up to three weld positions. Each of the weld positions is specified using the element ***weld_position*** with the corresponding attributes and nested elements inside the subtype definition.

8.1.10.1 Sheet Parameters

The parameters to describe the connection are:

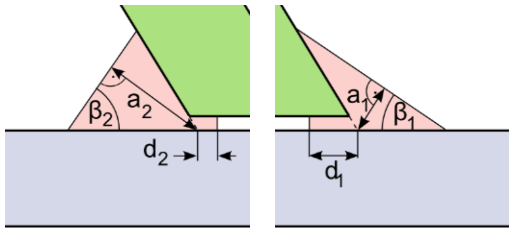
- t_B Thickness of base sheet
- t_1 Thickness of welded sheet
- α Sheet angle of welded sheet
- c Gap between base and welded sheet



8.1.10.2 Weld Parameters

The parameters of the welds are the same for all of the four potential welds on the connection:

- a_i Thickness of the weld (a-value, throat)
- d_i Depth of the penetration
- β_i Weld angle



For the penetration the ratio η_i of the penetration depth to the sheet thickness is specified inside the χMCF file.

This is computed by $\eta_i = \frac{d_i}{t_j} \sin \alpha_j$ where index *i* is specifying the weld index and index *j* is defined by the sheet index of the welded sheet related to the weld.

Inside the χMCF File only a subset can be specified:

Parameter	*χMCF-Key*	*Multiplicity*	*Value Range*	*Status*	*Default Value*
a	thickness	1 – 2	≥ 0	Optional	
β	angle	0 – 2	≥ 0	Optional	45 [deg]
η	penetration	0 – 2	0 ≤ η ≤ 1	Optional	0

8.1.10.3 Attributes

Attribute "base"

The index for the base sheet is specified using the attribute ***base***.

Attribute "technology"

The value for the attribute ***technology*** can be specified using the following values:

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- ***resistance***
- ***arc***
- ***laser*** (Energy beam / Laser)

8.1.10.4 Element "weld_position"

For the element ***weld_position*** the following attributes can be specified for the Y-Joint:

Attributes	***Type***	***Status***
base	Numeric	Optional
u	Numeric	Required
x	Numeric	Required
y	Numeric	Required
z	Numeric	Required
reference	Boolean	Optional
section	Selection	Optional
thickness	Numeric	* see attribute description
angle	Numeric	* see attribute description
penetration	Numeric	* see attribute description
filler	Selection	Optional
shape	Selection	Optional

Attributes "u, x, y, z, reference"

Detailed definition can be found in section 8.1.4.4.2 Welding Position.

Attribute "base"

For this type of weld the ***base*** sheet can be specified also inside the element ***weld_position***. This is necessary in the case of a stacked welding with two welded sheets.

Attribute "section"

The attribute ***section*** can be absent in the case of attribute value ***technology="laser"*** inside element subtype.

Valid values for the attribute ***section*** (if present) of a Y-Joint are:

- ***Fillet***
- ***HV***
- ***HY***

Attribute "thickness"

The attribute ***thickness*** specifies the thickness (a-value, throat) of the weld. Depending on the section this is required, optional or not allowed:

Attribute value "section"	***Attribute "thickness"***
HV	Optional
HY	Not allowed
Fillet	Required

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Attribute "angle"

The attribute ***angle*** specifies the angle of the weld relative to the base sheet.

Attribute "penetration"

The attribute ***penetration*** specifies the degree of penetration resulting from the welding.

Attribute "shape"

The attribute ***shape*** defines the shape of the weld throat.

Attribute "filler"

Valid values for the attribute filler can be:

- ***yes***
- ***no***

Note: *Depending on the technology the default value can different (see in Generic Seam Weld Definition section under attribute filler).*

Example A (within each ***attribute***, except ***base*** within ***weld_position*****):**

```
<seamweld>
    <y_joint base="1" technology="resistance">
        <weld_position u="0.5" x="1" y="0" z="1"
                       reference="no"
                       section="HY"
                       thickness="0.5"
                       angle="30"
                       penetration="0.5"
                       filler="yes"
                       shape="concave"/>
        <weld_position u="0.2" x="-1" y="0" z="1"
                       reference="no"
                       section="HY"
                       thickness="0.5"
                       angle="45"
                       penetration="0.5"
                       filler="yes"
                       shape="concave"/>
        <sheet_parameter ... />
    </y_joint>
</seamweld>
```

8.1.10.5 Element "sheet_parameter"

For the element ***sheet_parameter***, the following attributes can be specified for the Corner Weld:

Attributes	*Type*	*Status*	*Constraint*
index	Numeric	Required	It must be referenced to ***<part>*** index attribute
gap	Numeric	Optional	Default value is 0
sheet_thickness	Numeric	Optional	-
sheet_angle	Numeric	Optional	-

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Example A (within only required ***attributes*****):**

```
<seamweld>
    <y_joint base="1" technology="resistance">
        <weld_position u="0.2" x="1" y="0" z="1" .../>
        <sheet_parameter index="2" gap="1.0" sheet_thickness="1.5" sheet_angle="180"/>
    </y_joint>
</seamweld>
```


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8.1.11 K-Joint

The K-Joint connects two welded sheets from the same side to a base sheet.

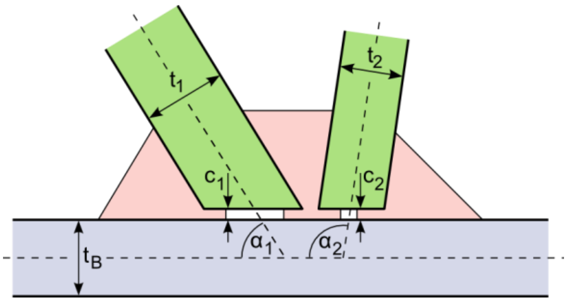
There are four potential welds that can be specified for this type of connection. The parameters for each of the welds can be described separately.

The XML definition of a K-Joint supports up to three weld positions. Each of the weld positions is specified using the element ***weld_position*** with the corresponding attributes and nested elements inside the subtype definition.

8.1.11.1 Sheet Parameters

The parameters to describe the connection are:

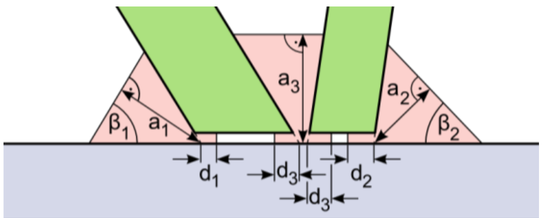
- t_B Thickness of base sheet
- t_1, t_2 Thickness of welded sheet
- α_1, α_2 Sheet angle of welded sheet
- c_1, c_2 Gap between base and welded sheet



8.1.11.2 Weld Parameters

The parameters of the welds are the same for all of the three potential welds on the connection:

- a_i Thickness of the weld (a-value, throat)
- d_i Depth of the penetration
- β_i Weld angle



For the penetration the ratio η_i of the penetration depth to the sheet thickness is specified inside the χMCF file.

This is computed by $\eta_i = \frac{d_i}{t_j} \sin\alpha_j$ where index *i* is specifying the weld index and index *j* is defined by the sheet index of the welded sheet related to the weld.

The following parameters can be specified for the K-Joint:

Parameter	*χMCF-Key*	*Multiplicity*	*Value Range*	*Status*	*Default Value*
a	thickness	1 – 3	≥ 0	Optional	
β	angle	0 – 2	≥ 0	Optional	45 [deg]
η	penetration	0 – 3	0 ≤ η ≤ 1	Optional	0

The penetration of the 3rd weld connection (d_3) is assumed to be equal on both welded sheet. There is only one value to be specified.

8.1.11.3 Attributes

Attribute "base"

The index for the base sheet is specified using the attribute ***base***.

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Attribute “technology”

The value for the attribute ***technology*** can be specified using the following values:

- ***resistance***
- ***arc***
- ***laser*** (Energy beam / Laser)

8.1.11.4 Element “weld_position”

For the element ***weld_position*** the following attributes can be specified for the K-Joint:

Attributes	*Type*	*Status*
base	Numeric	Optional
u	Numeric	Required
x	Numeric	Required
y	Numeric	Required
z	Numeric	Required
reference	Boolean	Optional
section	Selection	Optional
thickness	Numeric	* see attribute description
angle	Numeric	* see attribute description
penetration	Numeric	* see attribute description
filler	Selection	Optional
shape	Selection	Optional

Attribute "base"

For this type of weld the ***base*** sheet can be specified also inside the element ***weld_position***. This is necessary in the case of a stacked welding with two welded sheets.

Attribute “section”

The attribute ***section*** can be absent in the case of attribute value ***technology="laser"*** inside element subtype.

Valid values for the attribute ***section*** (if present) of a K-Joint are:

- ***Fillet***
- ***HV***
- ***HY***

Attribute “thickness”

The attribute ***thickness*** specifies the thickness (a-value, throat) of the weld. Depending on the section this is required, optional or not allowed:

Attribute value “section”	*Attribute “thickness”*
HV	Optional
HY	Not allowed
Fillet	Required

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Attribute “angle”

The attribute ***angle*** specifies the angle of the weld relative to the base sheet. The weld angle of a center weld of a K-Joint is assumed to be parallel to the base sheet (i.e. 0°).

Attribute “penetration”

The attribute ***penetration*** specifies the degree of penetration resulting from the welding.

Attribute “shape”

The attribute ***shape*** defines the shape of the weld throat.

Attribute “filler”

Valid values for the attribute filler can be:

- ***yes***
- ***no***

Note: *Depending on the technology the default value can different (see in Generic Seam Weld Definition section under attribute filler).*

Example A (within each ***attribute***, except ***base*** within ***weld_position*****):**

```
<seamwweld>
    <k_joint base=”2” technology="resistance”>
        <weld_position u="1.0" x="2" y="0" z="1"
                       reference=”yes”
                       penetration="3.0"
                       thickness="1.4"
                       angle="15"
                       section="HV
                       filler=”yes”
                       shape=”straight” />
        <weld_position u="0.0" x="1" y="0" z="2"
                       reference=”yes”
                       penetration="3.0"
                       thickness="1.1"
                       angle="90"
                       section="HV"
                       filler=”yes”
                       shape=”straight” />
        <weld_position u="1.0" x="-2" y="0" z="1"
                       reference=”yes”
                       penetration="3.0"
                       thickness=".5"
                       angle="30"
                       section="HV"
                       filler=”yes”
                       shape=”straight” />
        <sheet_parameter ... />
        <sheet_parameter ... />
    </k_joint>
</seamweld>
```

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8.1.11.5 Element "sheet_parameter"

For the element ***sheet_parameter***, the following attributes can be specified for the Corner Weld:

Attributes	*Type*	*Status*	*Constraint*
index	Numeric	Required	It must be referenced to ***<part>*** index attribute
gap	Numeric	Required	-
thickness	Numeric	Required	-
sheet_angle	Numeric	Required	-

Example A (within only required ***attributes*****):**

```
<seamweld>
    <k_joint base="2" technology="resistance">
        <weld_position u="1.0" x="2" y="0" z="1" .../>
        <weld_position u="0.0" x="1" y="0" z="2" .../>
        <weld_position u="1.0" x="-2" y="0" z="1" .../>
        <sheet_parameter index="1" gap="1.5" thickness="1.5" sheet_angle="45"/>
        <sheet_parameter index="3" gap="1.0" thickness="1.5" sheet_angle="30"/>
    </k_joint>
</seamweld>
```

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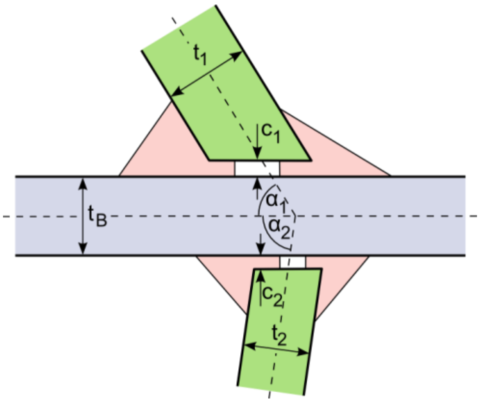
8.1.12 Cruciform Joint

The cross joint connects two welded sheets from different sides to a base sheet.

There are four potential welds that can be specified for this type of connection. The parameters for each of the welds can be described separately.

The XML definition of a Cruciform Joint supports up to four weld positions. Each of the weld positions is specified using the element ***weld_position*** with the corresponding attributes and nested elements inside the subtype definition.



8.1.12.1 Sheet Parameters

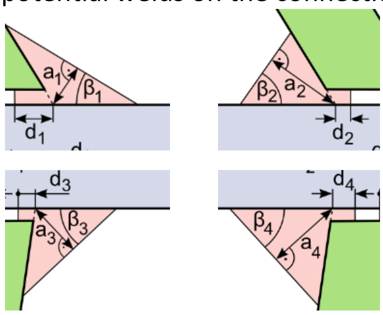
The parameters to describe the connection are:

- t_B Thickness of base sheet
- t_1, t_2 Thickness of welded sheet
- α_1, α_2 Sheet angle of welded sheet
- c_1, c_2 Gap between base and welded sheet

8.1.12.2 Weld Parameters

The parameters of the welds are the same for all of the four potential welds on the connection:

- a_i Thickness of the weld (a-value, throat)
- d_i Depth of the penetration
- β_i Weld angle



For the penetration the ratio η_i of the penetration depth to the sheet thickness is specified inside the χMCF file.

This is computed by $\eta_i = \frac{d_i}{t_j}\sin\alpha_j$ where index *i* is specifying the weld index and index *j* is defined by the sheet index of the welded sheet related to the weld.

The following parameters can be specified for the Cruciform Joint:

Parameter	***χMCF-Key***	***Multiplicity***	***Value Range***	***Status***	***Default Value***
a	thickness	2 – 4	≥ 0	Optional	
β	angle	0 – 4	≥ 0	Optional	45 [deg]
η	penetration	0 – 4	0 ≤ η ≤ 1	Optional	0

8.1.12.3 Attributes

Attribute "base"

The index for the base sheet is specified using the attribute ***base***.

Attribute "technology"

The value for the attribute ***technology*** can be specified using the following values:

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- ***resistance***
- ***arc***
- ***laser*** (Energy beam / Laser)

8.1.12.4 Element "weld_position"

For the element ***weld_position*** the following attributes can be specified for the Cross-Joint:

Attributes	*Type*	*Status*
base	Numeric	Optional
u	Numeric	Required
x	Numeric	Required
y	Numeric	Required
z	Numeric	Required
reference	Boolean	Optional
section	Selection	Optional
thickness	Numeric	* see attribute description
angle	Numeric	* see attribute description
penetration	Numeric	* see attribute description
filler	Selection	Optional
shape	Selection	Optional

Attribute "base"

For this type of weld the ***base*** sheet can be specified also inside the element ***weld_position***. This is necessary in the case of a stacked welding with two welded sheets.

Attribute "section"

The attribute ***section*** can be absent in the case of attribute value ***technology="laser"*** inside element subtype.

Valid values for the attribute ***section*** (if present) of a cross joint are:

- ***Fillet***
- ***HV***
- ***HY***

Attribute "thickness"

The attribute ***thickness*** specifies the thickness (a-value, throat) of the weld. Depending on the section this is required, optional or not allowed:

Attribute value "section"	*Attribute "thickness"*
HV	Optional
HY	Not allowed
Fillet	Required

Attribute "angle"

The attribute ***angle*** specifies the angle of the weld relative to the base sheet.

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Attribute "penetration"

The attribute ***penetration*** specifies the degree of penetration resulting from the welding[8].

Attribute "shape"

The attribute ***shape*** defines the shape of the weld throat.

Attribute "filler"

Valid values for the attribute filler can be:

- ***yes***
- ***no***

Note: *Depending on the technology the default value can different (see in Generic Seam Weld Definition section under attribute filler).*

Example A (within each ***attribute***, except ***base*** within ***weld_position*****):**

```
<seamweld>
    <cruciform_joint base="1" technology="arc">
        <weld_position u="0.2" x="1" y="0" z="1"
                       thickness="3.0"
                       penetration="0.8"
                       section="HY"
                       angle="30"
                       reference="yes"
                       filler="yes"
                       shape="straight" />
        <weld_position u="0.4" x="-1" y="0" z="-1"
                       thickness="4.0"
                       penetration="0.4"
                       section="HY"
                       angle="45"
                       reference="yes"
                       filler="yes"
                       shape="straight" />
        <weld_position u="0.6" x="-1" y="0" z="1"
                       thickness="5.0"
                       penetration="0.8"
                       section="HY"
                       angle="50"
                       reference="yes"
                       filler="yes"
                       shape="straight" />
        <weld_position u="0.8" x="1" y="0" z="-1"
                       thickness="6.0"
                       penetration="0.4"
                       section="HY"
                       angle="75"
                       reference="yes"
                       filler="yes"
                       shape="straight" />
        <sheet_parameter ... />
        <sheet_parameter ... />
    </cruciform_joint>
</seamweld>
```

[8] The attribute penetration of a *<weld_position>* holds for all sheets connected by this *<weld_position>* (e. g. important for K-Joints).

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8.1.12.5 Element “sheet_parameter”

For the element ***sheet_parameter***, the following attributes can be specified for the Corner Weld:

Attributes	*Type*	*Status*	*Constraint*
index	Numeric	Required	It must be referenced to ***<part>*** index attribute
gap	Numeric	Required	-
thickness	Numeric	Required	-
sheet_angle	Numeric	Required	-

Example A (within only required ***attributes*****):**

```
<seamweld>
    <cruciform_joint base=”1” technology="arc”>
        <weld_position u="0.2" x="1" y="0" z="1" .../>
        <weld_position u="0.4" x="-1" y="0" z="-1".../>
        <weld_position u="0.6" x="-1" y="0" z="1" .../>
        <weld_position u="0.8" x="1" y="0" z="-1" .../>
        <sheet_parameter index="2" gap="1.5" thickness=”1.5” sheet_angle=”90”/>
        <sheet_parameter index="3" gap="1.0" thickness=”1.5” sheet_angle=”90”/>
    </cruciform_joint>
</seamweld>
```

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8.1.13 Flared Joint

It is referred to Chapter 10.2.

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9 2D connections

Adhesive joints are typical 2D connections which will be described in a future version of the χMCF-Document. Details are referred to Chapter 10.2.

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10 Future extensions

So far only spot welds and seam welds with the corresponding parameters (basically geometrical) are described which cover mainly the applications of CAD and CAE. However χMCF is designed for the use in the complete development process and should be able to cover all major joint types thus two important extensions remain to be undertaken.

10.1 Additional parameters for spot and seam welds

For prototyping and manufacturing (CAM) additional parameters and information, like the type and the manufacturer of the welding device, the current density required in case of spot welds etc., may be relevant and needed. These parameters are not included in the present document yet. Their definitions will happen in the near future by the corresponding experts.

10.2 Other relevant and new joint types

In parallel with welded joints bolts, screws, rivets, adhesives in 1- or 2-dimensional forms etc. are employed widely, too. It can be expected that increasingly new joint types will arise due to the advance of the technological development.

Even if some proposals in view of extensions are available, bolts, screws, rivets, adhesives will be considered in χMCF in the very near future. As mentioned before χMCF is open for any new joint type which will come and be of relevance for the technical application.

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11 References

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