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Extended master connection file (χMCF) — Description of mechanical connections and joints in structural systems

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Foreword

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This document was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 4, *Industrial data*.

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Introduction

This document aims at describing mechanical connections or joints related to mechanical systems or structures. The demand for such a standard has grown from the observation that modern product lifestyle management (PLM) systems, while working well with part information (e.g. geometry, material, weight), are lacking a consistent handling of logical and process related connection information (e.g. parts being connected, orientation of point connections, assembly process parameter).

PLM workstreams need to include connection data to automate development processes and enable seamless data flows between engineering functions. χMCF is intended to be the “language” that is understood and used by the various tools to exchange connection data along the development chain.

The initial motivation to develop this document came from the automotive industry (see Annex C for background and context on this document). However, there is no element in this document that limits it to this industry. It is clearly targeted to support virtual development processes for mechanical systems or structures in any industrial area.

One design goal of χMCF is to support the widest possible range of development and manufacturing processes. This makes it very likely that xMCF and STEP (ISO 10303-242),[1] will be used together. Annex B investigates how this can be done in a way that benefits both standards.

Regardless of the respective industrial domain, complex technical systems (e.g. vehicles, planes, ships) typically consist of thousands of individual parts which are assembled by joints. Depending on the involved materials and the manufacturing processes, a wide range of joining types are used within an individual technical structure or system. Typical connection types are welds, bolt connections, adhesives, rivets, clips, etc. Efficient and reliable data management of such connection data is not only required for the actual design and verification process [computer-aided design (CAD) and computer-aided engineering (CAE)], but also for manufacturing planning and even cost estimation. Various design, material and manufacturing parameters are required to be managed for each connection.

Details for connections or joints grow and mature along the development process. At different development stages (e.g. concept phase, detailed design, verification, manufacturing planning) and engineering functions (e.g. CAD, CAE, manufacturing), data will be added and consumed. Therefore, a database for connection data is required. But also, the software tools adding or extracting data need to understand the data structure and use a common description language. χMCF, defined in this document, serves as this language.

The advantages are evident. Integrating dedicated connection data into the PLM structure and using a common language (χMCF) for data exchange avoids data conversions or re-generations and, therefore, decreases inconsistencies and flaws during system development.

Extended master connection file (χMCF) — Description of mechanical connections and joints in structural systems

1 Scope

This document specifies XML definitions that are used to describe data and information related to connections or joints in mechanical systems or structures.

The following is within the scope of this document:

— description and explanation of XML definitions for logical or process related data or other properties of a connection.

The following aspects are outside the scope of this document:

— geometry of fasteners or other parts,

— handling of χMCF data in

  — product data management (PDM) systems,

  — subscriber data management (SDM) systems, and

  — other data management systems.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp,

— IEC Electropedia: available at https://www.electropedia.org/.

4 Design principles and basic features of χMCF

4.1 General

The Extended Master Connection File (χMCF) is a container for connection information of complex structures. A complex structure consists of individual parts which are joined together. Connections establish a topology between the parts. Therefore, a database or container designed to gather connection information should be equipped with data structures which reflect this topology between the parts.

χMCF is intended to define an industry standard for the exchange of connection data between different CAx tools (e.g. CAD, CAE, CAM, CAT) along development process steps. Design principles for χMCF are required to keep the standard as lean as possible on one hand, but also enable use case dependent extensions.

Subclause 4.2 explains the design principles and basic features of χMCF.

4.2 Design principles

The design of χMCF is guided by the following principles:

a) χMCF should be able to completely and unambiguously describe all relevant connections/joints that are in use in the automotive or other industries. Amongst others, this includes spot welds, seam welds, rivets, adhesives.

b) χMCF should be able to address all kinds of CAx processes.

c) χMCF contains only information relevant for connections. Hierarchical product structures, assembly sequences, part variants etc. are not the subject of χMCF. Such kind of information needs different methods for propagation. However, χMCF may refer to such "external" information, for example part codes. This principle provides the flexibility to use χMCF in any development process variant established at different companies.

d) χMCF has to be flexible and easy to extend to any future joint types and applications.

e) χMCF is based on the industry standard extensible markup language (XML).[2]

f) Connection data in χMCF must be unique.

g) The content of χMCF data may be incomplete to a certain extent. This addresses the fact that new data is created continuously and needs to be stored throughout the course of CAx processes, without changing its vessel.

h) χMCF follows the max-min principle. It contains information as much as necessary and, at the same time, as little as possible.

i) χMCF shall enable the reconstruction of connections at any certain stage of the involved processes without loss of data or risk of ambiguities.

j) Data in χMCF format shall be kept compact. Elements shall be reused, whenever possible.

k) χMCF offers containers which can be assigned to any certain connector, to a collection of connectors or even to the complete file. This allows incorporation of software or usage specific data before or without standardization.

l) χMCF forms a good candidate for long-term archival of connection data due to its simplicity and extendibility.

XML has been selected as a foundation since it is by itself an industry standard and human readable. XML facilitates efficient data structures which describe the connection topology of such complex structures like automobiles or planes.

4.3 Idealization of joints

Different types of joints have different characteristics. They can differ from each other by their geometrical shapes, mechanical properties like strengths for different loadings, manufacturing processes etc.

To allow for efficient description of joints, some simplifications and idealizations are necessary. The approach 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.

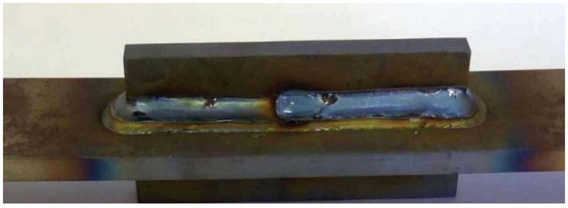


Figure 1 — Seam weld as 1-dimensional joint

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 typical representative of 1-dimensional joints, see Figure 1 above. It is characterized by a curve describing its spatial course and additional parameters (attributes) determining the sectional shape perpendicular to the curve.

Similarly, adhesive joints can be modelled as 2-dimensional surfaces.

4.4 Reconstruction of joints from χMCF

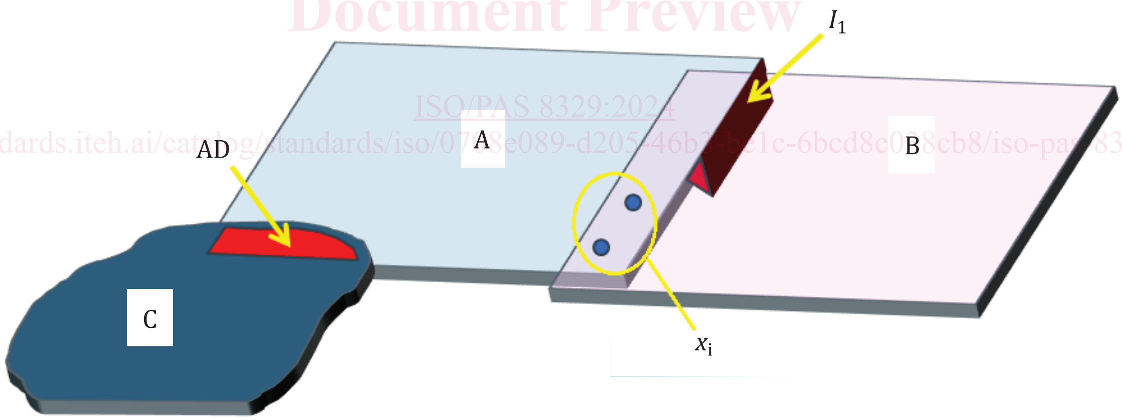
The reconstruction of joints from χMCF is an important use case. It is crucial that it is possible to reconstruct any joint in its idealized form uniquely by means of the introduced parameters and attributes. In case of a spot weld, a unique reconstruction is possible by the coordinate vector *x* and 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.

4.5 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 individual components. The following example (see Figure 2) demonstrates the way how χMCF facilitates description of such topology:

— Part (or Assembly) A is joined to Part B by the seam weld 1 along the curve l_1 and the spot welds at positions x_i, and

— Part (or Assembly) A is connected to Part C by the adhesive AD in the area A, etc.



Key

A, B, C parts

I_1 seam weld 1

x_i spot welds

AD adhesive

Figure 2 — Topological relations between parts and assemblies

This kind of topology is represented in χMCF by the element <connection_group/>. A <connection_group/> comprises all joints which connect the same parts (or assemblies).

Frequently, more than two parts are joined. A spot weld can, for instance, join three sheets, a screw even more. Such situations are covered, too.

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

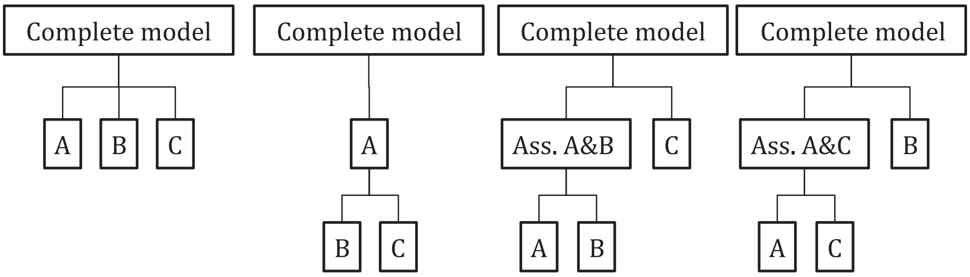


Figure 3 — Product structures fitting to previous figure

NOTE This list of four product structures shown in Figure 3 is not exhaustive.

4.6 χMCF in the development processes

A typical development process is a long chain involving many (maybe overlapping) single steps, e.g. design, construction, prototyping, simulation, testing, production planning (see Figure 4). Depending on the manufacturer considered, information of connections and joints arises at different stages of the process and comes from different parties (see 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 using χMCF.

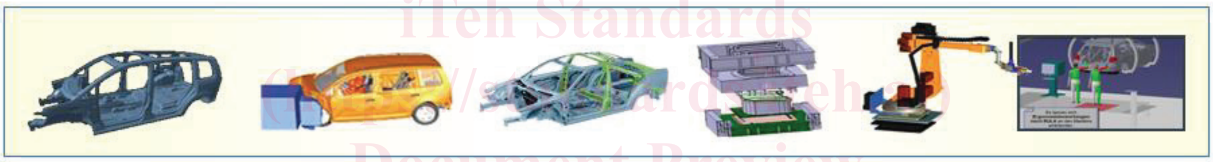
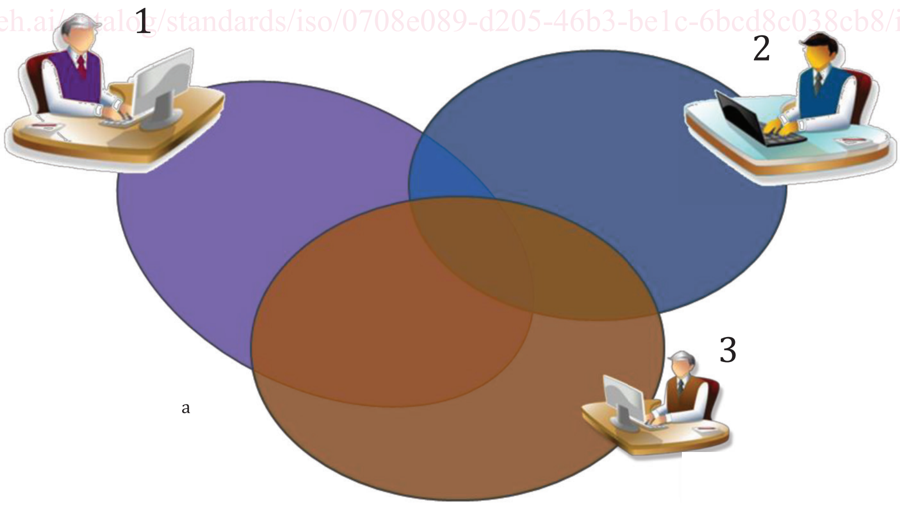


Figure 4 — Development process



Key

1 design, construction

2 engineering

3 production planning

[a] χMCF.

Figure 5 — χMCF as a platform for connection data in the complete development process

A careful look at Figure 5 provides understanding on how the work with χMCF in a real process can be organized: 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, for instance simulation or planning. The intersection of all subsets contains information which is of interest for all the 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 builds up a continuous process. As shown in Figure 5, connection information can be created by any of the involved parties (e.g. design, construction, engineering, planning). The common situation is that each party contributes part of the information (e.g. geometrical, technological) defining a specific joint. Merging of the partial 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 also illustrates that connection information (full or partial) is available to all involved parties once it is defined and stored in χMCF. Thus, unnecessary duplication of effort is avoided automatically. Typically, different teams work in different environments using different software tools. Provided all involved systems support χMCF, translation of data from one format to another will not be necessary anymore. This will save development cost and avoid loss of data caused by the translation.

Information contained in χMCF can be used to automate many tasks in a development process and will therefore facilitate efficiency gains:

— Automatic CAE model assembly
  Most FE preprocessors can mesh parts automatically in batch-meshing mode. An automated model assembly can be realized by the connection information contained in χMCF.

— Automatic Programming of Welding Robots
  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 a specific development process. Therefore, χMCF can be implemented into any development 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.

5 Keywords of XML specification

5.1 Keywords

As in any XML file, the carrier of information in an 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, e.g. boolean, float, double, string, date. The same applies to attributes. The user can determine how elements and attributes are used (optional, required or prohibited). If declared necessary, the frequency of occurrence of elements with a given name (number of siblings of identical names) can be restricted. In the XML schema, this is specified by the attributes `minOccurs` and `maxOccurs`.

In accordance with the XML Schema Definition Language version 1.1 Part 2 the following keywords 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 the XML schema),

— Restrictions (corresponds to the element `restriction` of XML schema).

NOTE 1 Up to now, only versions 1.0[2] and 1.1[3] of XML exist, where 1.1 is not widely used. Therefore, most systems still create XML 1.0 files (for differences between both versions see http://www.w3.org/TR/xml11/#sec-xml11).

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/>` element for instance is an integer, which is a built-in type of XML standard.

Examples for the most common types in XML are:

— `xs:string`,

— `xs:decimal`,

— `xs:integer`,

— `xs:float`,

— `xs:boolean`,

— `xs:date`,

— `xs:time`.

NOTE 2 The maximum number of decimal digits you can specify is 18.

However, only positive integers are usually used in this context. This means that the possible values of the ID (type integer) have to be restricted. To specify the values which are allowed for an element or an attribute, the key-word Value space is used. The Value space can be given as an enumeration (a finite set), or an explicitly defined set. For example, a positive integer is symbolized by > 0 whereas a float between 0,0 and 1,0 is given by [0,0, 1,0], according to mathematical notation.

Some elements and attributes obtain default values if they are not explicitly specified in the χMCF file. The default values to be adopted are defined by the keyword `Default`.

In this document, the special type “alphanumeric” is frequently used for labels of parts and assemblies, which deserves 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 such as “[-.$#±]” and more are used for labels. Sometimes, the 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, when using XML’s “encoding” attribute, even non-ASCII characters can be handled easily, e.g. Arabic, Chinese, Cyrillic, Greek, Hebrew. Nevertheless, labels should not start or end with white space.

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`, that is in the form: `minOccurs ≤ Multiplicity ≤ maxOccurs`. By convention, when `Use` is optional, `minOccurs` is 0. Any additional restrictions imposed on an element, or an attribute are specified by the key-word `Restrictions`.

As explained above, the individual use of some elements or attributes may be optional. But some of them must be coherent (thus redundant in certain sense). For instance, the `label`, numerical ID of a property (`PID`), and alphanumerical name of a property (`pname`) of a part or an assembly represent the same part (except for e.g. tailored blanks) and one can use one or the other or both to identify a part.