χMCF – Standard for Documenting Connection Information … and how SPDM can benefit

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1 Abstract

Complex technical systems such as a car are typically assembled from thousands of parts, which each have individual properties. A plethora of different methods is established for connecting such parts in industrial manufacturing. Mating is a core aspect that accompanies a product from design to simulation, testing, and production, and has decisive impact on its behavior in the end.
The information that defines a connection element or process (i. e. geometry, mating components, supplemental materials, process configurations etc.) can be very detailed and comprehensive. Depending on the context, the same mating element may be described in several different ways, using several different tools. This demands a standardized description of all connections throughout all CAx process steps.
Under the aegis of working group 25 “Fügetechnik” of FAT/VDA, the χMCF (Extended Master Connection File) format was developed for the Automotive Industry. It fulfills this demand and made its way to daily productive use.
The format is designed such that all common mating elements are defined in a generic way based on their geometric dimension (0d, 1d, 2d). It models the relationships between the mating components as well as all information relevant to design, processing and manufacturing. This allows a complete definition of the connection element. χMCF is easily extensible to cover new mating technologies and process information.
With the help of χMCF, a continuous process chain between e. g. CAD, CAE and CAM can be established with regard to mating information. This promises significant gains in efficiency.
This paper together with the slide set illuminates the backgrounds.

2 CAE within PLM Process Chain

A typical PLM process chain consists of several very distinct major processes. Over the years, the CAE process therein became more and more important, complex and crucial. Once located after CAT, it approaches the beginning of the process chain, sometimes happening during concept phase even before CAD data exists. This trend will continue over the coming years.
A 1st dimension of CAE complexity results from the wide and increasing range of questions, which need to be answered. Apparently, for any kind of question, there exists a specialized method with a number of specialized solvers. Various pre and post processors complete the tool set.
This complexity is addressed by subdividing CAE into a number of sub-processes from data collection to report generation. Although these sub-processes appear similar, they are quite differently shaped at the different OEMs. And so are their tools: They range from simple hand-knitted scripts to very sophisticated SPDM solutions. Frequently, one finds simulation teams substructured accordingly, at major OEMs.
The 2nd dimension of complexity results from the different types of data, which need to be propagated along the PLM process chain. Amongst well known product structure / metadata and CAD tracks, the track of connection data is frequently underestimated.
A 3rd dimension of complexity stems from the research nature of CAE: CAE deploys its full force, when used for solving technical problems that are not amenable to other methods. This in turn requires various loops of different approaches, trial and error and optimization.

3 What Makes Connection Data Special?

Investigating sophisticated PLM process chains at major OEMs frequently yields that connection data forms a distinct 3rd data track. There are good reasons:

- The function of connections dominates over their shape: Few people are interested in how a spot weld really looks like. They just want to know, how strong it is.

- Connections are created, edited and optimized using different tools or plugins, at special process steps, which at a certain point needs expert knowledge.
- Connections belong to inner nodes, not to leaves of product tree: A subcomponent may be reused in other components, probably at different positions. It should bring its internal connections with it, whereas the external connections to other parts of the component belong to that component. The component in turn may be a subcomponent of another, larger system or product and so on. On the opposite side of the spectrum, a single plain part without own substructure should not contain (open) connections, because they may be appropriate just for some assembly situations, but not for all. This would hinder reuse of that plain part.
- Size of connection data is much smaller than that of CAD geometry, allowing for different data handling strategies.
- Connections using a physical body, such as screws, rivets, clips etc. usually are treated as "standard parts" in PDM systems; CAD details are to be found in special catalogs. But their functional character, as the second side of the same coin, is not represented there. Hence, in most cases, such standard parts are just filtered out from the PDM download at very first steps of the CAE process. But then, the connection function must be re-added at a later date: FE preprocessors for instance are frequently confronted with the requirement to automatically detect any screw holes of an entire body in white etc. This practice is contrary to the principles of process safety, because information like screw diameter or length get lost.

Regarding the first two data tracks, exchange formats have a long tradition and are well established: For product structure and metadata, we have standards like STEP AP 214, PLMXML, FATXML [6] or upcoming STEP AP 242 XML. In contrast, CAD geometry usually would be transported in native formats or, where sufficient, as derived data in standards like ancient VDA-FS or state of the art JT.
However, for connection data, the situation is multifaceted.

4 What is the Situation?

Two major trends are common to entire automotive industry:

1. Release frequency of new products or variants increases every year.
2. Environmental and economic considerations force to reduce fuel consumption, where comfort functions and new drive concepts require higher mass of specific components (electric motors, batteries, …)

Answers to these trends are well known:

1. Re-use "non-design" components as far as possible. This leads to modular construction kit or platform strategies and distributed development. All of a sudden, teams with different setups of connection relevant processes and software tools need to work together closely.
2. Light weight design imposes use of new materials. Resulting new material mixes demand new and more complex connection technologies.

And there are even more effects, demanding improved handling of connections:

3. "Evergreen requirements" like increased automation with reduced cycle time, cost reduction, crashworthiness, reliability and durability do not make things easier. On the contrary, connection technologies obtain more process parameters and have to fulfill more quality criteria.
4. Moreover, increasing product complexity brings with it more parts and hence more connections.

5 What is the Problem?

Most likely, problems were initiated by lacking connection functionality of major CAD systems in their early years. This forced OEMs to look for their own solutions. And so, each of them created its own CAD macros or invested in proprietary software.
Until recently, in absence of any standard, data exchange along process chain needs additional tools, frequently "home-brewed". This is expensive and can be error-prone. – And it may be incomplete: In reality, these tools support only few techniques with only a fraction of their data. Consequently, inventing new techniques or just adding new parameters to existing techniques results in excessive costs and process threats. In case of proprietary software, changing software vendors implies high investments. The resulting "vendor lock-in-effect" impedes competition and hence hinders progress.

6 We Need a Standard!

From previous sections, we conclude: A standard for connection data is necessary, similar to standards for product structure and CAD geometry, which were introduced decades ago.
Which features are required for such a standard?

- According to the "3rd dimension of complexity", the standard must allow for data to be completed along the process chain.

- On the other hand, it must support skipping data which is contained but yet not needed at a certain process step.
- It must be easily extensible regarding new technologies or parameters, in order to address the need for new and more complex connection technologies.
- Well established process chains at OEMs must benefit from the standard, rather than being damaged. Hence, the standard must be easily implementable at OEMs regarding proven scripts or migration of other tools.
- A standard must be appropriate for long time archiving.
- It should be human-readable, to allow for some “last resort” in case of emergency.

Regarding all this, a standard based upon XML appears to be a good choice.

7 χMCF Paving its Way

Coming from the need to describe fatigue relevant attributes of weld lines, FAT/VDA working group 25 “Fügetechnik” decided to extend Ford-owned MCF format about 10 years ago, thereby inventing χMCF. As the above mentioned issues became more obvious, χMCF developed into the multi-purpose multi-technique standard it is today. In addition to section 6, it shows following features:

- All connection types can be represented (0d, 1d, 2d)

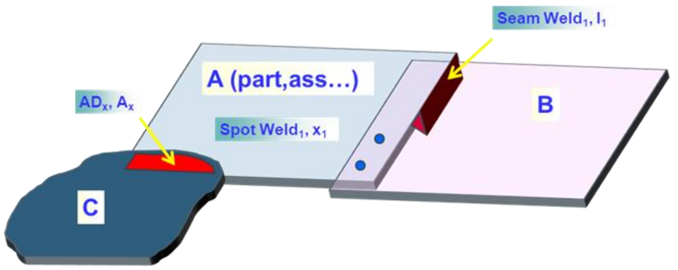

Figure 1: Some Schematic Connections

- All PLM processes are supported - CAD, CAE, CAT, CAM, including special sub processes, e. g. durability simulation, robot programming, and supplier integration.
- One file contains either data of one assembly, one car or all variants of a series – meeting any kind of OEM specific process design.
- Additional data specific to OEM, software or processes can be imbedded.

χMCF addresses in especially the flexibility about content described in section 6:

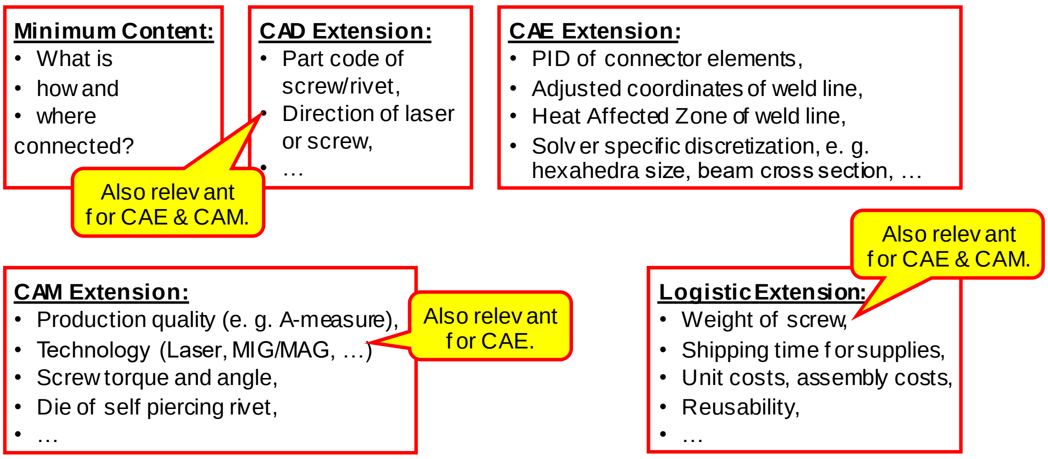

Figure 2: Flexibility of χMCF Regarding Data Completion

Current χMCF versions have been implemented in several CAE tools, such as MEDINA®, LMS.VirtualLab Durability® and FEMFAT®. Recent SyncroFIT® version reads and writes χMCF as a plugin to CATIA® and NX®. New version χMCF 3.0 is scheduled for implementation in further tools by end of 2015. χMCF is being applied in daily business during technical development, e.g. at Volkswagen, targeting for extension from CAE to a larger process chain, including CAD and CAT.

8 How SPDM Benefits from a Standard

SPDM has several main objectives. First of all, it must be guaranteed that all CAE simulations of all disciplines converge to the same result. This requires all disciplines to work simultaneously with the same, most recent data.

In context of PLM, it must be ensured that exactly this convergence result is tested on the rig and produced in the factory.
Legal regulations regarding product documentation and longtime archiving must be met.
Last but not least, CAE processes need to be accelerated and possibilities of errors must be reduced.
A manually driven connection data track with plenty of incompatible formats and tools involved is contradictory to these objectives.
Now, χMCF has the potential to integrate not only CAE processes and tools, but moreover to optimize integration of SPDM into PDM regarding connection data.

9 Conclusion

As complexity of technologies, products and related PLM processes (including CAE/SPDM) steadily increases, so does the demand for intensified process integration. In this regard, maturity of the track of connection data frequently is far behind in comparison with the tracks of product structure / metadata and CAD geometry. This is possibly due to the significant differences of these data types.
To remedy this situation, in particular a data exchange standard is urgently needed. There are a number of requirements for this standard, of which its flexibility probably is the most important.
XML-based χMCF format addresses these needs in an optimal fashion: It has been freshly designed exactly for this purpose, without respect to some deprecate or proprietary format or tool.
It forms the ideal basis for SPDM tool integration and has the power to replace existing proprietary formats sustainably.
Hence, χMCF is expected to become „Lingua franca” for connection data, just like the way JT did for CAD geometry.

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[1] Expected release date during preparation of this paper.