EUROfusion

EUROFUSION WPS1-CP(16) 16571

S Renard et al.

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Preprint of Paper to be submitted for publication in Proceedings of 29th Symposium on Fusion Technology (SOFT 2016)

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Software Eco-System for the Integrated Design of W7-X

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Wendelstein 7-X (W7-X) is a fusion device of the stellarator type with optimized magnetic field geometry and superconducting coils. The scientific goals of W7-X are to confirm the predicted improvement of the plasma confinement and to demonstrate the technical suitability of such a device as a fusion reactor. It is undergoing its first operation phase at the Max Planck Institute for Plasma Physics (IPP) in Greifswald, Germany.

The Design Engineering division is responsible for the design tasks and for the spatial integration of all the equipment in the Torus Hall. The complex management of space, the numerous designers operating simultaneously, the maturity gap of the designs pose acute concurrent engineering issues. Originally used to manage the space reservations, the PLM solution ENOVIA SmarTeam is now the backbone of the all the design tasks and at the heart of an eco-system that helps the designers to fulfill their tasks efficiently and reduce the risk of iterations. This eco-system is a set of software tools developed internally that interact with SmarTeam. The collision analysis, the delivery process and the digital mockup generation are some of the tasks with are speed up and secured through this eco-system.

In this paper the context and the challenges of the design process will be introduced. The role and implementation of the software tools will be presented and the benefits will be discussed through examples.

Keywords: W7-X; mockup; SmarTeam; concurrent engineering; integrated design; PLM system

1. Introduction

The W7-X machine underwent its first operation phase in 2015 and will see many operation phases in the decades to come. As an international research facility, W7-X will be the home of many types of equipment designed inside and outside.IPP. Therefore the design activities face several challenges.

The first challenge is the constant changes of the configuration of the W7-X machine due to the successive operation phases. The constant evolution of the environment of the W7-X machine means that it is crucial for designers to be able to visualize if and how their surroundings are changing. Concurrently there are maturity gaps between the different systems since some are still in a conceptual phase whereas others are already delivered and operational. These gaps are partially inherent to the operation phasing of the machine, yet their consequences, such as models being only based on concepts, must be mitigated.

The second challenge is concurrent engineering as dozens of designers are working on systems sharing the same space or having common interfaces. Space limitations dictate the necessity of shared support structures. Thus, designers must be able to share CAD models and information easily. As designers need to certify that their systems are collision free, they require a reliable system to check for possible collisions.

2. Enovia SmarTeam and its Software eco-system

The CAD program Catia V5 has been used for the design of W7-X since 2007. SmarTeam was successfully tested in 2009 before becoming the Product Lifecycle Management (PLM) system for the design of the systems inside the Torus Hall. The deep integration of Enovia SmarTeam with Catia, the presence of a programmable interface and the possibility to customize the database interface and behavior were the main reasons to choose Enovia SmarTeam.

SmarTeam allows tracking the status of each CAD model and offers a reliable storage solution through usage of server grade hardware and software. But there is a gap between the basic functionality of SmarTeam and the needs of the end users. The role of the eco-system developed around Catia and Enovia SmarTeam is to close this gap and to provide adequate solutions to the challenges described in the introduction.

The eco-system development is conducted internally in close cooperation with the end users to limit development time and maximize the user acceptance. The software tools are written in different programming languages. The main language is Python 2.5.4 for its simple interfacing with outside systems, its optimized modules and libraries available for specific usages such

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as handling large XML files. It is well-suited for interacting with Catia and SmarTeam via COM-interface. The others languages used, Visual Basic for Application (VBA) and CATScript, are best for interfacing solely with Catia. VBA is especially convenient for beginners as it includes a debugger and a great contextual help.

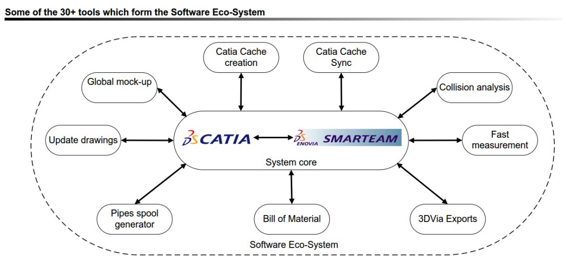

Fig. 1. Software eco-system overview

The software eco-system (fig. 1) is composed of 30+ tools which to help to the designers in different ways. Visualize models, create collision analysis report, create delivery, format models for manufacturing…This paper will focus on two fundamental ones. The digital mock-up and the collision analysis report.

3. The digital mockup

3.1 Definition and role

A mockup is a working full scale model of a machine in a specific configuration. In the context of W7-X it is a Catia assembly (CATProduct) that contains the CAD models and the associated metadata for all the systems inside the Torus Hall. Its role is to give an overview to the designers working on systems located in the Torus Hall. It is stored on a file server and is accessible to all IPP personnel.

It allows designers, physicists as well as assembly teams to visualize the whole W7-X machine with all its peripheries at once on a CAD suitable PC. For information this represents 35.000+ models and 250.000+ instances. It provides also access to a large spectrum of metadata directly in Catia, such as the delivery status, tolerances, material properties etc. The modified or newly created models stored in SmarTeam are visible to all CAD users within 24 hours as the digital mockup is updated overnight.

The W7-X machine is structured in 150+ systems such as diagnostics, heating systems, cooling circuits etc. Each system is composed of one or more sub-systems. In SmarTeam, each sub-system is represented by a Catia assembly (CATProduct). The digital mockup is the collection of all the sub-systems.

3.2 Creation and update

Every night, a Python script (fig.2) determines which models were modified by comparing the versions of the models in the digital mockup and in SmarTeam. Then all sub-systems containing modified models are extracted from the server and copied onto the machine hosting the process. The models are loaded in Catia to add metadata, be renamed and optimized for better performances. Finally updated sub-system assemblies are inserted into the main Catia assembly and uploaded to the file server to be available to the users.

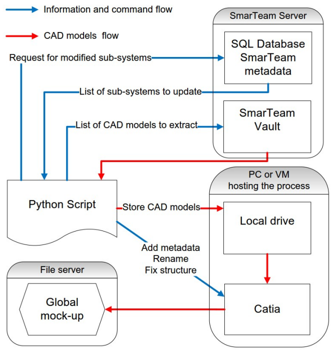

Fig. 2. Digital mockup update process

As the script runs every night, the digital mockup is updated every day. Thus a CAD models modified or inserted in SmarTeam is visible to the all the IPP designers within 24 hours.

3.3 Grouping

The above described digital mockup contains 330+ sub-systems from 150+ projects for a total of over 35.000 CAD models and over 250.000 instances. As the design activities go on the number of models will continue to increase, thus the size of the structure Catia assembly containing the digital mockup will increase too.

The loading and visualization performances of a Catia assembly are mostly dictated by how deep the structure is. Thus simplifying the structure by reducing the numbers of levels means better performances. The idea is to replace some assemblies (CATProduct) with parts (CATPart) using an embedded function of Catia (Generate AllCATPart from CATProduct) which concatenates all geometry elements of the selected CATProduct into one CATPart.

The implementation is composed of 2 parts. First the users mark the Catia assemblies eligible for grouping in SmarTeam by ticking a specific metadata. As a consequence the sub-systems containing these assemblies are marked to be updated even if no modification was performed in Catia. Second during the digital mockup update process the assemblies marked for grouping are replaced in the digital mockup by a CATPart.

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The benefit is that all details of the geometry are kept but the size of the structure is greatly reduced as a part (CATPart) as no structure information, unlike a CATProduct. The creation the AllCATParts is time consuming for the update process and it requires more resources on the hosting machine such as CPU time and RAM. But as this operation is performed overnight, it has no impact on the users.

Only CAD models which have a physical connection should be grouped like welded frame, bolted flanges and so on. It is the responsibility of the designers to check what can be grouped or not. Also it is not possible to group a whole sub-system.

A script allows the Catia users to replace any AllCATPart with the original assembly if the structure information is needed. The reverse process is also possible.

The size of the main CATProduct of the digital mockup is a good indicator of the gain. Ungrouped it is about 220MB whereas grouped it shrinks down to 32MB. The number of instances is also reduced from 250,000 to 50,000.

The loading time is reduced by a factor 4 at least and the manipulation or visualization of the models is much easier. The grouping function has been implemented for several years now and it allows the keep the size of the main CATProduct at about 30MB. This implementation is scalable and will adapt to future needs.

3.4 Real world application

The C/O Monitor [1] is a spectrometer with 4 channels: Carbon, Oxygen, Boron and Nitrogen that will be installed for the next operation phase. Thanks to the digital mockup it is possible to define the best position of the crystal chambers to maximize the width of the lines of sights. Crucial information can be extracted from the models such as the volume of visible plasma. The design of the platform extension (green on fig.3) and the diagnostic frame (blue on fig.3) can be visualized within their respective environment.

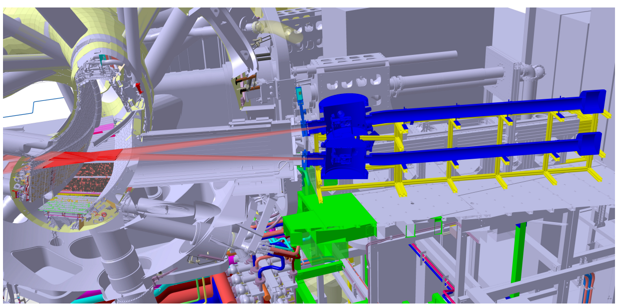

Fig. 3. C/O Monitor (blue) and its lines of sights (red)

4. Collision Analysis Report

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4.1 Definition and role

A collision analysis report is an Excel table listing all the interactions found in the digital mockup between a selection of CAD models and their surroundings within a given distance. The collisions are highlighted depending on several criteria. The role of the report, together with the digital mockup, is to guarantee that the design of a component is collision free prior to be delivered to its customer.

4.2 Creation of the report

The creation of a collision analysis report can be split in 3 distinct phases.

The first phase, called pre-processing (fig.4), consists in defining the scope of the analysis. The designer will use the digital mockup and an embedded Catia function, Spatial Query, to retrieve all the CAD models within a given distance of the CAD models to investigate. Then another embedded function, Clash, is used to create and export an XML file called a clash report. This file contains information such as position and distance for all the interactions between the components.

During the second phase, called processing (fig.4), a Python script uses the previously generated clash report as input to generate an Excel table. This table contains all the interactions taking into account for each CAD model its tolerances and relative movements retrieved from SmarTeam using SQL queries. The interactions are assessed automatically to highlight the conflicts

In the third phase, called post-processing (fig.4), the designer can focus on the highlighted conflicts. Additional information can be manually added to the collision analysis report to help assess the interactions and solve conflicts. If after this phase no conflict is found, the systems are considered collision free. If however conflicts are found and cannot be resolved, the designer must solve them by either modifying the design or get into a conflict mitigation procedure with the responsible officer of the other system [2].

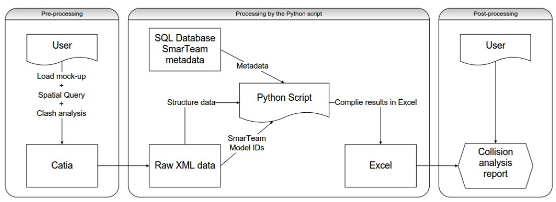

Fig. 4. Creation process of a collision analysis report

The script can be used with CAD models known or not to SmarTeam which is a big advantage when working on CAD models not yet saved in SmarTeam. In this case the tolerances and relative movements have to be entered manually by the user during the post processing phase. There is no limit in size but the larger the selection of components to check is the longer the report will take to generate. It can take up to 20 minutes for 2000 interactions to be checked and assessed.

4.3 Real world application

The ICRH antenna [3], is designed and manufactured by Forschungszentrum Jülich and the IRVIS endoscope [4], is designed by Thales Seso. A collision analysis report (fig.6), created using the newly received models showed a critical collision (fig.5).

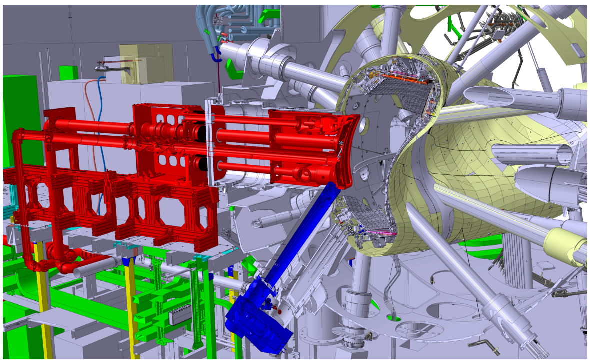

Fig. 5. ICRH antenna (red) and IRVIS endoscope (blue)

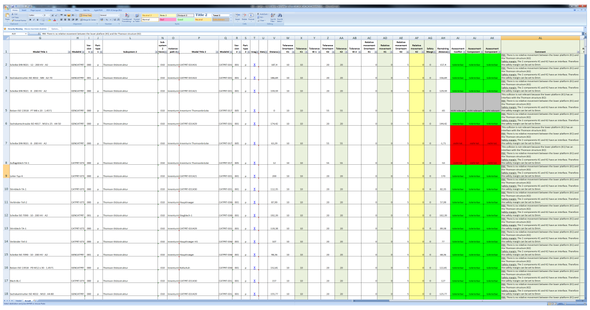

Fig. 6. Collision highlighted in a report in red

In this example the IRVIS endoscope will be moved to another port to solve to collision. This collision shows the importance of performing systematic collision analysis when new models are received and if possible at an early stage of the design. It also highlights the necessity for the external partners of IPP to be able to visualize the environment of their components likewise what is done in IPP.

5. Summary and future developments

As a result of the systematic use of these tools, the design lead time is optimized by detecting possible collisions early on, avoiding iterations at a later stage of the design process where it would be time consuming and expensive. It is difficult to quantify the gain in efficiency but in spite of a reduction of the number of designers and an increase work load all deadlines were met, which speaks for itself. The digital mockup also encourages communication among designers as modifications are visible to all CAD users within 24 hours of their implementations.

The main future development is to grant external partners an access to a piece of the digital mockup in the vicinity of the system they are responsible for. On the other way the external partners will provide IPP CAD models of their system at defined intervals or milestones. The implementations will require an exchange platform and a new set of tools

Another axis is to implement a configuration management system so designers and customers can visualize W7-X in each operating or assembly phase. This is needed as some components are only installed during a specific phase.

Acknowledgments

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