Research on the Simulation Process for the CFETR Divertor Assembly in Delmia

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Abstract. Divertor is an important inner component for Tokamak. In the conceptual design stage, the divertor should be assembled according to the design process in order to guide the work in site. Inner and outer targets, Dome, cassette body are studied in terms of their assemble process to validate the assembly process. Besides, Inner and outer targets and Dome are connected to the cassette body to form the whole divertor model in Delmia. Therefore, it is feasible to do assembly simulation in the virtual environment.

1. Introduction
Divertor is an important inner component for Tokamak where the fusion reactor is operated. It is maintained by remote handling ways rather than by personnel directly for the purpose of safety [1-3]. In addition, in order to reduce maintenance time to improve efficiency, the assemble process for the divertor should be conducted in the virtual environment in the conceptual design stage or in the discussion stage. On one hand, it can establish the assemble sequences in the design stage and then the technical documents could be formed to guide performance in site. On the other hand, through simulation in the virtual environment, it can save time and energy for the workers in site, besides, drawbacks in the assemble process can be predicted and avoided [4]. Then technician can optimize the assemble process for the work. So the assemble process in the virtual environment is studied for CFETR divertor in the conceptual design stage taking the EAST divertor as an example to illustrate it. The assemble process for CFETR divertor could be adopted according to EAST divertor.

2. Overall Description for the Divertor Model
Divertor model is established in 3D software, for example, UG, Solidworks, CATIA, Delmia, PRO/E, et al. Considering the simulation process, divertor model is finished in the software CATIA and then the assemble simulation is conducted in the software Delmia. Because CFETR is still in the conceptual design, its divertor is also in this stage. EAST divertor is adopted as an example to illustrate the assemble simulation. Figure 1 is the 3D digital model for EAST divertor, including inner target, outer target, Dome, cassette body. Generally, the inner and outer targets consist of the end boxes and the monoblocks and they are connected to the cassette body by pins.
3. Assemble Simulation Analysis for the Divertor

According to the working requirements, the assembly simulation is conducted in the software Delmia. In this virtual environment, the procedures for the simulation can be listed in the following figure 2. The contents for the assemble simulation include the project of the process documents to the virtual environment to establish the simulation workstation in Delmia. And then the simulation process would be determined to guide the work procedures. Finally, the simulation results will be checked to validate whether the simulation process is feasible to obtain the simulation scheme in this stage.

3.1. Import the Model

When the 3D digital model is finished in CATIA, it will be imported to Delmia. And the DPM-Assembly Process Simulation is selected. Here, in order to illustrate the simulation process briefly, we
just import the divertor model into Delmia, ignoring the other components to the virtual environment. The workstation for simulation is shown in figure 3. The ProductList contains all 3D digital models information in Delmia and then the simulation operation will be added to the Process to guide the specific simulation process.

Figure 3. Workstation for simulation in Delmia.

3.2. Assemble Simulation

Actually, the assemble simulation can be regarded as the translation or rotation from one position to the target position. Therefore, a component must be defined as the reference point so that the other components could be gathered to it forming a whole part. In order to assemble the components, following buttons will be used usually.

- Create a Move Activity. If the components need to move, including translation and rotation, then it will be used.
- Create a Viewpoint Activity. In order to see the simulation process vividly, some viewpoints needs to be changed and we can know whether the simulation is feasible.

3.2.1. Cassette body. In figure 4, we can know that the cassette body is made up of some plates to work as the support structures. So its assemble process is to gather plates to ensure that the divertor can be fixed in the vacuum vessel.

Figure 4. Cassette body.

3.2.2. Monoblock assembly. Monoblock is made up of tungsten block, Cr/Zr/Cu and heat sink. The relationship between them is shown in figure 5. The tungsten and Cr/Zr/Cu consist of the first wall and the heat sink in located in the middle. Several monoblock is connected series one by one becoming a strand of monoblocks. And then the strand of monoblocks is connected parallelly becoming a group of monoblocks.
3.2.3. Inner and outer targets. According to figure 1, the targets are made up of monoblock groups, end-box A and end-box B. They are connected due to the cooling pipes, the specific structures for targets are shown in figure 6.

3.2.4. Dome. Like cassette body, we can know that the Dome is also made up of some plates. Therefore, some plates would be assembled, as shown in figure 7.
4. PERT Charts
In the virtual environment, the simulation procedures are defined. However, some procedures maybe need to be revised in order to optimize the simulation process. Therefore, when the simulation process is defined, the simulation procedures can be re-arranged in PERT chart [5]. The features to do so can be summarized that:
- If the procedures are series situations, the procedures can be revised as parallel so that it can reduce assemble and improve assemble efficiency.
- Through PERT chart, the assemble process is revised and then the GANT chart can be adopted to show time vividly. Then we can know the total time we spent in the assemble process. Besides that, the sequences of all assembles can be depicted vividly to illustrate the relationships of all assembles.

The PERT chart of the cassette body assemble simulation can be listed in figure 8. Here, we just take the cassette body as an example, and the other parts are similar with it. Compared with figure 8(a) and figure (b), we can conclude that if some processes can be conducted by parallel, they can be carried on together to reduce time and improve efficiency [6].

![PERT chart in series](image1)
![PERT chart in parallel](image2)

(a). PERT chart in series  (b). PERT chart in parallel

Figure 8. PERT chart for simulation in Delmia.

5. Conclusion
Dome, inner and outer targets are connected by pins. Besides that, we should still consider the fixation of the divertor to vacuum vessel, especially the maintenance for the divertor should be taken in consideration. Considering the harsh working conditions, the maintenance operation would be handled by remote handling ways rather than by personnel directly. Therefore, it is necessary to do some research on the divertor structures which can fulfill requirements for remote handling in the next step. The simulation process for the divertor assembling is conducted and then the PERT chart is obtained to validate that the feasibility for the assembling process.

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