CAD data extraction tool for 2D equilibrium calculations

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The process of CAD data extraction starting from data acquisition from the DO (Design Office) to the final form usable for the numerical simulation is long and cumbersome. Two paths were foreseen by the authors to address this problem. The first path includes a CAD database in which extracted CAD data are stored in several levels of detail and various formats, and are ready for direct use in the numerical simulation [1]. The second path includes programmable re-modelling of the CAD models where CAD details are organised into different levels of detail during the process of CAD modeling [2]. However, the second path is not a favourable choice since remodelling a complex CAD models is time consuming and the models are already modelled and available at the DO. Hence, the first path is favoured in making CAD data more "user friendly" for use in physics codes. There is no live-link between the CAD model and the physics code model. Most of the time the representation of the elements used in the physics codes is different of the real geometry and some manual work is needed before the data extraction.

A python code has been written and used as a machine description pre-processing tool to extract the data geometry accurately and efficiently from the CAD. The extracted machine description model has been used as an input for 2D axisymmetric electromagnetic modelling. The data extraction can be done for arbitrary torodial angles. Data could be written in different formats (CSV, netCDF) and consists of main machine description metadata from magnetic measurements, poloidal field currents and passive structures. A "pixelisation" process has been implemented in order to simplify the machine description used by the main 2D electromagnetic codes and plasma equilibrium codes. A Mega-Ampere Spherical Tokamak (MAST) Upgrade use case will be described.

Machine description

Physics codes need the full machine description of the model to run the numerical simulation. The machine description consists of data for signals, material, geometry, etc. Most of the data are already available and stored in various data bases with access through different plug-ins. Exception to this is the CAD data. There is a need for CAD data to be extracted in a more

*Meyer et al, Overview of progress in European Medium Sized Tokamaks towards an integrated plasma-edge/wall solution, accepted for publication in Nuclear Fusion automatic way, using pre-processing tools where extraction errors will be avoided and extraction will be done more efficiently.

For this a python tool has been written and is used to extract the CAD data, Fig. 1. As one can see from the Fig. 1, data for materials and signals are acquired from the metadata and the CAD data from the CAD model with the python pre-processing tool (pyOCC). This information is used to build the axisymmetric model for the equilibrium calculation. A dry run to test the magnetic configuration (a discharge with all currents in the coils but no gas in the chamber) and calibration of the probes and loops for the magnetic field (known current is put in the system and measure the magnetic field) are done, and "production runs" are executed after the system check.

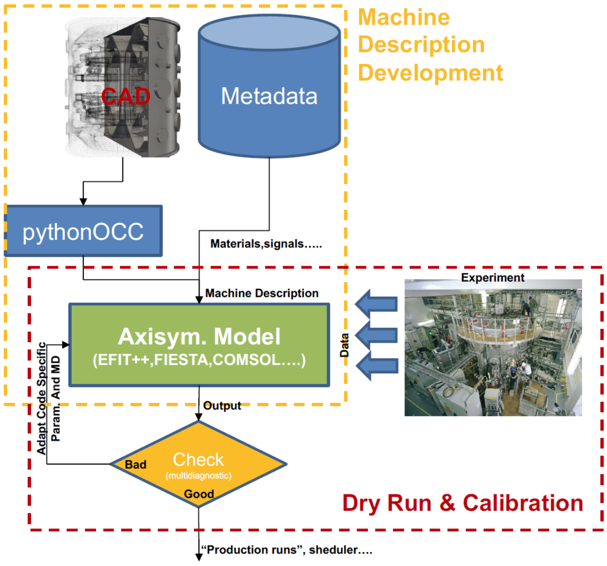

Figure 1: Machine description development for MAST-U.

CAD data extraction

The CAD data are automatically extracted from the passive structure, PF coils and the magnetics system of the tokamak machine. The CAD data is read in the pyOCC tool as a 2D or 3D STEP depending on the machine component complexity. Most of the components are just read without any manual shape modification. Extraction process is substantially faster than the manual data extraction. For example, if one needs the position and size of the coils (large number of copper windings) or the magnetics components (pickup coils, full and partial flux loops), manual extraction would take a long time and human error is introduced.

There are three shapes that can be used to describe the component geometry in 2D equilibrium calculations, Fig. 2. The process of programmable component description using these three shapes is named "pixalisation" and is mainly utilised for the passive structure since its component shape is more complex. Some components of the passive structure need only one shape to be describe, but other need two or three shapes.

To fully describe these shapes, one needs to specify the following geometry data: center radial distance (rCentre) and center height (zCentre) from the machine absolute centre, the width and height of the shape (dR, dZ) and the two angles: angle1 (A1) and angle2 (A2). If the shape's sides are 90° to each other, the two angles are zero. Only two shape variants of the first shape, Fig. 2a, are allowed to be used for component description, Fig. 2 (b and c). The first shape variant, Fig. 2b, has angle1 different from zero and angle2 equal to zero, and the second shape variant, Fig. 2c, has angle1 equal to zero and angle2 different from zero. A shape which has both angles different from zero is not allowed, that is one side must be always horizontal or vertical.

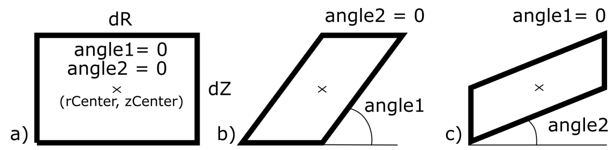

Figure 2: Three basic shapes are used for the component description.

Extra information could be needed besides the one defined above to describe different components. Geometry parameters for component description are the same for the passive structure and the PF coils, whereas for the magnetics system instead of width and height, toroidal begin and end angle are written. There is no need for "pixelisation" of the PF coils and magnetics due to their simple shape and simpler coding is used for the data extraction.

Passive structure

The passive structure is more complex and needs more attention. Passive structure includes the carrier/support for the graphite tiles, coil casings, machine vessel, etc. "Pixelisation" is needed to describe the component's complex shapes of the passive structures using the shapes described above, Fig. 2. Besides the complex shape, the CAD models from DO are modelled for manufacturing purposes and the geometry is not usually appropriate for any automatic extraction. The "pixelisation" process starts with a polodial cut of the 3D component model with defined toroidal angle, Fig. 3a. This 2D section cut is than used as an input for the "pixelisation", Fig. 3b. However, some manual intervention is needed to "lead" the pixelisation process to a wanted pixelised shape since limited number of shapes are allowed for the description. Also, the manual intervention is used to avoid any shape overlapping with the neighbouring components and to precisely "suggest" what shape is desired. This is required since there is not much space between components and more accurate positioning of the components is needed.

Pixelisation simplifies a complex shape and if there is no "guidance" overlapping of the shapes will occur especially with the plasma facing component (PFC) line.

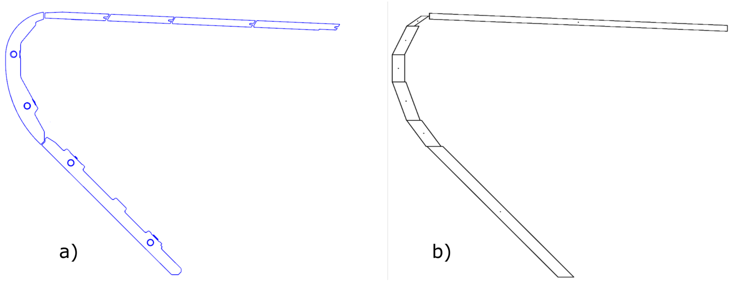

Figure 3: Component real geometry and pixelisation (nose tiles): a) original component 2D section cut, b) pixelised shape.

Conclusion

Python pre-processing tool is written to extract the CAD data needed for the machine description. Extraction of the data for most of the components is automatic. Some of the components due to their complexity need manual work to be prepared for the data extraction. In addition, a "pixelisation" process is introduced to describe the components with arbitrary shape with shapes suitable for the equilibrium calculations. Manual preparation is mostly restricted to the components from the passive structure and presents a small part of the complete model data extraction process. Other components such as coils and magnetics do not need any manual intervention and the data extraction is automated. This tool, besides the faster, more accurate and more convenient extraction, provides repeatable extraction process and with that insures reproducibility, transparency, internal and external data reuse and dissemination [3].

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References

[1] M. Telenta and L. Kos, in *Distributed Computing and Cloud computing* (Opatija, Croatia, 2016) pp. 707.1 – 707.8.

[2] M. Telenta, L. Kos, R. Akers, and I. Lupelli, in *25th International Conference Nuclear Energy for New Europe* (Portoroz, Slovenia, 2016) pp. 904.1 – 904.8.

[3] I. L. et al., Fusion Engineering and Design **96-97**, 835 (2015), proceedings of the 28th Symposium On Fusion Technology (SOFT-28).