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Summary of the first ITM-TF meeting on 3D machine descriptions held on 04/06/2009

Participants:

Rui Coelho, Christian Konz, David Coster, Erika Strumberger, Tilmann Lunt, Fabbio Subba, Maurizio Ottaviani, Lars-Göran Eriksson, Knud Thomsen, Wayne Arter and Seppo Sipilä

Agenda

1. Overview of ITM tasks relating to 3D mach.desc.
2. Challenges/solutions for porting a 3D wall description to the ITM (W. Arter) *(~20min)*
3. Code examples using 3D wall - ongoing effort. (S. Sipilä) *(~15min)*
4. ITM-TF code candidates aiming at 3D wall. (D. Coster, C. Konz, M. Ottaviani) *(~20min)*
5. Joint Discussion : strategy, prioritized actions to be undertaken and timeline.

1. Overview

A brief introduction to the ITM-TF goals and strategy was presented by the EDRG task coordinator (R. Coelho) considering that one participant at the meeting (W. Arter) is not involved in the ITM-TF work. The intents of the EDRG group were depicted with a special emphasis on the machine descriptions and in particular on the prospects for a 3D description of the tokamak vessel. An overview of the ITM-TF tasks connecting with 3D machine descriptions was presented.

2. Challenges/solutions for porting a 3D wall description to the ITM

An overview of some CAD concepts was presented by Wayne Arter (see *CADtophys.pdf*), namely of :

- the constructive solid geometry (CSG) and Boundary representation (BREP) geometry types.
- linear elements and the curvilinear NURBS modelling.
- CAD repairing.
- CAD defeaturing
  - this involves a selective removal of particular details from the original CAD drawing intended to provide a coarser description. Defeaturing may often leave "holes" behind that ought to be repaired with dedicated software (e.g. CADfix)
  - an in-depth example of CAD defeaturing and mesh generation using CADfix was presented for an ITER duct design (see *wa_cadfix_test.pdf*). The resulting file may then be exported to the SolidWorks 3D mechanical CAD program.

The particular requirements for the neutronics group at Culham were shown and the possible approaches to deal with geometry conversion (CAD->CSG, BREP and CSG⇔BREP) discussed. Most of the software tools are licensed and some have proprietary data formats. An example of geometry generation of a full 3D domain of a 40º ITER section with the software MCAM and SolidWorks, and tetrahedral meshing with Simmetrix was presented and its application to the neutron transport calculation with the ATTILA commercial code displayed. (The meshing is done internally to ATTILA using Simmetrix.)

3. Code examples using 3D wall - ongoing effort

A presentation on the current research with the ASCOT code incorporating a 3D wall was made (S. Sippilä). The wall geometry is not calculated within ASCOT and arrives directly from a defeatured CAD drawing and quadrilateral generated mesh, elaborated by a drawing office. A portion of a typical 3D wall data format read by ASCOT was shown. The adopted format and import is quite flexible since several toroidal wall sectors, each with their own peculiarities (with/without extended limiter, ports,…) can be imported in one single file. Once more, it was stressed that the "wall model" is application dependent, i.e. for the particular case of ASCOT, the wall needs to be gas tight to avoid leakage of particles.
A particle collision model with the 3D wall was presented, based on a ray-polygon algorithm, with applications for particle loads in the divertor (with and without charge exchange effect) from extreme particle orbits and ITER wall and divertor loads due to ripple loss.

A numerical tool (running on MS-Windows) for the 2D/3D visualization of the ASDEX Upgrade device was displayed (T. Lunt). The tool gets input from CAD STL files a comprehensive 3D description of device, including among others, antennas, ports, ducts, limiters, divertor and vessel tiles. The device is coated with a triangular mesh and although the detail level can be controlled, a full defeaturing/fixing of the wall is not performed. Lines of sight and images from AUG diagnostics can be overlayed and ray tracing features are also available.

4. ITM-TF code candidates aiming at 3D wall.

Maurizio Ottaviani commented on the ongoing effort in IMP2 to integrate a RWM code in the ITM infrastructure. Owing to practical obstacles in the necessary CPO implementations that are being pursued, an actual critical review of the code requirements regarding the type of wall model the ITM should adopt has not been made yet. However, it was noted that the latest evolution of the CarMa code, coupling the MHD stability code MARS-F and the electromagnetic quasi-static CARRIDI code, can handle complicated 3D wall geometries.

Suggestion : CarMa/CARRIDI contributors should take part in the future discussions on wall descriptions within the ITM-TF.

Christian Konz and Erica Strumberger briefly mentioned some of the codes relating to the domain of IMP1 (see *ITM_3D_Codes.doc*) that encompass 3D descriptions. It was mentioned that one of the codes included in the list, VMEC, does not incorporate any particular wall details since it calculates the magnetic fields in vacuum. The code CEDRES++, an equilibrium reconstruction/prediction fixed/free boundary code, was brought to the discussion since it uses a finite element grid that extends up to the poloidal fields coils (with local refinement) and may read an input file with a wall description similar to the one used in the ITM-TF machine descriptions.

Suggestion : Details on any CEDRES++ particular details and/or requirements of the wall meshing (planar/curved, refinement and fitting to wall surface) and physics (eddy currents, resistivity) included should be obtained.

David Coster and Fabbio Subba provided some details on the plausible choice of IMP3 code candidates requiring a 3D wall description (see *EDRG-3D_2009-06-04_IMP3_codes_v2.doc*) and ongoing effort in meshing algorithms for edge codes in the vicinity on wall elements (both in limiter and divertor configurations – see *ASPOEL_Mesh_Generator_2009-06-03.ppt*).
Regarding 2D edge codes, it was identified that the ITM-TF should ***go beyond the crude descriptions presently used for the vessel and limiter CPOs***. In particular, encompassing non-contiguous wall elements is considered a necessary extension given the not so trivial structure of some devices, namely AUG. Once a 3D wall description in set, the actual demand for 2D codes is to have a toroidally symmetric 2D projection of the wall.
Several 3D codes have been identified, namely the Monte-Carlo codes ASCOT, EMC3-EIRENE and EIRENE. Algorithms for particle collisions with the wall and 3D meshing appear to be the most stringent requirements when dealing with a 3D wall.
Ongoing effort on 2D meshing algorithms with ***linear elements*** were displayed. For edge/SOL transport simulations, orthogonal grids with magnetic field aligned cells (triangular or quadilateral), may be build except at the last cells at the boundary of domain. The latter, however, does not fill the full plasma vacuum region up to the actual wall. This is being pursued with the ASPOEL code and it was mentioned that the final goal (1-2 yr) is to be able to provide a full quadrilateral/triangular mesh of the domain given as inputs any device boundary. The ASPOEL *doesn't use higher order curved elements*. However, if needed, there is the possibility of extending the code capabilities to *read curved elements* and then *convert back to planar geometry*.

5. Joint discussion.

The ASCOT effort was highly appreciated and could be taken as a starting point for future developments of the ITM-TF vessel CPO. However, additional feedback is required from EMC3-EIRENE and EIRENE contributors to learn more about the particular features and requirements of their wall implementation.

Action : contact D. Reiter (EIRENE) and Y. Feng (EMC3) to have their feedback on the wall requirements and handling that is in place in their codes. Can these codes adopt a solution similar to that of ASTRA ?

Action : contact CarMa/CARRIDI contributors to have their feedback on the wall requirements and handling that is in place in their codes.

Action : contact CEDRES++ contributors to get particular details and/or requirements of the wall meshing (planar/curved, refinement and fitting to wall surface) and physics (eddy currents, resistivity) that is included in the code.

The ASCOT effort uses a wall description that is already at a sufficiently coarse level (although with several options in terms of wall sections). However, from the ASCOT experience, two important messages emerge :

- The **wall file** should preferably be **produced by the drawing office** following the requirements outlined by the code developers/expert users (as was the ASTRA case). The ITM-TF does not have the skills or manpower to provide the intended deliverable.

- Only planar wall geometry is easily tractable. Deriving collision points within curved surfaces is far more demanding (considerable saving in memory/CPU resources may be achieved when testing only a few wall elements that might get a collision).

It is not yet clear what should be the ultimate stage of a wall element, vessel CPO or wall mesh. One could have several modular layers of detail for the wall, of which the ASCOT case is an example. This would call for a section-like vessel CPO. Alternatively, one could build several versions of a wall description with increasing detailed level. However, it is not clear how to merge with, for instance, antenna CPOs and the associated meshing.