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Pre/Post Processing for Thermal-Hydraulic Codes using the SALOME Platform

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1. Introduction

The governing equations for the thermal-hydraulic solver can be obtained through several steps of averaging operations from the basic material transport equations. The time/volume average over the domain that has the structural material is the most rigorous process [1]. The volume averaging process gives rise to the concept of the volume porosity.

Considering the structural complexity of the reactor internal design, one can imagine how much efforts should be put to get the proper porosity data. Personal experience tells that over one man-year of efforts are not enough to develop a reasonable input preparation report for a reactor because of the notorious error-prone tedious calculations based on the design drawings. To overcome this problem, any one can imagine that the utilization of a CAD system will be very much helpful. But, some efforts have to be exercised to evaluate the capability of the present day CAD systems for this type of application before their full scope applications. Even if the evaluation is affirmative, some efforts have to be devoted to develop the necessary procedure for the porosity calculation. The first investigation by authors were made [2] with the commercial CAD, Pro/Engineer [3] and the mesh generator Pointwise [4]. Paraview [5] was used as the post processing system.

In this paper, open source SALOME platform [6] is utilized as a replacement for the above commercial codes. he platform SALOME is an extensive libraries that include CAD, mesh generator, post processor and many others.

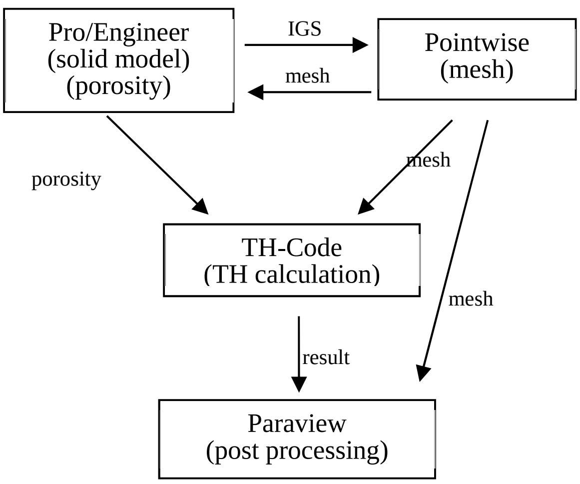

Figure-1. Data Processing Flow using Pro/E

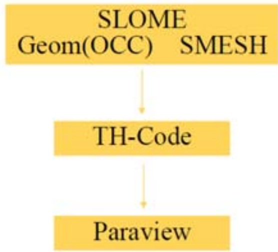

Figure-2. Data Processing Flow based on SALOME

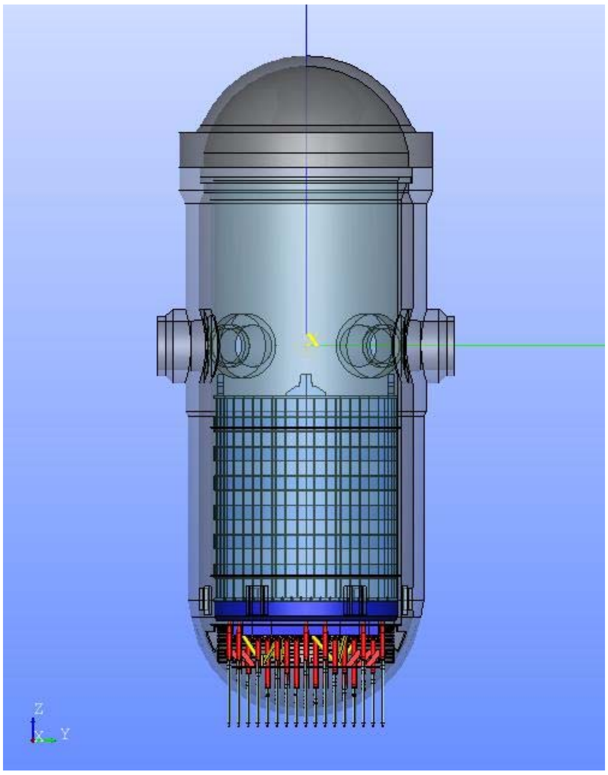

Figure-3. Reactor Vessel by CAD

2. Description of Data Processing System

As shown in Figure-1, Pro/Engineer (Pro/E) was adopted as a solid modeler in the old data processing system. Using the Pro/Engineer one can model the thermal-hydraulic system such as reactor vessel as shown in Figure-3. Pro/Engineer supplies not only the solid modeling capability but also the very powerful geometry evaluation tool which is called Pro/Toolkit. It is a user Application Program Interface (API) to Pro/E. Through it, one can access almost all the Pro/E functions. The API Pro/Toolkit is used to develop the necessary procedure for handling the geometric calculations.

Pointwise is a mesh generation software. It accepts the solid model from Pro/E in IGS format to generate the mesh data. The mesh data are sent back to Pro/E for calculation of porosity for individual mesh cells and faces. These information, mesh and porosity, are sent to the TH calculation code. Mesh data are also given to Paraview which is a post-processor. It is given the TH code calculation results as well. And any calculation results can be visualized in user selected form by Paraview.

In the newly developed system, as shown in Fig. 2, free open source SALOME platform is used. Its geometric module, i.e., CAD system, is the open source OpenCascade (OCC) [7]. SMESH is a collection of mesh generators such as NETGEN [8] and several structured mesh generators. Paraview is also used as a post-processor in the SALOME platform with the name Paravis.

Since the OCC is seamlessly integrated with the mesh generator in the SALOME, the geometric model data are directly transferred to mesh generators without any involvement of the intermediate file system like IGES. The comparison between Pro/E and OCC is not the main topic of this paper. But two points are to be stated for dragging reader attention. Pro/E has very powerful editing capability of the geometric entities. But OCC has almost no capability to edit the already generated geometric entities. Instead, SALOME including OCC has the Python [9] wrapper interface using Simplified Wrapper and Interface Generator (SWIG) [10]. Any geometric generation procedure can be dumped through Python script. If necessary, the dumped script can be edited and re-run to modify the geometric entities. Python script is a very powerful because it can be used to program the geometric modelling as well. For example, 61 bottom nozzles in Figure-3 are simply generated by 61 times calling a Python function script that generate a nozzle in SALOME Python windows.

Since the source itself is available, any procedure can be developed without limitations. The expensive API such as Pro/Toolkit system is not necessary for the new system. Any procedure developed for handling data can be implemented in SALOME through Graphic User Interface (GUI) supports from the platform. SALOME has Qt [11] based GUI widgets that can supply components such as dialog boxes.

Once the geometric model such as reactor in Figure-3 is developed, the porosity calculation is straight forward. An example is illustrated in Figure- 4 and Figure-5. In Figure-4, a cube (red color), which represents a cell, is inserted into its location in the lower part of the reactor. It has interferences with the lower core support structure, the instrumentation nozzles and the instrumentation nozzle support plate. The calculation of the porosity of the cubic cell is performed through several steps of the Boolean operations. As shown in Figure-5, the Boolean algebra "common" between the reactor vessel model and the cell model produce (c). Then, the Boolean algebra "cut" the cell model (a) by (c) yields (b). Considering the volume of the cell (a) is 0.72 m^3 (=1.0m x 0.8m x 0.9m) and the volume of (b) is 0.563 m^3, the porosity becomes 0.782 (=0.563 / 0.72). This process should be repeated for all cells. It can be implemented by the C++ programming or by the Python script.

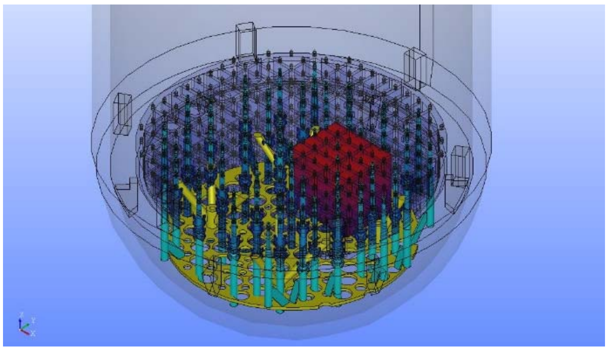

Figure-4. Lower Plenum and a Cell

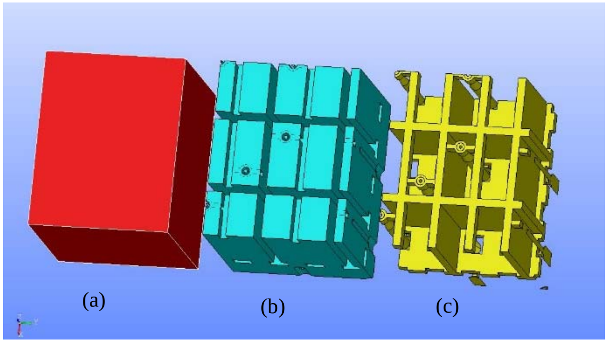

Figure-5. Cell (a), Cut (b) and Common (c)

3. How to use the Data Processing System for the network codes like RELAP5

Unlike the regular multi-dimensional codes where the mesh is well defined, the cells in one-dimensional network code like RELAP5 or MARS are not well defined. Typical cell in RELAP5 can be represented as a cylindrical pipe block which can't be represented by regular cell like the cube or the tetrahedron. Immediate problem with this situation is that any post processor like Paraview can't be used for those codes.

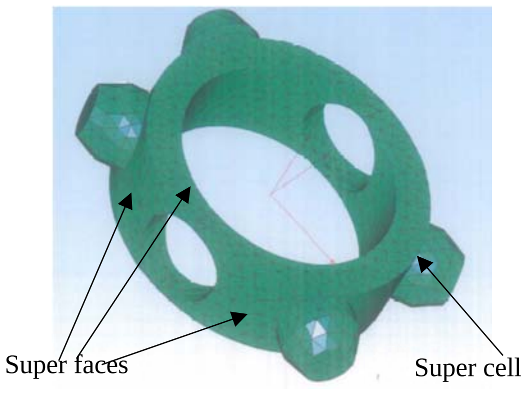

Figure-6. Super Mesh, Super Cell and Super Face

One of the suggestions to overcome this problem is to introduce the "super mesh" with "super cell" and "super face". Super cell and super face are the collection of the regular cells and the regular faces respectively. Super cell represents a cell and super face represents a face for the network codes. For example, a section of a downcomer can be represented by a super cell of tetrahedron and many super faces of triangle as depicted in Figure-6. Since the tetrahedrons and triangles that constitute the super mesh can be handled by the post processor. Any code calculation results such as the gas volume fraction for a network code cell, for example, should be copied to all of the super cell for the post processing. In this way it is possible to use the regular post processor for the network codes.

One more example can be seen on the Figure-7 and Figure-8, where the super mesh approach is applied to model the cold leg pipe.

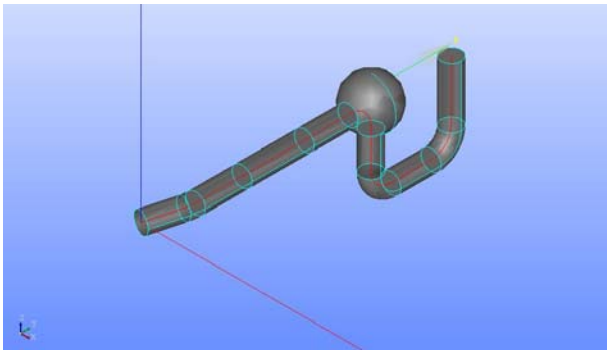

Figure-7. Cold leg geometric model

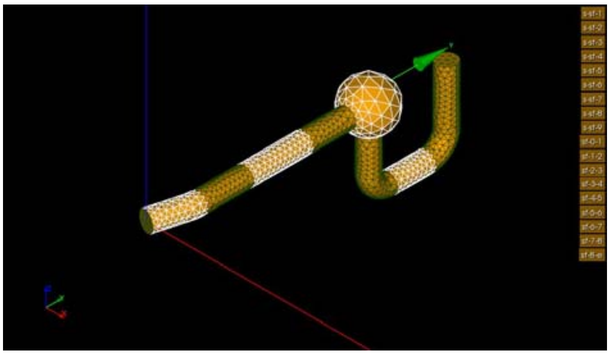

Figure-8. Super mesh on the cold leg

Eight super cells are used to model the cold leg including pump. Many super faces that represent the cold leg pipe surface are not used for RELAP5 calculation. Only those surfaces that represent the pipe cross sections are used as junctions in RELAP5

4. Conclusion and Further Works

The replacement of the commercial codes like Pro/E and Pointwise by SALOME platform in the mesh handling system has been successfully made. This system can estimate the cell and face porosity without any involvement of the expensive commercial codes. The Geometric model for the reactor vessel has been developed and used to evaluate the applicability of the system. The concept of the super mesh with super cell and super face has been re-checked for the utilization of the post processor. In the near future, all the procedure developed in this work should be implemented in the SALOME platform using either C++ programming or using the Python scripts.

REFERENCES

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