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Multi-Components Mesh Connection and its Application to the System Analysis Code

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1. Introduction

KOPEC has been developing a two-phase thermal hydraulic solver for the safety analysis of nuclear power plants [1]. The pilot code adopts the multi-dimensional, three field governing equations. Several numerical schemes, such as collocated, staggered, semi-implicit, and implicit schemes, have been tried so far.

Among the various numerical solution schemes implemented in the pilot code, the staggered mesh semi-implicit and implicit schemes are formulated using the orthogonal hexahedral mesh. This mesh system is a little inconvenient to represent complex geometry, compared to the general polyhedral mesh. However, the hexahedral mesh is useful to generate 1-D, 3-D Cartesian, cylindrical, spherical meshes, which can cover most of the geometry encountered in nuclear power plants systems. It is also noticeable that this type of mesh can be easily generated on an algebraic basis, on the contrary to the general polyhedral meshes which generally need mesh generator like GAMBIT [2].

In this paper, a simple algebraic way to generate the 1-D, 3-D Cartesian, and cylindrical block meshes will be described. In addition, a methodology to construct complex system will be demonstrated by connecting the already generated block meshes with the block linkage data provided by users.

2. Multi-Components Mesh Connection

2. 1 Cartesian block mesh

In general, most of geometry in the nuclear reactor systems including 1-D pipe can be constructed by using the Cartesian mesh. Once users provide the dimensions of the block and the cell division numbers in x, y, z-direction, sequential identification(ID) numbers can be determined for all of the cells and faces as functions of i, j, k. For example, the i, j, k-th cell ID number is given by (k-1)*jmax* imax+(j-1)*imax+i, where imax, jmax, and kmax represent the maximum cell numbers in x, y, z-direction, respectively.

The geometric quantities of each cell and face are expressed in terms of the cell volume, centriod, face area, face center. The owner and neighbor cell ID of a face can also be easily found based on the structured mesh information in the (i, j, k) domain.

The constructed geometric data and connectivity information are reproduced and reorganized in order for the hydraulic solver to calculate each spatial integration term of the discretized equations. Fig. 1 shows an example of the 1-D Cartesian block mesh generation.

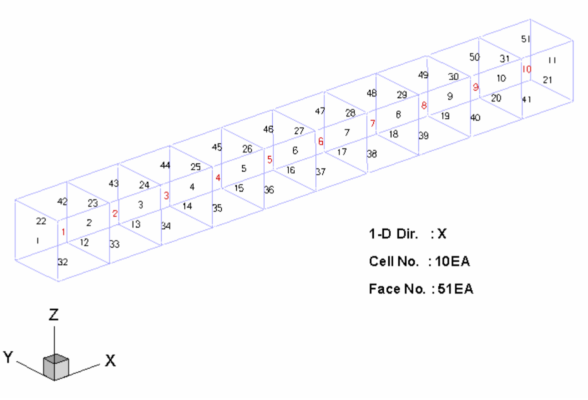

Fig 1. 1-D Pipe Cartesian Mesh.

2.2 Cylindrical block mesh

Cylindrical block mesh is sometimes useful to represent the reactor vessel geometry. The mesh generation methodology is the same as in the Cartesian block, except that cells and faces are aligned with the cylindrical coordinate. Fig. 2 shows the example to construct an annulus using cylindrical block mesh generation.

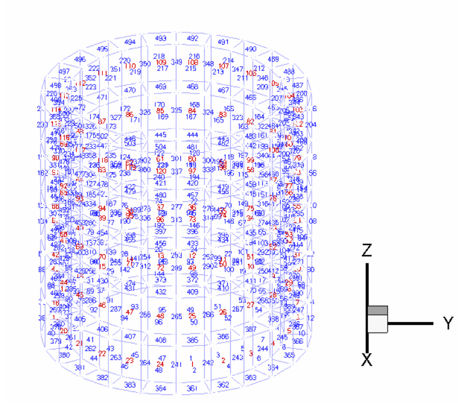

Fig 2. Example of cylindrical block mesh

2.3 Methodology to link multi-components

Provided the block linkage information, such as linkage ID, the associated block ID, the linked location, and the reference block ID, the BlockLink procedure constructs the entire system by linking the blocks according to the linkage data. One can go to the reference block at first, and then find the linked block ID and the associated face IDs, using the user-provided linkage data. Second, one compares the center of associated faces, and translates the neighbor block to fit the linked faces. Third, a flag denoting 'the linkage has been done' is set for the correspondent link. Fourth, the neighbor blocks ID is saved as 'new block IDs'. Then the BlockLink procedure goes to the first step, and searches the 'new blocks' instead of the reference block. The above procedure is repeated, until all of the links has the flag, 'linkage done'. Of course, the link having the flag of 'linkage done' is not necessary to search new blocks, during repetition of the procedure.

3. Test results

3.1 Test problem

For the purpose of verification, the block generation and multi-block link procedure are applied to construct the system comprised of eight 1-D blocks. Eight 1-D blocks are generated by following Cartesian block generation procedure. Then, with the linkage data assumed to be given by users, the eight 1-D blocks are integrated into a closed system as shown in Fig. 3, using the BlockLink procedure. Finally, to verify whether the hydraulic solver works properly for this multi-block system, the following hydraulic test is performed.

The constructed system consists of 70 uniform regular hexahedrons cells. The inlet boundary condition is given at the lower center face of the bottom block, and the outlet boundary condition is given at the upper center face of the top. The whole system is initially filled with vapor. The inlet liquid flow velocity is 1 m/s, and the outlet pressure is 10 bar.

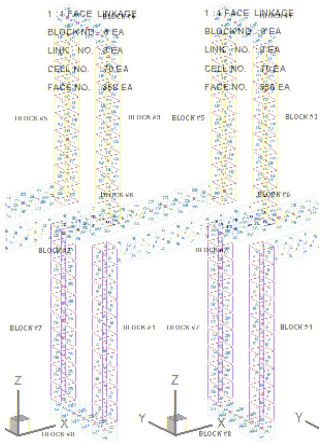

Fig. 3 Geometry of the test problem

3.2 results

Fig. 4 shows the velocity vector at cells and the pressure distribution, respectively. Fig. 4-(a) shows the liquid flow is well established along the linked blocks symmetrically. This indicates that the connectivity information of all the cells and faces is properly built. Fig. 4-(b) shows the liquid(blue color) fills from the bottom up to the upper outlet pressure boundary face. The pressure gradient in the z-direction is well established symmetrically.

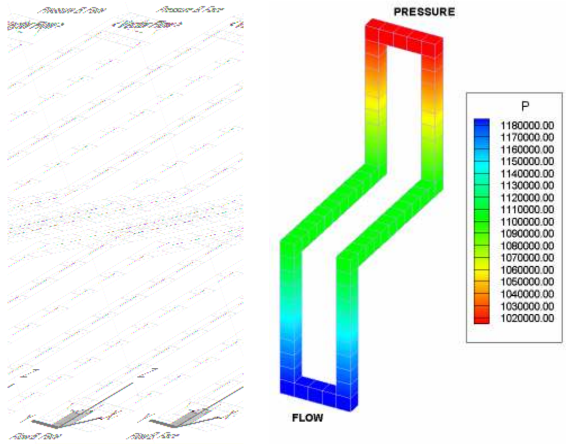

Fig. 4 (a) Velocity vector (b) Pressure contour

4. Conclusion

This paper proposes a simple algebraic way to generate the 1-D, 3-D Cartesian, and cylindrical block meshes, and to construct complex system by linking the already generated blocks. The test results show that the proposed methodology successfully generates block meshes, and performs the multi-block connection. The hydraulic solver also works properly for the well constructed multi-block system.

Acknowledgment

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REFERENCES

[1] S. Y Lee, Development of a Hydraulic Solver for the Safety Analysis Codes for Nuclear Power Plants(I). Korean Nuclear Society Spring Meeting, 2007.
[2] Gambit User Guide