Transactions of the Korean Nuclear Society Spring Meeting
Pyeongchang, Korea, May 27-28, 2010

Staggered Mesh for the SPACE code and its Application to the System Construction

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1. Introduction

The SPACE structured/staggered mesh system is based on the orthogonal hexahedral shape of cell and its surrounding faces. All of the geometric quantities are described in terms of cell volume, centroid, face area, and face center, so that 1-D pipe, 3-D Cartesian, and cylindrical mesh systems can be expressed in the same manner. In this paper, simple algebraic ways to generate the component-wise block meshes are described. In addition, a methodology to construct complex system by connecting the already generated block meshes is demonstrated.

2. Mesh system

2. 1 Staggered mesh

Fig. 1 shows the staggered mesh used in the SPACE code. Each scalar cell has normally six faces in 3-D Cartesian or cylindrical mesh blocks. But 2-D Cartesian meshes or 1-D pipe can be also represented only by reducing the number of the surrounding faces. Direction of the cell and the associated faces can be distinguished by the unique number sequentially given to each face. Each momentum cell is shifted by the half size of scalar cell. Hence, it consists of the front half part of the owner scalar cell and the back half part of the neighbor scalar cell. Each face can be divided into several sub-faces. With these sub-faces, one-dimensional or three-dimensional branches are easily modeled. Generally curved pipes can be also represented by providing vertical and azimuthal angles to each scalar cell.

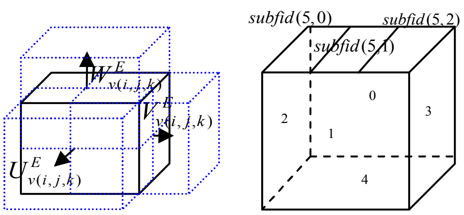

Fig. 1 SPACE staggered mesh system

2. 2 Component-wise block mesh generation

The SPACE code provides simple ways to generate 1-D pipe, 3-D Cartesian, and cylindrical block meshes. Once users provide the dimensions of the block and the number of cells 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 denote the maximum cell numbers in x, y, z-direction, respectively. 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 reorganized in order for the hydraulic solver to calculate each spatial integration term of the discretized equations. The methodology of cylindrical block mesh generation is the same as in the Cartesian block, except that cells and faces are aligned with the cylindrical coordinate.

2.3 Methodology to link multi-component block meshes

Provided the block linkage information, such as linkage ID, the associated block ID, the link location, and the reference block ID, the "block link procedure" constructs the entire system by linking the blocks according to the linkage data. The block link procedure goes 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, it compares the center of associated faces, and translates the neighbor block to fit the linked faces. Third, a flag indicating that the linkage has been done is set for the corresponding link. Fourth, the neighbor blocks ID is saved as 'new block IDs'. Then the block link 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, 'the corresponding linkage has been done'. Fig. 2 shows overall flow chart of the block link procedure.

3. Test results

For the purpose of verification, the component block mesh generation and multi-block link procedure are applied to construct a typical PWR primary system. Cartesian type block meshes are constructed for the reactor core, lower and upper plena, and vessel head. Cylindrical mesh block is used to represent annulus type of downcomer. The hot leg and cold legs, pressurizer, surge line, and SG U-tubes are constructed by using the one-dimensional pipe type meshes. The component block connection technique is used to merge all of the component mesh blocks into the whole reactor coolant system. Then, a simplified test for reflood phenomena during a cold leg break LOCA is performed for the typical PWR. The entire system is initially filled with saturated vapor at 10 bars. Fig. 3 shows the distribution of void fraction at 200 seconds after initiation of safety injection. It can be seen that the reflood process for typical PWR system is reasonably simulated with the above nodalization.

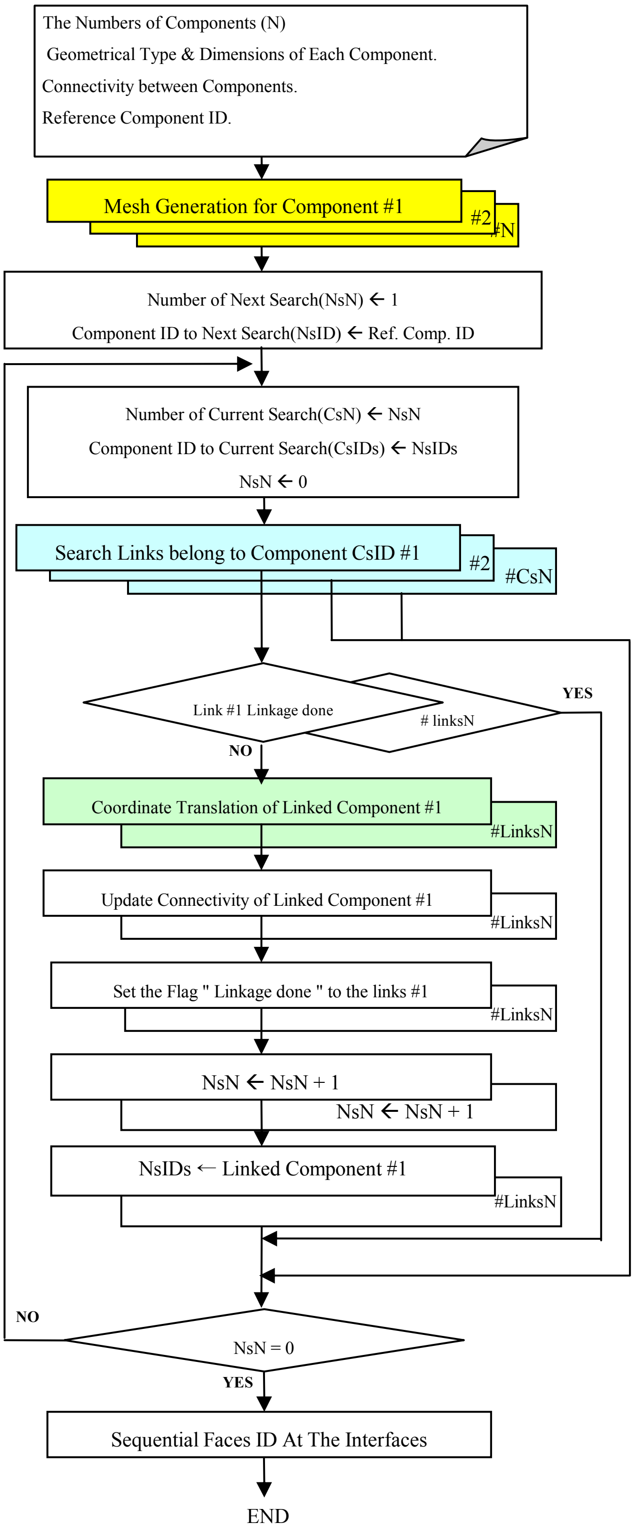

Fig. 2 Flow chart of the block mesh link procedure

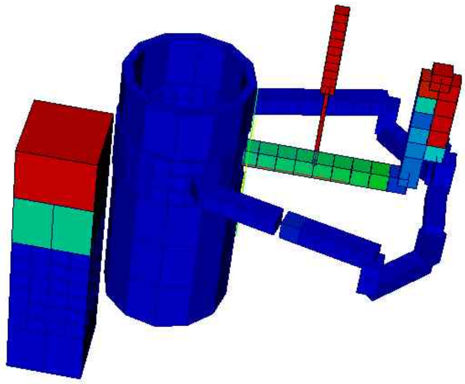

Fig. 3 Test result for the cold leg break reflood phase in a typical PWR system

4. Conclusion

The SPACE code provides simple algebraic ways 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 result shows that the SPACE code staggered mesh handlers successfully generates block meshes, and have the capability of multi-component block mesh connection. The hydraulic solver also works properly with the well constructed multi-block mesh system.

Acknowledgment

This study was performed under the project, “Development of safety analysis codes for nuclear power plants” sponsored by the Ministry of Knowledge Economy.

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