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A Study on Improvement of the Reactor Cavity Model

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1. Introduction

The determination of a grid size in the computational fluid dynamics (CFD) closely relates to accuracy and solution time. For such a reason, an iterative procedure to properly size the first grid in the near wall region is required for the reduction of uncertainty [1]. The flow characteristics in the near wall are used as the critical factors for solving the fluid-structure interaction (FSI) problem. Especially, the temperature under the turbulent condition has a large degree of uncertainty unless the experimental data are measured or the CFD is simulated by considering the geometry and flow conditions.

The airflow in the reactor cavity moves from bottom of reactor vessel to containment building via the access holes of the reactor cavity pool seal assembly (RCPSA) during the plant operation (Fig. 1). However, the reactor cavity has a complicated shape particularly at inner region of the RCPSA. So, the temperature of air, which is of key importance in the design of the RCPSA, needs to be examined by using CFD.

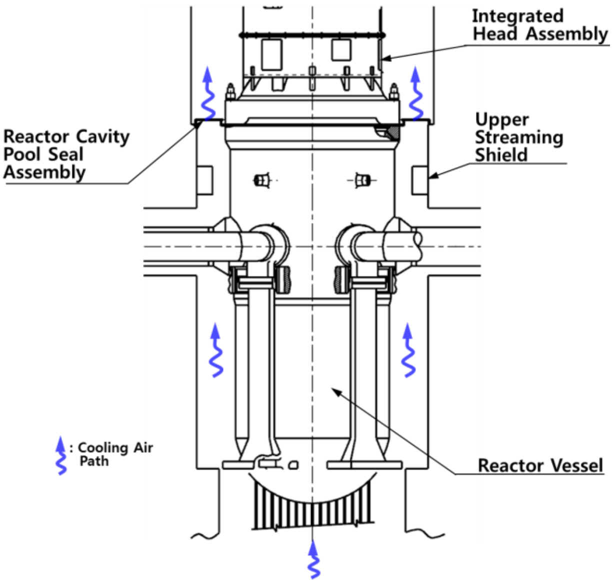


Fig. 1. General Arrangement (section view)

The objective of this paper is therefore to investigate properly grid size of the reactor cavity model for reducing the uncertainty of the model. Simulations using CFD with turbulence model have been carried out for the cases with various grid sizes in the near wall region at the inner surface of the inner and the outer flexures of the RCPSA. These results are encouraging in view of the relation between temperature distribution and grid size in the reactor cavity model.

2. Methods and Results

2.1 Configuration of Geometric Model

The reactor cavity is the annular space by surrounding of the concrete structure, the RCPSA and the reactor vessel. In analyzing the fluid behavior in reactor cavity, the one-sixteenth model, which is a represented shape to describe the swirl and eddy phenomenon in the narrow region, was generated as shown in Fig. 2.

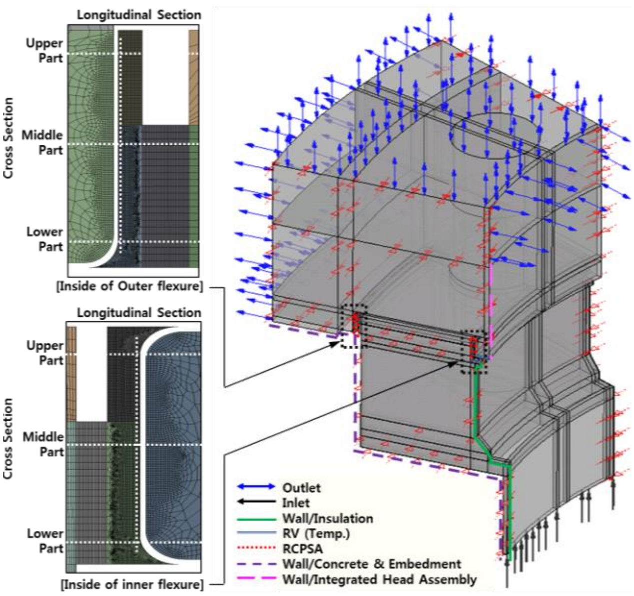


Fig. 2. Configuration of Model and Boundary Conditions

2.2 Turbulence Model

The shear stress transport (SST) k-ω model, which accounts for the transport of the turbulent shear stress and gives highly accurate predictions of the onset and the amount of flow separation under adverse pressure gradients, was applied [2, 3].

2.3 Boundary Condition

The boundary conditions for CFD analysis were defined by assuming the plant operation condition as described in Fig. 2. The mass flow rate with the static temperature at the inlet as well as the pressure and constant temperature at the outlet were set as the boundary condition. The various temperatures on the structures such as the RV, the embedment, the concrete, and the insulation were considered to the designated walls. Bulk temperature was set as ambient temperature. The symmetry boundary conditions for the side were chosen.

2.4 Grid Independency Analysis

The five cases with various grid sizes were generated and computed. The grid in the near wall region at the inner surface of the inner and the outer flexures, which are of key importance in the structure integrity of RCPSA, were uniformly generated by using the finer grid. Cases by each grid size in the near wall region at inner surface of the inner and the outer flexures were used as case I through case V for evaluating the grid sensitivity of reactor cavity models. Cases by the grid dimension have been chosen to investigate the grid size effect on the results as shown in Table I.

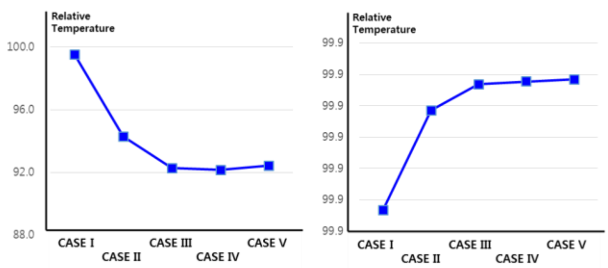
Table I: Grid dimensions

Cases	I	II	III	IV	V
No. of Grids*	5	17	22	25	28
Sweep Element Size**	10	3	2.3	2	1.8

*) Number of grid between the inner surface of the flexure and the outer surface of the support
**) Relative value for element size

2.5 Results

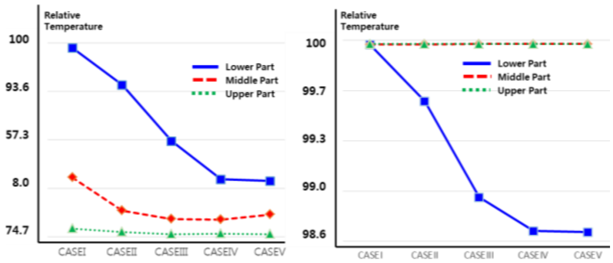
The results for the relative temperature of each case at the longitudinal section (refer to Fig. 2) of the inner and the outer flexures are shown in Fig. 3. The results on five cases show that the temperature profile in the inner flexure is obviously distinguished from those in the outer flexure. Additionally, the temperature profiles in the inner and the outer flexures tend to converge according to the increase of the number of grid and the reduction of the sweep element size.



[Inner Flexure] [Outer Flexure]
Fig. 3. Temperature in Longitudinal Section

The analyses of temperature distribution in the cross sections at upper, middle, and lower parts (refer to Fig. 2) of the inner and the outer flexures as shown in Fig. 4 are another way of evaluating the effect of the grid size. The results show that temperature profiles in each part excluding the lower and upper parts of the outer flexure decrease as the number of gird increases. The results at both flexures indicated that the temperature in lower part is strongly influenced by the number of grid. The results mean that grid sensitivity of reactor cavity models has a correlation with the geometry of the inner and the outer flexures and the temperature on the structures. However, the temperature profiles in the near wall region at inner flexure are more sensitive to the number of grid than it at outer flexure.

The results in longitudinal and cross sections indicate that the temperature is seriously affected by the number of grids and the geometry of the RCPSA.



[Inner Flexure] [Outer Flexure]
Fig. 4. Temperature in Cross Section

3. Conclusions

The feasibility and accuracy of reactor cavity model to calculate the temperature in the near wall region at the inner surface of the inner and the outer flexures of the RCPSA are examined.

1) A grid size is seriously affected on the temperature in the near wall at the inner surface of the inner and the outer flexures of the RCPSA. The temperature distribution in the near wall region of the inner and the outer flexures of the RCPSA show that the reactor cavity model by using finer grid decreases the uncertainty in contrast with it with coarse grid.

2) A grid size in the near wall region at the inner surface of the inner and the outer flexures of the RCPSA for reactor cavity model is decided as the proper grid size between the case IV and V in the light of the assessment of the temperature gradient.

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