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Structural Integrity Effect of Reactor Cavity in Turbulence Models

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1. Introduction

The cooling air moves from bottom of a reactor vessel to a space on operating floor in reactor containment building via a pool seal assembly, insulation of reactor vessel (RV), and an upper streaming shield, which have complicated shapes, during the plant operation (Fig. 1) to maintain a constant environment in the reactor cavity. Subflows split away from main flow of the cooling air have a disordered and abnormal flow in vicinity of related structures for concrete and nuclear steam supply system. The assessment of turbulence model by using computational fluid dynamics (CFD) has been conducted to understand the features of these subflow [1] and effect on structures in various industrial field [2].

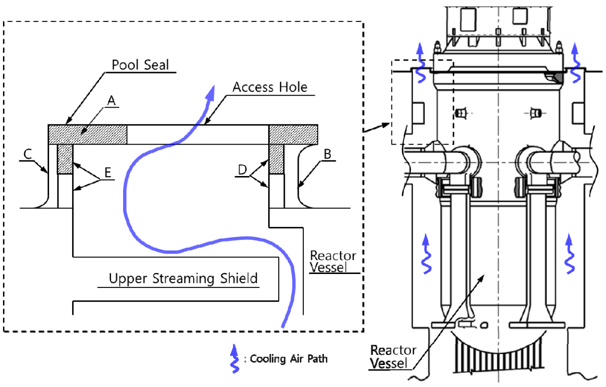

Fig. 1. General arrangement

The purpose of this study is to compare appropriate turbulence models in evaluating the structural integrity for the pool seal design.

2. Methods and Results

2.1 Analysis Procedure

Procedure of unidirectional Fluid Structure Interaction (FSI) analysis for evaluating the turbulence models mainly consisted of cooling air flow, steady-state thermal and static structural analyses by using commercial software as ANSYS Ver.15.0. To estimate an appropriate turbulence model for the structural integrity evaluation for the pool seal, two representative turbulence models of k-epsilon (k-ε) and k-omega (k-ω) are adopted considering that the intricate turbulence flow would occur due to the swirl and eddy phenomenon caused by various complex shape of all structures.

2.2 Models

The 3D models for CFD and FEM were generated as the one-sixteenth model as shown in Fig. 2.

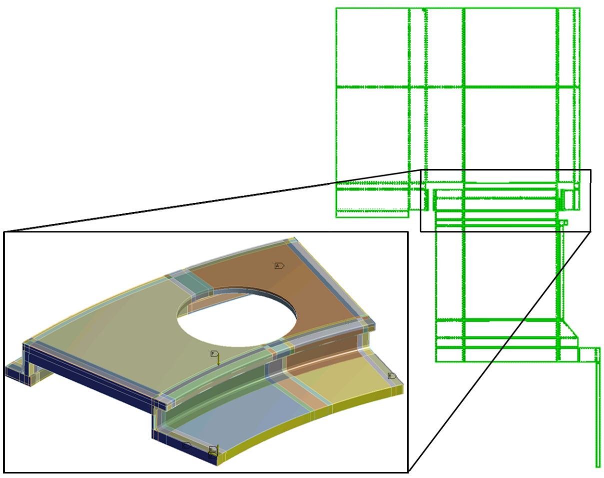

Fig. 2. Model for FEM and CFD

The inputs for the fluid analysis under the steady-state were considered as mass flow rate, static temperature, pressure, and the boundary conditions. For the analysis, the grid sensitivity evaluations were evaluated in grid cases [3]. The load conditions for the thermal analysis were convection heat transfer coefficient (CHTC) from the CFD analysis and the temperature of structures. The static state structural analysis was performed by considering the body temperature from the analysis for steady-state thermal, dead weight, and RV thermal expansion as a load condition and the symmetric at side and fixed on structures as a boundary condition.

2.3 Analysis Results

The fluid analysis in reactor cavity were performed for obtaining CHTCs at 5 regions (A to E, refer to Fig. 1) on pool seal. The CHTCs according to the k-ε and the k-ω turbulence models have been definitely distinguished as shown in Fig. 3. In particular, the average CHTCs in regions B, C, and D by using the *k-ω* model were approximately 20 times higher than those in *k-ε* model.

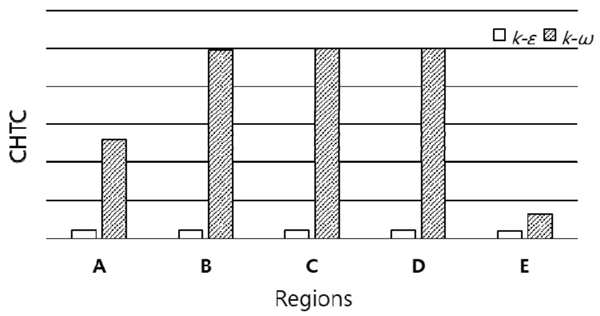

Fig. 3. Convection heat transfer coefficient in regions

The analysis for the steady-state thermal by the turbulence models, is shown in Fig. 4, was carried out for calculating the body temperature of the pool seal.

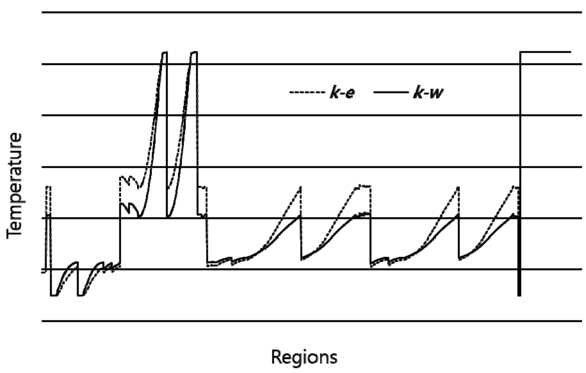

Fig. 4. Body temperature in regions

The results of the steady-state thermal analysis show that the body temperature distribution were calculated with similar trend regardless of the turbulence models in all regions. However, the temperature difference in partial regions between the analyses considering *k-ε* and *k-ω* turbulence models was calculated up to 20% due to the temperature of structures such as the RV thermal effect.

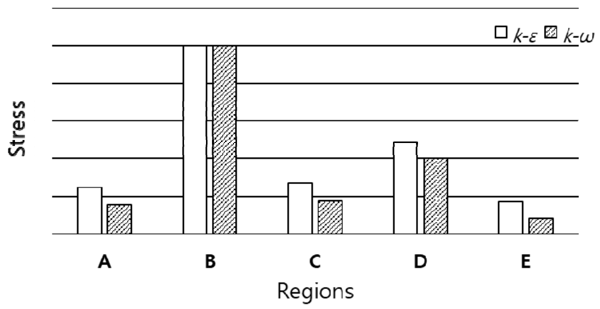

Fig. 5. Stress intensity in regions

The static structural analysis for stress intensities shown in Fig. 5 is performed by using the FSI technique. The highest stress intensity was calculated at region B than at other regions, but the difference in stress intensities according to the turbulence models were less than 1%. However, the lowest stress intensity was calculated at region E, but the difference was calculated to be 212%.

3. Conclusions

The work presented in this study evaluates the stress intensities in the pool seal considering different turbulence models: *k-ε* and *k-ω*.

First, CHTC in the *k-ω* turbulence model are severely affected by cooling air in reactor cavity.

Second, body temperature in regions seems to be influenced by the turbulence models and high temperature of reactor vessel.

Third, the *k-ε* turbulence model accounting for the CHTC effect seems to have a positive effect on its application in terms of conservative structural integrity on the pool seal.

However, it is necessary to conduct further studies on the half model and the application of the bi-directional FSI in order to improve the accuracy of stress analysis results.

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