Preliminary Study on Load and Stress Characteristic Evaluation for Handling Reinforcement Device of Spent Nuclear Fuel

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1. Introduction

Spent Nuclear Fuels (SNFs) have been stored in spent fuel pools of the nuclear power plants since the plants started commercial operation. In some case, it is necessary to enhance handling safety for imported nuclear fuel types with Inter-Granular Stress Corrosion Cracking (IGSCC) [1]. To do this end, global nuclear vendors developed reinforcement devices. In recent years, the inventive reinforcement devices have been developing in Korea.

The developing device will be installed in Guide Tube (GT) of SNF, and various working mechanisms of the device have been considering. In this study, the load and stress characteristics are evaluated for the device with the friction coupling working mechanism. For the evaluation, a Finite Element (FE) model has been developed and FE analyses are performed. Also, the correlations for FE analysis results are evaluated using regression analysis. The FE model is generated based on the Westinghouse 17×17 type Fuel Assembly (FA), which is the heaviest among the FAs with the IGSCC concern.

2. FE Analysis for Characteristic Evaluation

2.1 Finite Element Model

The FE model is developed based on the sensitive parts under the handling condition of SNF. The developed FE model is a quarter model, and symmetric boundary conditions are used for each symmetry plane. The schematic of device and the FE model are illustrated in Fig. 1 and 2.

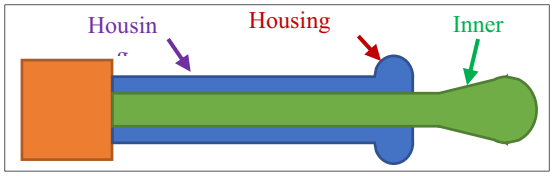

Fig. 1. Schematic of reinforcement device (Sectional view).

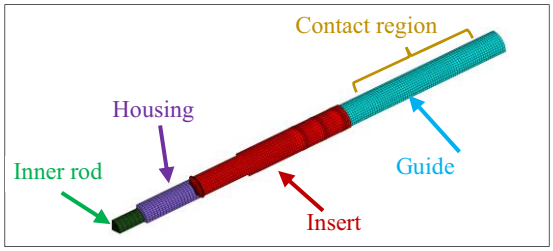

Fig. 2. FE model.

2.2 FE Analysis

The FE analysis is sequentially performed friction coupling analysis and handling analysis. The friction coupling analysis is carried out to simulate fastening between GT and device, and the handling analysis is performed to simulate handling operation of SNF with the device.

Boundary and loading conditions of friction coupling analysis are that one ends of GT and housing are fixed and inner rod is moved. Those of handling analysis are that end of GT is fixed and both inner rod and housing are moved.

2.3 FE Analysis Results

The load and stress characteristics for SNF with the device are evaluated from graphs using responses from each analysis. The graphs between each response are illustrated in Fig. 3, 4 and 5. The stress response is calculated from stress of GT, and the load response is calculated from reaction force of GT. Each regression curve is generated to describe correlation between each response, and R^2 value is calculated to verify the statistical significance of regression curve [2].

All data in these figures are non-dimensional values. Non-dimensional stresses are calculated based on the yield strength of GT material, and non-dimensional loads are calculated based on the handling load of SNF with 4 devices.

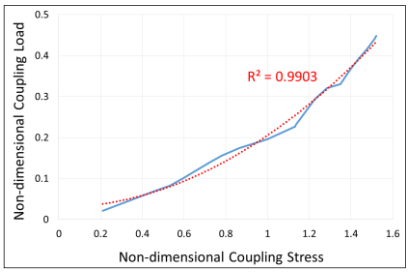

Fig. 3. Coupling stress vs. coupling load.

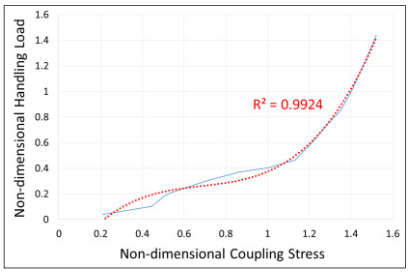

Fig. 4. Coupling stress vs. handling load.

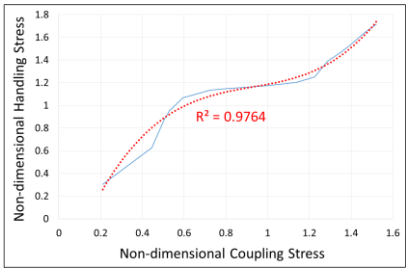

Fig. 5. Coupling stress vs. handling stress.

From these curves, it can be concluded that relationships between coupling stress and other responses are increasing functions although trends of functions are different. When coupling stress is over than yield stress, the gradients of handling load and stress are rapidly increased. If the high handling load is necessary, the plastic deformation of GT should occur due to high friction coupling load.

3. Conclusion

The FE analyses are performed to evaluate load and stress characteristics for reinforcement device. The correlations are verified using statistical analyses among each response. To obtain high performance of the device, coupling stress is larger than yield stress. In the future, coupling load will be optimized to increase handling load using stress limit constraints.

ACKNOWLEDGMENTS

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