Special Approval Arrangement for the Supplementary Structure of Wolsong Spent Nuclear Fuel Basket Transfer Flask

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1. Introduction

The Wolsong nuclear power station has four CANDU 6 units operated by Korea Hydro and Nuclear Power Co. Ltd. (KHNP). From the early 1990's, unit 1 was equipped with spent fuel handling equipment at the storage bay and with a dry storage facility using concrete silos. Unit 2 of the Wolsong site has been operating since July 1997 and also requires a spent fuel preparation and transfer facility to be installed at the storage bay. The preparation and transfer equipment consists of in-bay tooling, a shield work station and auxiliaries and of a spent fuel basket transfer flask.

The spent fuel basket transfer flask(FBTF) was not fabricated in accordance with the requirements for Type B packages because the FBTF only used for the purpose of on-site transport. However, the FBTF must meet the requirements of Type B package in accordance with the Korea Atomic Energy Act.[1] Therefore, KHNP decided to use the supplementary structure which meets the minimal structural and thermal integrity to transport of the FBTF in accordance with the special approval arrangement of the Korea Atomic Energy Act until new Type B transport cask is acquired.

In this study, the special approval arrangement and the safety analyses to evaluate the structural and thermal integrities of the supplementary structure for the FBTF are introduced.

2. Supplementary structure

The FBTF is designed to transport the basket of 60 CANDU 6 spent fuel bundles cooled for 6 years. Fig. 1 shows the configuration of the FBTF. FBTF is designed with satisfying its radiation shielding requirements. The bulk shielding is provided by 178mm of lead, lined on each side with 13mm carbon steel plate and 50mm of pure polyethylene attached to the exterior surface.

The supplementary structure is designed that the FBTF with the supplementary structure maintains structural integrity under 1.6m free drop of maximum handling height and thermal integrity under 30 minute-800°C fire condition. Also, the FBTF provides containment, radia- tion shielding and criticality control for itself.[2]

3. Safety analysis

3.1 Structural analysis

Free drop analysis is carried out to evaluate the structural performance of the FBTF with the supplementary structure under normal transport conditions in accordance with the related regulations using ABAQUS/ Explicit code[3]. Five directions of free drops from maximum handling height of 1.6m for the FBTF with the supplementary structure are considered; lower vertical, upper vertical, left side, right side and front directions. The FBTF with the supplementary structure is modeled and interactions between all contacting components are also modeled. Analysis model consists of 129,400 3D solid elements. Stresses for the inner or the outer shell of the FBTF as containment boundary must be within yield strength of material(A36, 250MPa). And, deformation of the lead shield must not exceed the thickness of 20%, i.e, 35mm in order to maintain the shielding performance.

Figure 2 shows the maximum stress distribution of the supplementary structure for the 1.6m free drop at the lower vertical direction. The lower vertical drop is the worst possible free drop to cause the maximum damage on the supplementary structure. Besides the upper vertical drop, maximum stresses of outer shell exceed the stress limit. However, maximum stresses of the inner shell are satisfied with the stress limit. The inner shell as the containment boundary maintains the structural integrity, and then the FBTF with the supplementary structure provides the structural performance for the drop of maximum handling height. As deformations of lead are very small, the effect of radiation shielding is not reduced.

3.2 Thermal analysis

To evaluate the thermal integrity for accidental conditions, thermal analysis is performed using FLUENT code[4]. The transient thermal analysis is carried out under 800 °C fire conditions for 30 minutes. Heat flux of 105.48W/m^2 emitted from spent nuclear fuels is con- sidered and initial temperature for the FBTF is 38 °C. To satisfy the thermal integrity, calculated temperatures for shielding materials of the FBTF must not exceed their melting points; melting points of the lead and the poly- ethylene are 327 °C and 124 °C, respectively.

Figure 3 shows maximum temperature distribution at 30 minute fire phase. Temperature of the FBTF in the supplementary structure is mostly similar to the initial temperature. Therefore, maximum lead and polyethylene temperatures are below their limiting temperatures and the FBTF with the supplementary structure maintains the thermal integrity.

4. Conclusion

The supplementary structure for the FBTF is designed and analyzed to satisfy with the requirements of the Korea Atomic Energy Act. Structural analysis results under 1.6m free drop are satisfied with the allowable strength and deformation. Maximum temperature distri-bution under 30 minute-800°C fire condition meets their allowable limits.

REFERENCES

[1] Korea Ministry of Science and Technology, Korea Atomic Energy Act, 2001.
[2] AECL, Spent Fuel Basket Transfer Flask - Shielding Analysis, AECL Technical Report 8600-35373-220-001, 2002.
[3] ABAQUS Inc., ABAQU/Explicit Ver.6.4 User's Manual, 2004.
[4] Fluent Inc., FLUENT Ver. 6.1 User's Manual, 2004.

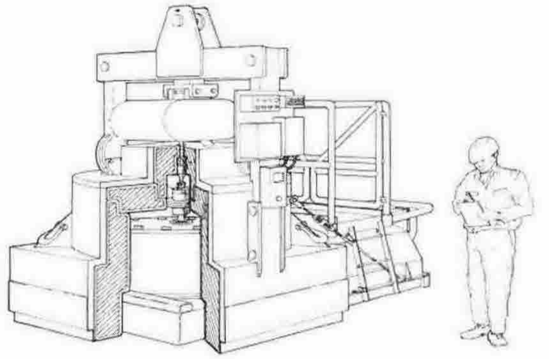

Figure 1. Configuration of the FBTF

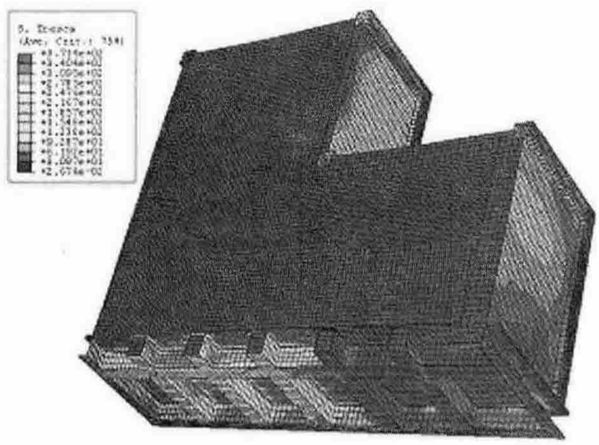

Figure 2. Maximum stress distribution for the 1.6m free drop at the lower vertical direction

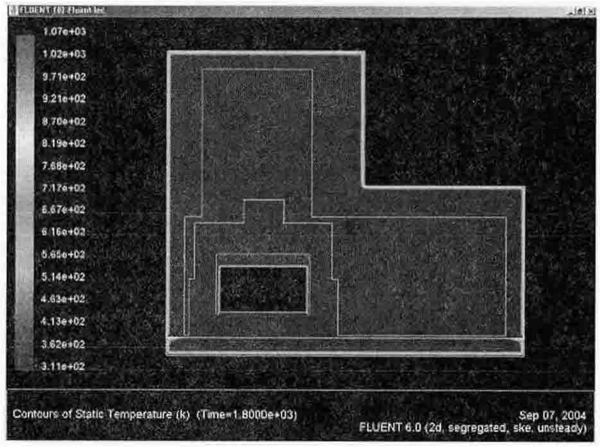

Figure 3. Maximum temperature distribution under 30 minute-800°C