Sensitivity Analysis of COBRA-SFS for Dry Storage of Spent Fuel

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1. Introduction

The storage in the spent fuel pool for spent fuels of the domestic power plant is expected to be saturated from 2024 [1]. As a practical alternative to solve this problem, an intermediate storage through the dry storage of spent fuel is considered. Studies about spent fuel for the dry storage are performing for the low burnup fuels, which accounts for 80% of the domestic spent fuels. The degradation of the spent fuel during the dry storage depends on the temperature profile. Thus the temperature profile is suggested as the first item on the gap analysis report [2]. The sensitivity analysis with COBRA-SFS, a thermal hydraulic analysis code for spent fuel storage and transportation casks [3] is performed to decide the priority of the model development and experiment variables.

2. Sensitivity parameter and results

For the sensitivity study, a dry storage cask, TN24p is used from sample input in this analysis. The explicit data in fluid flow model, the properties of backfill gas, and thermal conductivity of conduction heat transfer are consider to analysis sensitivity of the peak and the minimum temperature of cladding surface.

2.1 Fluid flow models

The momentum exchange terms are a primary source of empiricism in the fluid flow equations in COBRA-SFS. In this paper, three parameters of wall friction, form drag of spacer grids, and turbulent mixing for momentum exchange between subchannels is estimated.

The friction factor used in COBRA-SFS is the Darcy-Weisback friction factor, a dimensionless number determined from experimental measurement. Idelchik [4] suggested the following relation for rectangular array of the rod bundle geometry.

$$f_{bundle} = \frac{64}{Re}\left(0.96\frac{p}{d} + 0.63\right) \qquad (1)$$

As shown in table 1, when the friction factor of 64~124 is applied, the variation of minimum temperature is less than 3℃ and the effect of friction on the peak temperature is negligible.

The flow area due to local obstructions result in axial pressure losses. However the flow velocity in the natural convection is much less than 5 of Reynolds number. The pressure loss coefficient for the low Reynolds number was suggested as 5 by Idelchik. For the range of 0.01 to 10 of the form loss coefficient, the temperature variation is neglible as shown in Table 1.

Table 1. Cladding temperature for variation of friction factor and form loss of spacer grid

Friction Factor	Temperature (℃)		Form Loss	Temperature (℃)	
	Peak	Min.		Peak	Min.
64	222.29	85.27	0.01	222.41	87.07
100	222.41	87.07	1	222.41	87.07
124	222.42	87.87	10	222.41	87.08

2.2 Helium properties

In dry storage cask, the helium gas will be filled for heat transfer within a cask. The helium properties of enthalpy, specific heat and volume, thermal conductivity, and viscosity are necessary to calculate heat transfer in the cask. The variation of the property is ± 20% of NIST property data at the 0.1 MPa. As shown in Fig. 1, the thermal conductivity is dominant for the peak temperature and the specific volume and enthalpy is dominant for the minimum temperature. The deviation of temperature prediction is less than 3%.

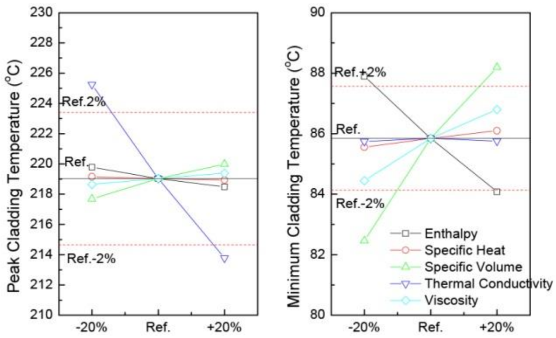

Fig. 1. Sensitivity for helium properties.

2.3 Slab material and fuel conductivity

A dry storage cask of TN24P for the sample input consists of fuel basket of aluminum, steel body, neutron shield, and shell. The fuel conductivities of pellet and cladding is related to conduction heat transfer in a fuel rod. As the heat generation rate of spent fuel is extremely low to 1 kW or less for a spent fuel assembly, the effect of the thermal conductivities of fuel pellet and cladding can be neglected.

Radiation heat transfer from fuel rods, which are the heat source transfers to the fuel basket made of aluminum alloy. The main radiative heat transfer occurs between the fuel and the fuel basket. Thus, as shown in Fig. 2, the variation in the thermal conductivity of the fuel basket of aluminum alloy has a great influence on the cladding temperature. A 10% change of the thermal conductivity results in 0.5% for the peak temperature and 1% for the minimum temperature of cladding.

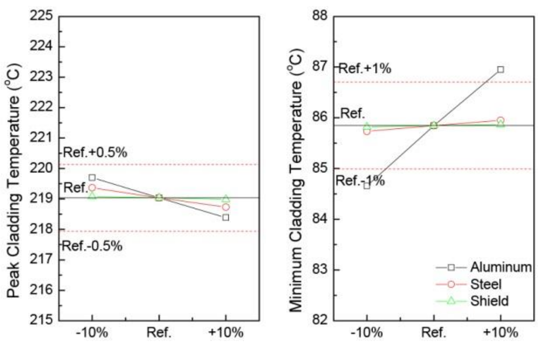

Fig. 2. Sensitivity for the thermal conductivity of slab materials.

3. Conclusions

The sensitivity on the peak and the minimum of fuel cladding surface temperature is evaluated with COBRA-SFS. For the fluid flow, the friction factor causes the variation of less than 3 ℃ for the minimum temperature and the effect of friction on the peak temperature is negligible. The form loss caused by flow area change is also negligible.

The properties of a backfill gas such as helium cause a difference of about 3%. In particular, it can reduce error by providing precise properties for thermal conductivity, enthalpy, and specific volume.

Although the thermal conductivity of the fuel basket connected by radiation heat transfer to fuel rod has the greatest effect, the difference is less than 1% for a change of 10%.

The sensitivity analysis about the energy exchange models, which is expected to cause major deviation is currently in progress.

ACKNOWLEDGEMENT

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