Thermal Expansion Analysis of Concrete Spent Nuclear Fuel Dry Storage Developed in Korea

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1. Introduction

SNF dry storage facility is temporary storage stage before the SNF is reprocessed or moved to final disposal facility. For that reason, the SNF has to be maintained in safe and retrievable in anytime. Concrete SNF dry storage component can be expanded when SNF is loaded because of decay heat of the SNF. In this paper it is evaluated how much SNF dry storage is expanded at the different conditions.

2. Thermal expansion evaluation

2.1 COMSOL MULTIPHYSICS program

COMSOL MULTIPHYSICS program is a simulation tool for electrical, mechanical, fluid flow and chemical analysis in complex natural phenomenon by using finite elements method.

2.2 Structure modeling and materials

To model the concrete SNF storage simply and calculate fast, major components which affect heat transfer and solid mechanics analysis significantly, are selected and modeled in two dimensionally.

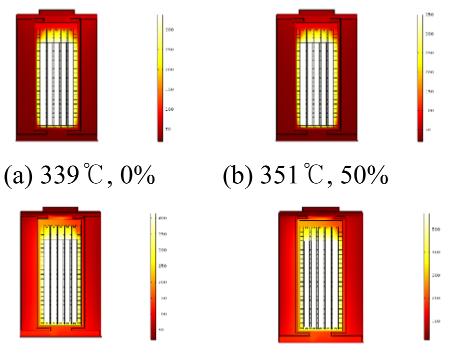
Several types of materials are adopted to consist of each components. Zircaloy-4 is used for Fuel assembly in the fuel basket. SA 240 type 304 stainless steel is used for fuel basket and disc. Canister shell consists of SA 240 type 316L. Lastly, concrete and carbon steel are used for concrete cask and liner. Because material properties change as temperature changes, material properties are adopted as functions of temperature.

2.3 Evaluation method

SNF peak temperature, already evaluated in Safety Analysis Report (SAR), is used as heat source. Heat distribution evaluation of dry storage is conducted in normal and off-normal (50% and 100% air inlet is blocked) conditions in two dimensional model. Thermal expansion evaluation is conducted by using the temperature from heat distribution evaluation.

2.4 Result and discussion

Fig. 1 and Table 1 are the result of heat distribution evaluation in two dimensional model. Surface temperature of canister shell is almost similar to heat distribution evaluation in SAR but surface temperatures at concrete and liner are lower than SAR.



(a) 339℃, 0% (b) 351℃, 50%

(c) 416℃, 100% (d) 570℃, 100%

Fig. 1. Heat distribution depending on fuel temperatures and percentage of blockage.

Table 1. Max. Temperature of components depending on fuel temperatures and percentage of blockage

(Unit: ℃)

	Blockage of air inlet	Adopted Fuel temp.	Canister shell	Liner	concrete
Normal condition	0 %	339	176.01	69.276	67.095
	0 %	400	205.14	78.081	75.609
Off-normal condition	50 %	351	184.44	55.817	52.893
	100 %	416	288.85	147.26	140.35
	100%	570	403.64	205.45	196.62

Table 2. Max. Displacement of canister shell based on heat distribution evaluation result

(Unit: mm)

	Blockage of air inlet	Adopted Fuel temp (℃)	Radial displace-ment	Axial displace-ment
Normal condition	0 %	339	2.643	5.2483
	0 %	400	3.6016	6.9406
Off-normal condition	50%	351	3.029	5.0813
	100%	416	6.1393	15.758
	100%	570	13.085	29.817

Fig. 2 and Table 2 are the result of thermal expansion evaluation. Displacements of most case are not severe in both radial and axial directions. However, when the air inlet is 100% blocked and SNF cladding temperature is 570℃, which is temperature limit in off-normal conditions, displacement of canister shell is 13.085 mm. Since the gap between canister shell and cask structure (T-channel) is 10 mm, the gap can be disappeared although fuel cladding temperature is less than limit.

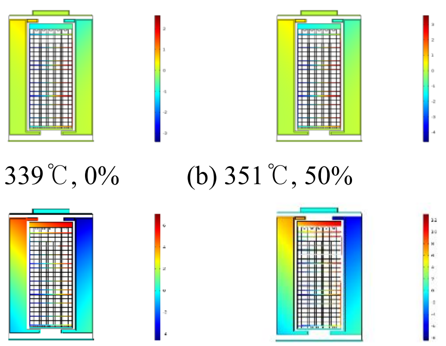


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Fig. 2. Thermal expansion evaluation depending on fuel temperatures and percentage of blockage.

3. Conclusion

According to evaluation result, it seems that canister shell cannot maintain retrievable condition in this off-normal condition. Therefore, thermal expansion effect needs to be considered in safety analysis importantly.

REFERENCES

[1] KORAD, "Concrete Storage System Thermal Safety Analysis Report", 14220-P1-N-TR030, 2013.