Fuel Integrity Evaluation During the Dry Storage by FRAPCON

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1. Introduction

Currently, it is needed to store spent nuclear fuels in dry condition(dry storage). During the dry storage, spent fuels have to meet regulatory requirement. Regulatory commission limits the cladding temperature to 400℃ for fuel with a burnup greater than 45 GWD/MTU. The 400℃ is set to prevent damage of the fuel rod cladding and the dry storage cask components related to high temperature. Also, it is important to analyze the hoop stress and determine if it remains below the 90 MPa for hydride reorientation in high-burnup fuel.

Recently, David j. Richmond[3] shows that the hoop stress may be related to the axial cladding temperature and oxidation profiles of the rods as well as the rod internal pressure at the end of life and in storage[3].

The aim of this paper is to predict spent fuel integrity evaluation such as the axial cladding temperature and the hoop stress in the dry storage.

2. Methods and Results

2.1 Analysis methods

FRAPCON-4.0 and COBRA-SFS were used. FRAPCON-4.0 is the fuel performance code in reactor and also calculates the peak cladding temperature in the dry storage though spent fuel module. To predict accurately the axial and peak cladding temperature in the dry storage, COBRA-SFS is used to reflect the geometry of dry storage cask. Westinghouse assembly (WH 15 ×15) and TN-24P dry cask were used. The major specifications provide in Table 1 and Table 2.

Table 1. WH 15 x 15 Major specifications

Description	Value
Cladding outer diameter	10.71 (mm)
Cladding thickness	0.62(mm)
Total (active) fuel length	3658 (mm)
Fuel U-235 enrichment	3.2 (a/o)
Cladding type	Zry-4

Table 2. TN-24P Major specifications

Description	Value
Cask outer diameter	2281(mm)
Cask length	5063(mm)
Loaded Weight	100(ton)
Basket length	4121(mm)
Basket material	Aluminum
Backfill	Helium

2.1.1 Cladding Temperature. The cladding temperature is calculated by COBRA-SFS with the burnup information which was calculated from FRAPCON-4.0. FRAPCON-4.0 can calculate the axial burnup distribution and the average burnup. The axial burnup distribution is the important factor to predict the axial cladding temperature because it depends on operation. So, FRAPCON-4.0 and COBRA-SFS were connected for calculation.

2.1.2 Hoop stress. In FRAPCON-4.0, The cladding hoop stress, σ, is calculated according to eq[1].

$$\sigma = \frac{r_i P_i - r_o P_O}{t} \quad (1)$$

The outer diameter of the cladding is changed along with cladding oxidation. It can reduce Zircaloy metal thickness. Ratio of a oxide thickness to Zircaloy metal consumption is 1.56. But, FRAPCON-4.0 uses multiplying related to ratio.

To calculate the hoop stress in dry storage, burned fuel information such as rod internal pressure, axial cladding temperature, hoop stress is used. It was calculated with ideal gas equation.

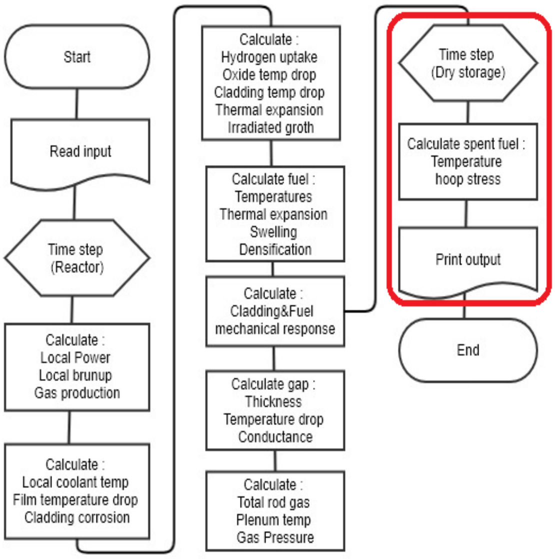

Fig. 1. Flowchart of analysis methods.

2.2 Results

Fig. 2 shows the peak cladding temperature at 53GWD/MTU. The peak cladding temperature decreased sharply before the storage time of about 40year. Fig.3 shows the axial cladding temperature. The axial temperature distribution depends on storage time. It is nearly uniform after 40year. Fig.4 shows axial hoop stress.

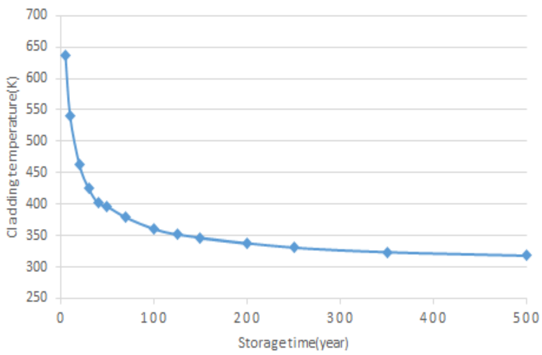

Fig. 2. Peak Cladding Temperature.

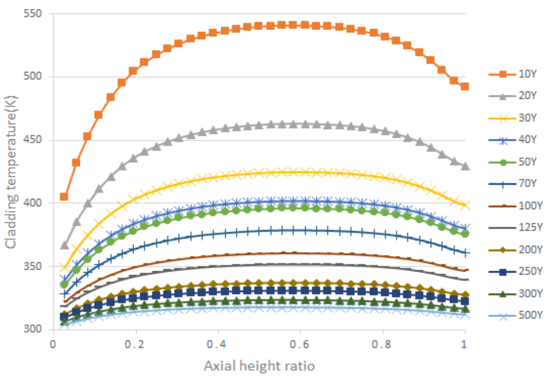

Fig. 3. Axial Cladding Temperature.

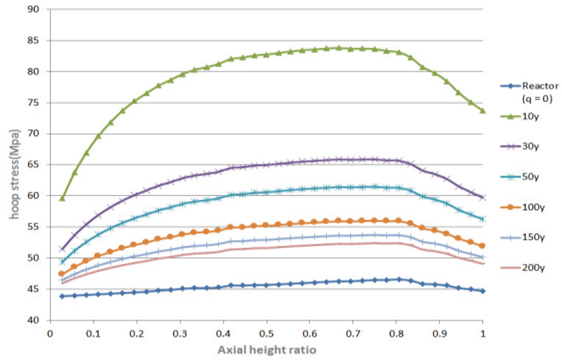

Fig. 4. Axial Hoop Stress.

3. Conclusion

To predict the cladding temperature and hoop stress of spent fuel is very important for integrity evaluation during the dry storage. The axial temperature and hoop stress during dry storage will give information such as the weakest location. If the locations of the maximum temperature and hoop stress are same, it will be weaker than other location.

REFERENCES

[1] FRAPCON-4.0: A Computer Code for the Calculation of Steady-State, Thermal-Mechanical Behavior of Oxide Fuel Rods for High Burnup.

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