Transactions, SMiRT-22
San Francisco, California, USA - August 18-23, 2013
Division IX

EFFECT OF UO_2 FUEL PELLET IRRADIATION ON FUEL CLADDING TEMPERATURE IN DRY STORAGE SYSTEM FOR USED FUEL ASSEMBLIES

Slava Guzeyev[1], Jayant Bondre[2], and Kamran Tavassoli[3]

[1] Principal Engineer, Transnuclear Inc, Columbia, MD
[2] Chief Operating Officer, Transnuclear Inc, Columbia, MD
[3] Manager of Thermal Analysis, Transnuclear Inc, Columbia, MD

ABSTRACT

Irradiation of UO_2 in fuel pellets reduces the thermal conductivity of irradiated used nuclear fuel. The dry shielded canister (DSC) for storage and transportation of used nuclear fuel includes fuel compartments containing fuel assemblies (FAs). The transverse FA effective thermal conductivity for irradiated FA is lower than for unirradiated FA. The transverse FA effective thermal conductivity of irradiated FA is used for the DSC thermal analysis to evaluate effect on maximum fuel cladding temperature. The effect of UO_2 irradiation on FA effective thermal properties and thermal analysis results for a DSC are evaluated based on AREVA/Transnuclear DSC loaded with 32 pressurized water reactor (PWR) Westinghouse 17x17 FAs and fuel compartment dimension of 8.7x8.7 inches.

INTRODUCTION

Used nuclear fuel is stored in dry storage system inside a dry shielded canister (DSC). Fuel cladding and DSC component temperatures are calculated to demonstrate that they are below the limits to assure safe storage of used fuel assemblies. For the Transnuclear NUHOMS® System the methodology used for calculation fuel cladding temperature is based on detailed finite element models and supported by test results.

This paper examines the effect of irradiated UO_2 thermal conductivity on the temperature of fuel assemblies that is stored in NUHOMS® storage system, which was analyzed before for unirradiated fuel assemblies.

The thermal analysis of a dry shielded canister (DSC) for used nuclear fuel is based on finite element model of DSC components and fuel assemblies (FAs) within fuel compartments. FAs are included in the DSC model as homogenized region. The FA effective thermal conductivity in transverse (radial) direction is calculated based on finite element FA model and uses thermal conductivity of UO_2 fuel. The FA effective thermal conductivity in axial direction conservatively neglects thermal conductivity of fuel inside FA fuel rods.

The irradiated UO_2 thermal conductivity is evaluated by Ronchi et al. (2004) for irradiation temperatures from 680 to 1490 K and burnups from 34 to 94 GWd/t. A review of Ronchi et al. (2004) results shows that the thermal conductivity of irradiated UO_2 drops significantly when burnups increase.

The unirradiated values are compared to interpolated irradiated UO_2 values from Ronchi et al. (2004) for 62 GWd/t FA average burnup. The comparison shown in Figure 1 indicates that the irradiated UO_2 thermal conductivities are 50-60 percent less than unirradiated UO_2 thermal conductivities for 62 GWd/t to 92 GWd/t FA average burnup. The Figure 1 includes unirradiated UO_2 thermal conductivity values calculated by approximation equation from Popov et al. (2000) based on analysis by Fink (1999) along with values from USNRC (2000) and USNRC (1981).

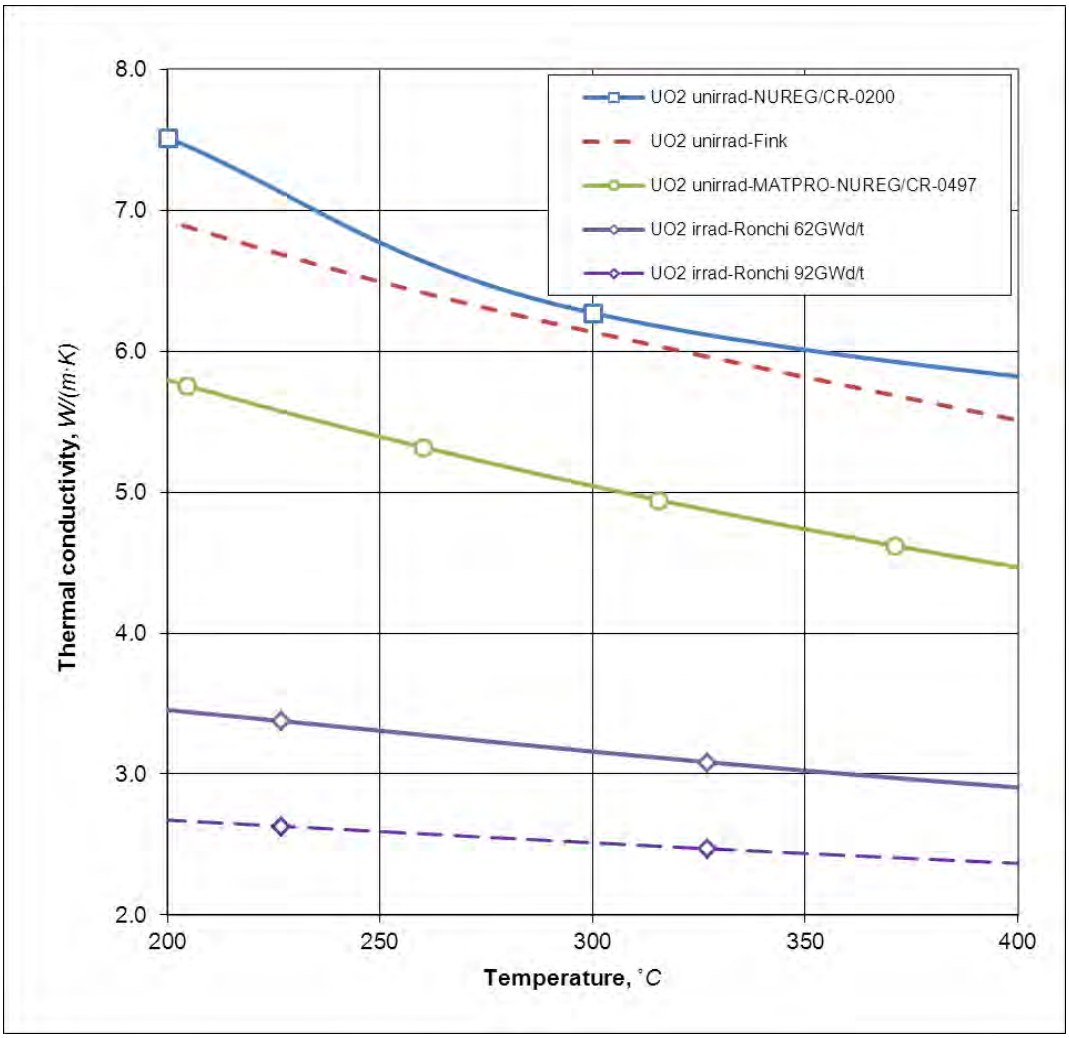


Figure 1. Unirratiated and Irradiated UO_2 Thermal Conductivity

The results provided in Figure 1 show that the USNRC (1981) provide more conservative thermal conductivity for unirradiated UO_2 fuel than USNRC (2000).

Effect of UO_2 irradiation on transverse FA effective thermal conductivity is evaluated based on an ANSYS® (2005) 2D finite element model for a Westinghouse 17x17 FA with helium backfill in compartment, using methodology described in Sanders et al. (1992).

For the comparison purpose, the effective thermal conductivity of Westinghouse 17x17 FA loaded in DSC is calculated using USNRC (1981) and Ronchi et al. (2004) UO_2 thermal conductivity values. The finite element FA model includes UO_2 pellet, fuel rods, guide tubes, other assembly components, backfill gas, and fuel compartment walls and considers conduction and radiation within the fuel compartment. Figure 2 shows a typical finite element model of Westinghouse 17x17 FA.

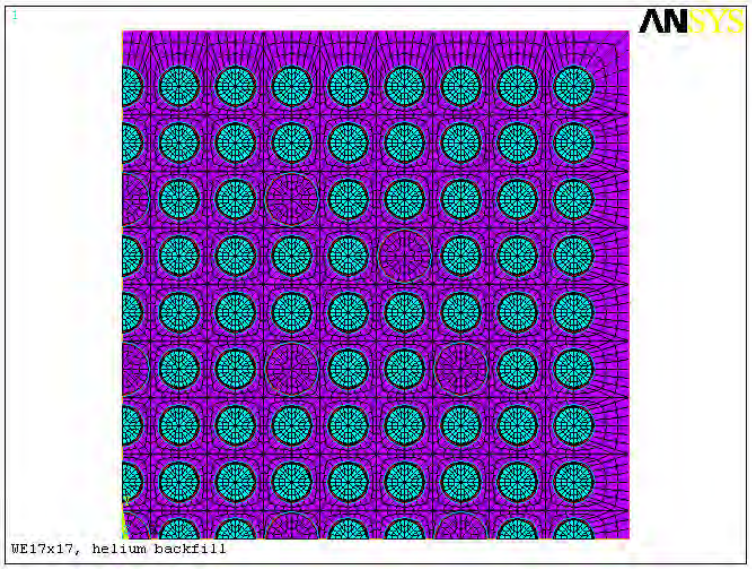


Figure 2. Typical Finite Element Model of Westinghouse 17x17 FA

The results of transverse FA effective thermal conductivity are shown in Figure 3.

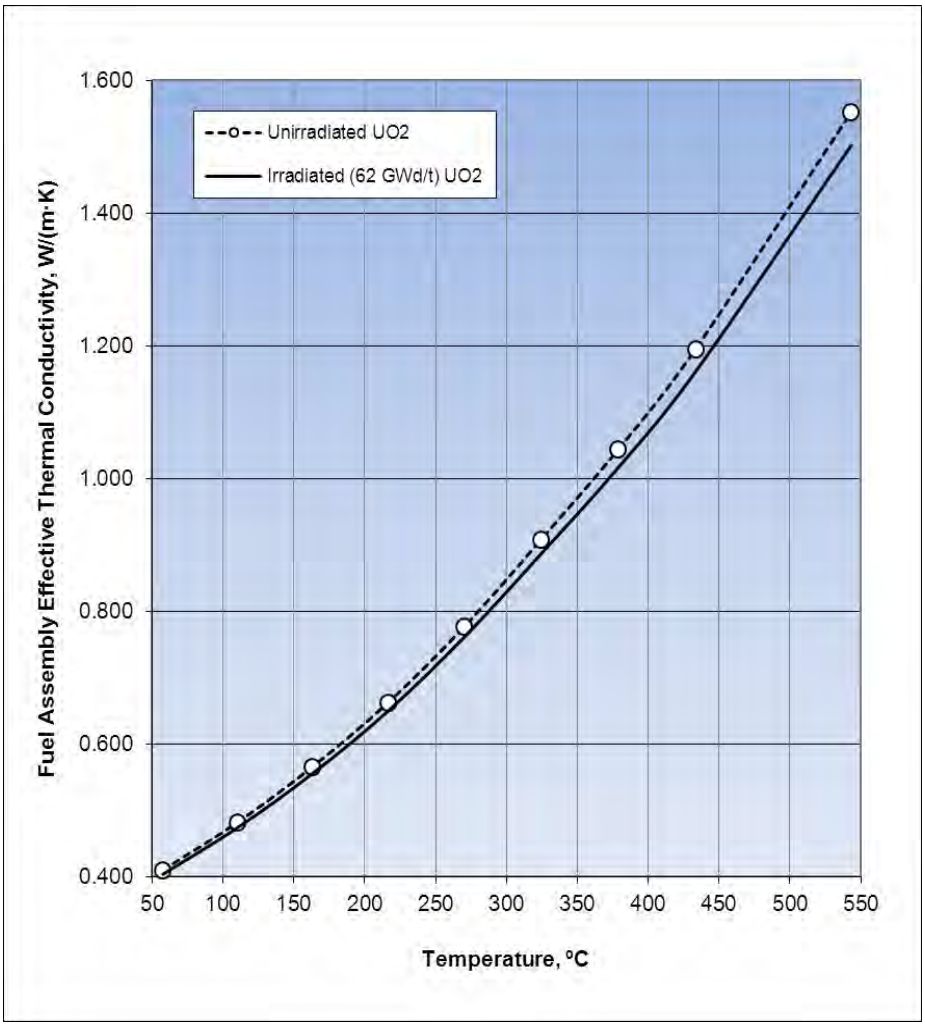


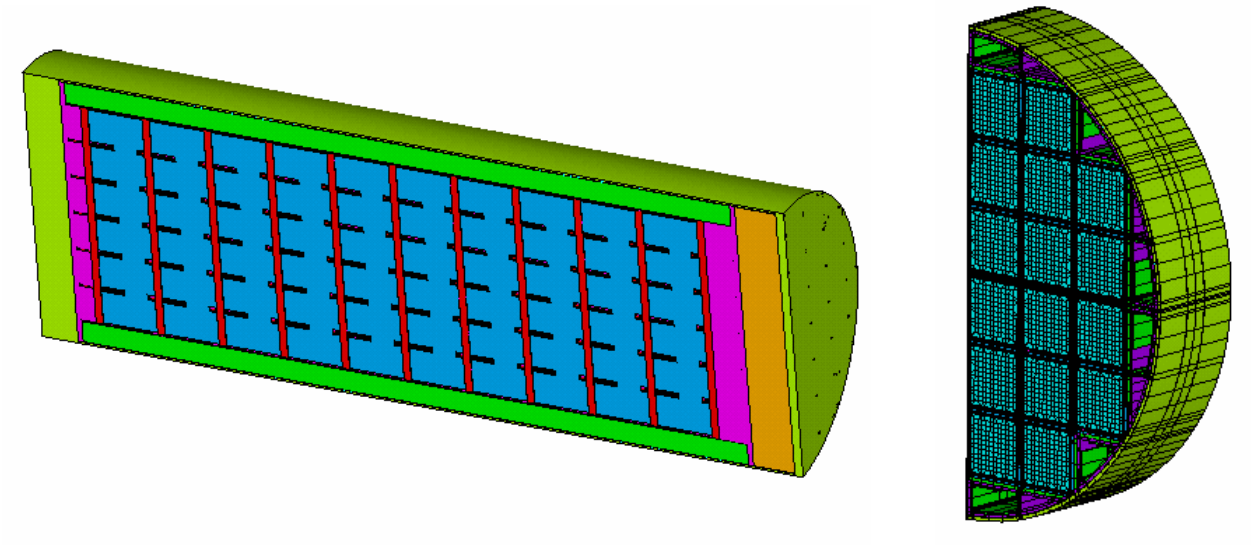
Figure 3. Transverse FA Effective Thermal Conductivity

As shown in Figure 3, the transverse FA effective thermal conductivity for irradiated UO_2 fuel is decreased by ~3 percent compared to unirradiated fuel.

An increase of FA average burnup to 92 GWd/t decreases the UO_2 fuel thermal conductivity by additional 10 percent compared to 62 GWd/t FA average burnup and results in a negligible drop in FA effective thermal conductivity.

As a part of fuel assembly, UO_2 fuel pellet property affects fuel cladding and DSC component temperatures.

Effect of UO_2 fuel irradiation on thermal analysis of dry shielded canister (DSC) is evaluated using an ANSYS 3D finite element model of DSC for transfer condition in a transfer cask with 46˚C ambient temperature. DSC model includes fuel assembly as homogenized regions within fuel compartment with FA effective thermal conductivity. See Figure 4 for finite element model of the DSC.



DSC model DSC slice cross-section

Figure 4. Finite Element Model of 32PTH DSC

The analysis results shows that maximum fuel cladding and fuel compartment temperatures considering irradiated UO_2 fuel conductivity are 1˚F higher than values for unirradiated UO_2 fuel, which is negligible (0.16 percent). This result has negligible change with an increase of FA average burnup from 62 GWd/t to 92 GWd/t due to its negligible effect on FA effective conductivity.

Note that axial FA effective thermal conductivity is conservatively based on the fuel cladding material only and does not include the UO_2 fuel pellet thermal conductivity. Therefore, the axial effective conductivity is not impacted.

The effect of UO_2 irradiation on FA effective thermal conductivity and DSC thermal results for storage in a generic NUHOMS® DSC design with Westinghouse 17x17 FA is insignificant.

For engineering design of a storage/transportation system with 32 PWR FAs in DSC with a fuel compartment dimension of 8.7x8.7 inches, the UO_2 fuel irradiation has negligible effect on the fuel cladding temperature and the DSC component temperatures.

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