BURN UP AND FLUX PROFILE DEPENDENT TEMPERATURE DISTRIBUTION IN THORIA PELLET

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INTRODUCTION

Use of thorium fuel in a power reactor requires addition of fissile materials that can be in the form of enriched uranium (U-235) oxide, plutonium (Pu-239) oxide or uranium (U-233) oxide from reprocessing of irradiated thorium fuel. [Herring et al, 2001] indicated that mixed ThO2(65w%)-UO2(35w%) fuel with 6 wt% enrichment of U-235 can achieve a burnup of 72 GWd/t. [Loewen et al., 2002] showed that fuel fabricated from ThO2-UO2 mixtures can reach an average discharge burnup of up to 70 GWd/t. [Lemehov, et al., 2003] has developed thermal conductivity models for oxide fuels such as UO2, ThO2, AmO2, Am2O3 and CM2O3 fuel material. In this study, the temperature dependent thermal conductivity profiles of Thoria fuel for various burnup values such as 20 GWd/t, 40 GWd/t and 60 GWd/t are analysed using multiphysics software COMSOL. The temperature margins that is the difference between the central line temperature and the melting point for thorium fuel have been calculated for different burnups and LHRs.

CALCULATION METHODOLOGY

The spatial distribution volumetric heat generation rate based on the flux shape is given in the equation 1 [Bera and Anuj, 2012].

$$q^f(r) = \frac{\chi}{\pi R^2} \left( 1 + \frac{a}{R} + \frac{b}{R^2} \right)$$

where $\chi$ is linear heat rate; R is the pellet radius, $r$ is the radial point where calculation is to be carried out; a and b are the flux shape constants which vary with enrichment. For an enrichment of 5%, the value of ‘a’ and ‘b’ are -0.007 and 0.7 [Bera and Anuj, 2012]. Fuel pellet is modeled using multiphysics software COMSOL. The variation of thermal conductivity with respect to the temperature for various burnup of thorium pellet [Lemehov, et al., 2003] has been shown in the Figure 1. From Figure 1, it can be observed that the thermal conductivity for a burnup corresponding to 60 GWd/t is almost 25 % as compared to the unirradiated fuel.

![Figure 1. Variation of thermal conductivity of thoria for different burnup](image1.jpg)

![Figure 2. Temperature distribution in unirradiated ThO2 pellet (350 W/cm), K](image2.jpg)
RESULTS AND DISCUSSIONS

A diameter of 10 mm has been selected for fuel pellet. The spatial distribution of temperature across the unirradiated thoria pellet for the volumetric heat generation as given in the equation 1 with \( \chi \) equal to 350 W/cm and fuel surface temperature of 400 K, has been depicted in the Figure 2. The temperature distribution of unirradiated thoria pellet has been compared with irradiated fuel in the Figure 3 for two cases- first for uniform heat generation case and second for non-uniform case. From Figure 3, it is observed that the centerline temperature increases as the burnup increases. It is also observed from Figure 3 that assumption of uniform heat generation predicts the centerline temperature conservatively. The centerline temperature for unirradiated thoria is around 833 K and 804 K for uniform and non-uniform heat generation respectively, however, it is around 1423 K and 1367 K for the fuel having seen a burnup of 60 GWd/t which means that the uniform heat generation assumption predicts the temperature higher by 56 K. Figure 4 compares the temperature across the pellet (60 MWd/t) for different Linear Heat Rating (LHR). The change in centerline temperature is to be observed for the uniform and non-uniform heat generation cases.

CONCLUSIONS

In a thermal reactor, the thermal neutron flux profile is depressed in the central region of the fuel pellet and hence, the heat generation is non-uniform across the pellet. In this work, the effect of assumption of uniform and non-uniform heat generation in thoria pellet has been studied at different burnup using multiphysics software COMSOL. It is observed that uniform heat generation assumption predicts the temperature higher by 56 K in comparison to non-uniform heat generation for a pellet corresponding to 60 GWd/t.

REFERENCES


