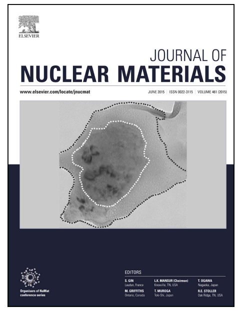

Development of effective thermal conductivity model for particle-type nuclear fuels randomly distributed in a matrix

Maolong Liu, Youho Lee, Dasari V. Rao

PII: S0022-3115(17)31850-0

DOI: 10.1016/j.jnucmat.2018.05.044

Reference: NUMA 50974

To appear in: *Journal of Nuclear Materials*

Received Date: 15 January 2018

Revised Date: 16 May 2018

Accepted Date: 17 May 2018

Development of Effective Thermal Conductivity Model for Particle-Type Nuclear Fuels Randomly Distributed in a Matrix

Maolong Liu[1], Youho Lee[1*], Dasari V. Rao[2]

[1]The University of New Mexico, 1 University of New Mexico, Albuquerque, NM 87131, USA

[2]Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, New Mexico 87545

Abstract

Several advance nuclear reactors use particle-type Tristructural-Isotropic (TRISO) fuels randomly distributed in a matrix to allow aggressive operating conditions. Since those fuels are composites with randomly distributed TRISO particles in a matrix, suitable smearing methods are needed to obtain effective pellet-level thermomechanical properties for reactor design, and safety analysis. Currently available smearing methods for effective thermal conductivity assume uniform or no heat generation, thereby neglecting the random heat source distribution. By developing three-dimensional finite-element heat conduction models for randomly distributed heat generating kernels in a matrix, this study demonstrates that the consideration of a randomly distributed heat source is important in predicting the peak fuel temperature. In this study, (1) random packing of heat generating fuel particles introduces the statistical distribution of peak and average temperatures, and (2) those statistical temperature distributions are quantified. In light of this, thermal conductivity models with randomly distributed heat generating kernels are developed to predict peak pellet temperature for Fully Ceramic Microencapsulated (FCM) fuel and Cermet fuel for space propulsion. The developed methodology and models provide a practical methodology to predict statistically-informed peak and average fuel temperatures of nuclear fuel pellets of heat generating particles. The presented methodology is useful to quantify uncertainties in predicting nuclear fuel temperatures with TRISO particles.

1. Introduction

The Tristructural-isotropic (TRISO) fuels dispersed in a matrix are considered promising nuclear fuel candidates for several advanced reactors due to their unmatched high temperature tolerance and suitability for high burnup operations [1]. Today, several advanced reactor candidates – Fluoride-salt-cooled High-temperature Reactors (FHRs), Very High Temperature Reactor (VHTR), Fully Ceramic Microencapsulated (FCM) of Light Water Reactors (LWRs), and space propulsion reactors – are adopting TRISO fuel concepts to allow for aggressive operating conditions, economic benefits, and improved safety [2-9].

After the Fukushima accident, the recent achievements on TRISO fuel development have triggered interest to utilize TRISO fuel in LWRs or in Small Modular Reactors (SMRs) due to its superior oxidation resistance and fission product retention capabilities [10]. Oak Ridge National Laboratory (ORNL) and Ultra Safe Nuclear Corporation (USNC) proposed a TRISO-based FCM fuel concept as a potential replacement for current UO_2 fuel pellets of LWR nuclear fuel rods [8, 9]. In the FCM concept, the TRISO particles are embedded in a silicon carbide (SiC) matrix [11]. It is one of the accident-tolerant fuel concepts with potential enhancement on the proliferation resistance [11]. Ceramic metallic (cermet) fuel for space nuclear reactor system is another fuel type

*Corresponding Author.
E-mail: euo@unm.edu