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Numerical calculation for estimating anisotropic elastic modulus of UO_2 - 3 vol.% Mo microplate pellet

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1. Introduction

Mitigating the steep temperature gradient of the nuclear fuel to improve reactor core safety is one of the important factors [1]. Therefore, to improve low thermal conductivity of UO_2 pellet, high thermal conductive materials such as metal Mo and Cr have been considered as additives [2,3]. In particular, the increase of the radial thermal conductivity of the nuclear fuel could satisfy these requirements [4,5]. UO_2 – Mo microplate pellets in which the plate shape Mo particles were placed radially were successfully manufactured, and the central temperature of a nuclear fuel pellet could be effectively reduced by improving the thermal conductivity in a radial direction 47% compared to UO_2 pellet at 1,000°C in an ideal case in which a Mo microplates were arranged in an in-plane [5]. The effective thermal conductivity of the UO_2 – Mo microplate pellet was depended on the Mo plate shape factor, which is a ratio of thickness to diameter. Specifically, first, as the shape factor of the Mo microplate increases, the effective thermal conductivity was shown logarithmically increases. Second, in the same shape factor, the thermal conductivity was independent regardless of particle size. In particular, the UO_2 – Mo microplate pellet was shown anisotropic thermal conductivity according to the heat flow direction, because radial thermal resistance more decreased then axial it by Mo particle shape. In order words, plate shape Mo particle could affect to effective properties in UO_2 – Mo microplate pellets. Therefore, it is necessary to confirm the anisotropic properties of UO_2 – Mo microplate due to the addition of Mo plate particle. In this study, the effective elastic modulus of UO_2 – 3 vol.% Mo microplate pellet was calculated through numerical calculation for radial and axial directions by employing strain energy.

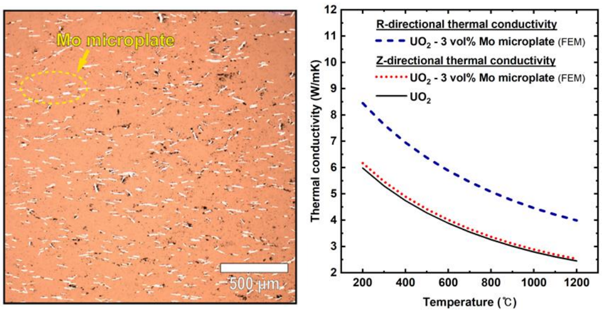

Fig. 1. Optical microscope image of UO_2 – 3vol.% Mo microplate pellet (left) and calculated effective thermal conductivities of UO_2 – 3 vol.% Mo microplate pellets (right) [5].

2. 3D cubic model of UO_2 – Mo microplate pellet

To calculate the elastic modulus of the UO_2 – 3 vol.% Mo microplate pellet, a three-dimensional cubic model having eight Mo microplates with a shape factor of 30 was designed. It was assumed that the interface between Mo and UO_2 was perfect, and the properties of Mo and UO_2 were applied as a function according to temperature. The uniaxial tensile force uniformly distributed in surface was employed at one side and the opposite side, and the R and Z direction was conducted respectively (Figure 3). The remaining surfaces of cubic model was set as free condition, and the numerical simulation was conducted in the range of room temperature to 600K. The elastic modulus was determined using the strain energy density, and the equation was as follows (Eq (1)).

$$E = \frac{\sigma^2}{2u} \quad (1)$$

, where E is elastic modulus (Pa), σ is uniaxial stress (Pa), and u is strain energy density (J/m^3).

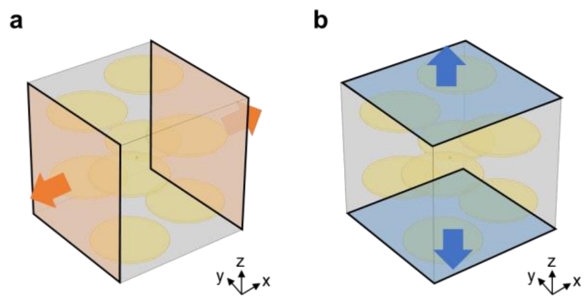

Fig. 2. Boundary condition for calculating (a) radial elastic modulus and (b) axial elastic modulus of UO_2 – 3 vol.% Mo microplate pellets.

3. Result and discussion

The numerical calculation results were shown in Figure 3. The radial elastic modulus of the UO_2 – 3 vol.% Mo microplate pellet was maximum 1.5% higher than UO_2 pellet. Specifically, the elastic modulus had average 0.3% higher in the radial direction than in the axial direction due to the shape of Mo particle, which has a higher elastic modulus than UO_2. However, the elastic modulus between radial and axial didn't shown significant anisotropy such as thermal conductivity because of the low Mo plate content. Furthermore, due to this low relative error, the anisotropic elastic modulus of the UO_2 – 3 vol.% Mo microplate pellet would be difficult to confirm by experimental measurement.

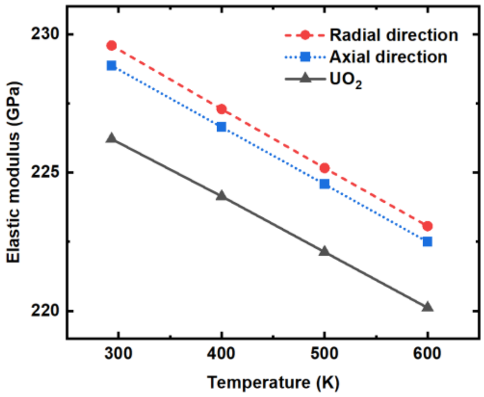

Fig. 3. Elastic modulus of UO_2 – 3 vol.% Mo microplate pellets according to direction.

4. Conclusions

The elastic modulus of the UO_2 – 3 vol.% Mo microplate pellet which has been developed to improve the thermal conductivity in the radial direction of nuclear fuel was confirmed through numerical calculation. Although, in the UO_2 – 3 vol.% Mo microplate pellet, the anisotropic elastic modulus was present due to the shape of Mo particle, but the additive Mo content was low, thereby it will appear similar to isotropic elastic behavior. However, anisotropy of elastic modulus may be increased according to the shape ratio and the amount of additive Mo content to be employed.

ACKNOWLEDGMENT

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