

## Numerical Calculation of $\text{UO}_2 - 3 \text{ vol}\% \text{ Mo}$ Microplate Fuel Pellet for Enhancing Radial Thermal Conductivity

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### 1. Introduction

To improve fuel pellet structure stability, various researches of reducing fuel pellet central temperature were conducted by increasing pellet thermal conductivity [1-3]. Molybdenum as additive in fuel pellet is noticed that has high thermal conductivity, high melting temperature [4,5]. In order to effectively reduce the central temperature of the fuel pellets, radial direction thermal conductivity need to enhance [6]. Recently,  $\text{UO}_2 - 3 \text{ vol}\% \text{ Mo}$  microplate fuel pellet with Mo microplates arranged to radial direction was reported [7].

The effective thermal conductivity of  $\text{UO}_2 - 3 \text{ vol}\% \text{ Mo}$  microplate pellets is expected to depending on the arrangement of Mo microplate in pellets. Therefore, in this study, the Simulation model is developed for calculating the effective thermal conductivity of  $\text{UO}_2 - \text{Mo}$  microplate fuel pellet and compare the results with theoretical models.

### 2. Numerical model

Fig. 1a shows the  $\text{UO}_2 - 3 \text{ vol}\% \text{ Mo}$  microplate pellets was successfully fabricated by conventional sintering methods [7]. The Mo microplates was well arranged to radial direction and the aspect ratio of thickness over diameter was about 30. To calculate effective thermal conductivities of the composite pellets, simplified numerical model was designed (Fig. 1b). In the model, Mo microplates was arranged equally spaced and the boundary condition were set at constant temperature on left and right side, and the others were insulation condition. The effective thermal conductivity was calculated by Fourier's law of conduction (eq (1)).

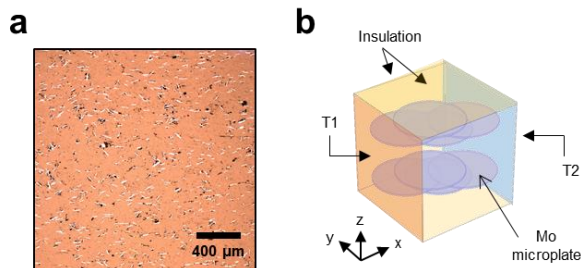


Fig. 1. (a) Optical cross section image of fabricated  $\text{UO}_2 - 3 \text{ vol}\% \text{ Mo}$  microplate pellet. (b) Thermal boundary condition of numerical calculation model.

$$q'' = -k_{eff} \frac{T1-T2}{L} \quad (1)$$

, where  $q''$  is the heat flux ( $\text{W}/\text{m}^2$ ),  $L$  is numerical model domain length (m), and  $T1$  and  $T2$  are fixed temperature (K).

### 3. Validation of numerical model

In fig. 2, the effective thermal conductivity of  $\text{UO}_2 - 3 \text{ vol}\% \text{ Mo}$  microplate pellet was investigated in range of  $400^\circ\text{C}$  to  $1200^\circ\text{C}$ . The average radial thermal conductivity of  $\text{UO}_2 - 3 \text{ vol}\% \text{ Mo}$  microplate pellet in the temperature range investigated was increased by 55% compared to the  $\text{UO}_2$  pellet. In addition, the calculated results were within the Hashin-Shtrikman bound that could predict the thermal conductivity of the composite materials. In order to determine the more accurate validity of the calculated results, the results were compared to Hatta-Taya model, which could predict the effective thermal conductivity of composite materials with mixed penny shape particles. Hatta-Taya model is proper for comparison to this calculation model due to identical assumptions that the particles in the penny shape are uniformly distributed and aligned in the same direction.

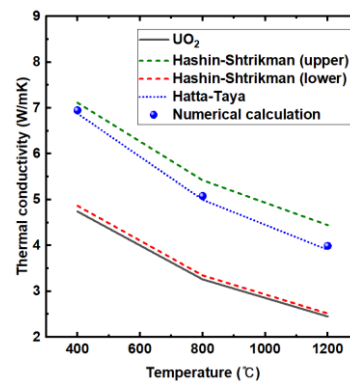


Fig. 2. Effective thermal conductivities of  $\text{UO}_2 - 3 \text{ vol}\% \text{ Mo}$  microplate pellet

Figure 3 shows the effective thermal conductivity in terms of aspect ratio of Mo microplate at  $1000^\circ\text{C}$ . In constant Mo content and same Mo microplate diameter, the effective thermal conductivity was increased as decreased Mo microplate thickness, and this tendency was also shown in Hatta-Taya model. This result is because when the diameter of Mo microplate is constant,

the Mo content should be maintained as the thickness decreases, so the length of the numerical model decreases and the total thermal resistance reduces. Consequently, there is more effective to increase radial thermal conductivity in applying high aspect ratio of Mo microplate.

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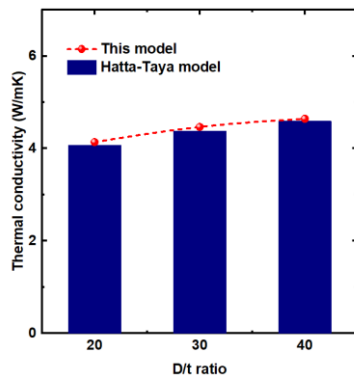


Fig. 3. Effects on aspect ratio of Mo microplate at same 3 vol% Mo content.

#### 4. Conclusion

We designed and validated the numerical calculation model of UO<sub>2</sub> – 3 vol% Mo microplate pellet for evaluating effective thermal conductivities. The results were well matched with the values of Hatta-Taya model. The geometric effects on effective thermal conductivity of Mo microplate such as microplate shapes and arrangement in UO<sub>2</sub> – 3 vol% Mo microplate fuel pellet will be possible to evaluate through our designed numerical model.

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