Thermal Conductivity Modeling of U-TRU-RE-Zr Metal Fuel for PGSFR

Byoung Oon Lee*, Chan Bock Lee, June Hyung Kim, Jin Sik Cheon, Jeong Yong Park, and Sung Ho Kim
Korea Atomic Energy Research Institute, 111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, Republic of Korea
*bolee@kaeri.re.kr

1. Introduction

The U-TRU-Zr metal fuel for PGSFR (Prototype Gen-IV Sodium-cooled Fast Reactor) is being developed in combination with the pyro-processing. Since RE (Rare Earth) and MA (Minor Actinide) will be included in the metal fuel, the behavior of RE and MA in the metal fuel is needed to be evaluated. In this paper, the thermal conductivity model of U-TRU-RE-Zr was developed based on the theory of two phase solid bodies using the existing thermal conductivity model of U-Pu-Zr alloy, the available data in the literature and the thermal conductivity theories of the solid solution.

2. Thermal conductivity model

2.1 Thermal conductivity model of the two phase solid bodies

RE and some MA (such as Am and Cm) are precipitated in the U-Pu-Zr matrix. The effect of the precipitates on the unirradiated thermal conductivity for U-TRU-RE-Zr was evaluated based on the Bruggeman model [1]. The thermal conductivity of U-PU-Zr alloy fuel is based on the model by Billone [2].

Fig. 1 compares the calculated thermal conductivities for U-19Pu-10Zr-(MA-RE) using the Billone and Bruggeman models with the data measured in METAPHIX [3].

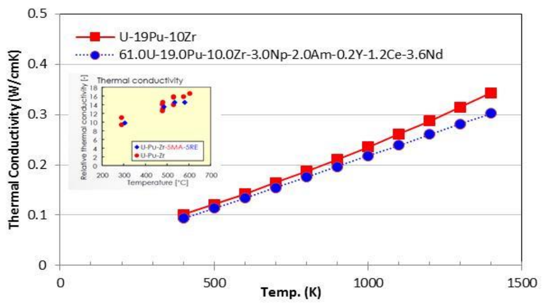

Fig. 1. Calculated and measured thermal conductivity for U-19Pu-(MA-RE)-Zr.

According to the METAPHIX results, the thermal conductivity decreases by about 10% when containing 5wt% MA and 5wt% RE. Bruggeman's model also predicts about 10% reduction of the thermal conductivity. So it is estimated that Bruggeman's model has a good capability for predicting the thermal conductivity of U-TRU-RE-Zr.

2.2 Adjusted thermal conductivity model of U-Pu-Zr alloy

As shown in Fig. 2, Billone's model shows a very low thermal conductivity value according to Pu or Zr contents. So, the U-Pu-Zr thermal conductivity model is needed to be adjusted for the case where the Zr or Pu content is greatly increased in the fuel.

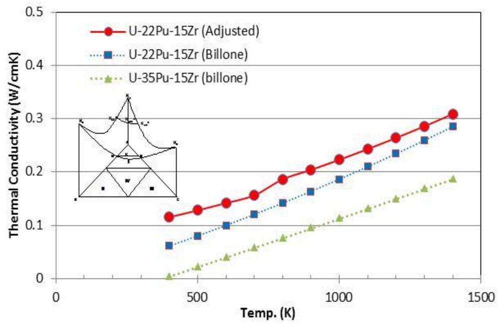

Fig. 2. U-Pu-Zr thermal conductivity comparison.

The ternary solid solution theory by Zarichnyak [4] was applied for the development of U-Pu-Zr alloy thermal conductivity.

Fig. 2 also shows the comparison of thermal conductivities. It was estimated that the value by Zarichnyak's model is higher than that of Billone's model for the higher Zr contents.

2.3 Thermal Conductivity of U-TRU-RE-Zr

U-TRU-RE-Zr thermal conductivities based on the Bruggeman's model were calculated using the adjusted U-Pu-Zr model as well as Billone's model. Fig. 3 shows the comparison the measured data [5] with the calculated thermal conductivities.

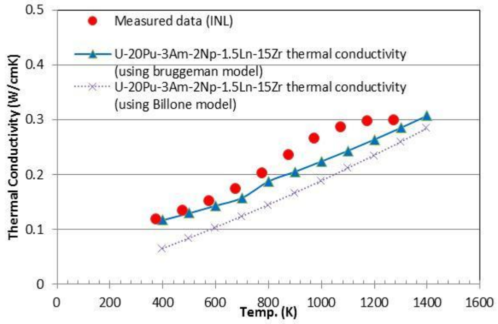

Fig. 3. Calculated and measured thermal conductivity for U-TRU-RE-Zr.

Even though the thermal conductivity model in this paper is likely to be conservative, it is estimated that the prediction by the adjusted model has a reasonable capability.

3. Conclusion

The thermal conductivity model of U-TRU-RE-Zr for PGSFR was developed and compared with the measured data. Even though more experimental data are needed, the developed models have a good capability to calculate the thermal conductivity. This work forms the basis for the establishment of key technology that will evaluate the performance of U-TRU-RE-Zr metal fuel.

ACKNOWLEDGEMENT

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