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Analysis of Thermal Conductivity Models for Performance Evaluation of TRU Metallic Fuels

Cheol Min Lee[a*], June-Hyung Kim[a], Ju-Seong Kim[a], Byoung-Oon Lee[a], Heung Soo Lee[a], Jin-Sik Cheon[a], Chan-Bock Lee[a],
[a]*Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon 34057, Republic of Korea*
[*]*Corresponding author: cmlee@kaeri.re.kr*

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1. Introduction

Against the backdrop of impending saturation in interim storage capacity for spent nuclear fuel within nuclear power plants, policy deliberations surrounding its management have risen to paramount significance at both national and societal levels. To mitigate the toxicity of spent nuclear fuel, the imperative incineration of Transuranic (TRU) elements, which constitute the primary hazardous components, emerges as a pivotal requirement.

The preliminary validation of the TRU nuclear fuel performance analysis code has extended the operational scope of the metallic fuel performance analysis code. This expansion encompasses the transition from the established uranium (U) fuel application to that of TRU fuel, thereby enriching the comprehensiveness of the nuclear fuel performance assessment.

In this study, various thermal conductivity models for U-TRU-Zr metallic fuels were analyzed by comparing them with the thermal conductivity measured data of TRU metallic fuels. Based on this analysis, an optimal thermal conductivity model was identified and subsequently incorporated into the metallic fuel performance analysis code "LIFE-METAL". By utilizing several irradiation histories of TRU metallic fuels, fuel performance analyses were conducted, and the outcomes of the analyses were compared with the results from post-irradiation examination (PIE). Based on this comparison, the thermal conductivity model was revised to incorporate irradiation effects.

2. Evaluation of Thermal Conductivity Models

Thermal conductivity models for U-TRU-Zr metallic fuels were evaluated by comparing them with various measured data (U-10Zr, U-20Zr, U-30Zr, U-40Zr, U-50Zr, U-79Zr, U-10Pu, U-15Pu-10Zr, U-18.4Pu-14.1Zr, U-40Pu-10Fz, U-25TRU-15Zr, U-35TRu-30Zr) [1-8]. Several important results from these comparisons are shown below.

As illustrated in Fig. 1 and Fig. 2, thermal conductivity models were in agreement with the U-Zr measured data. However, the thermal conductivity models of T. Ogata and M. C. Billone overpredicted when the zirconium concentration is higher than 40 and 50, respectively.

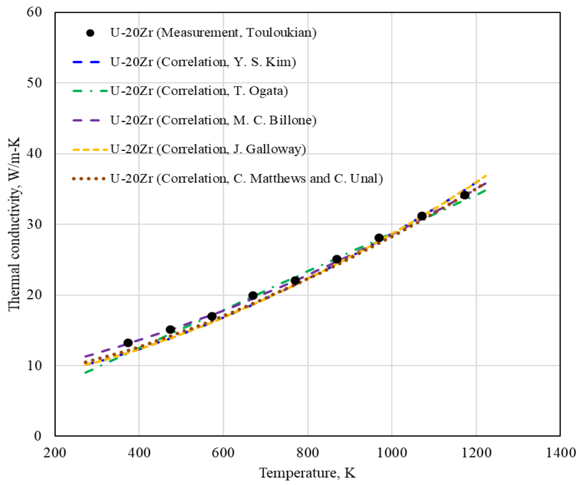

Fig. 1. Comparison between predictions of thermal conductivity models and measured data for U-20Zr.

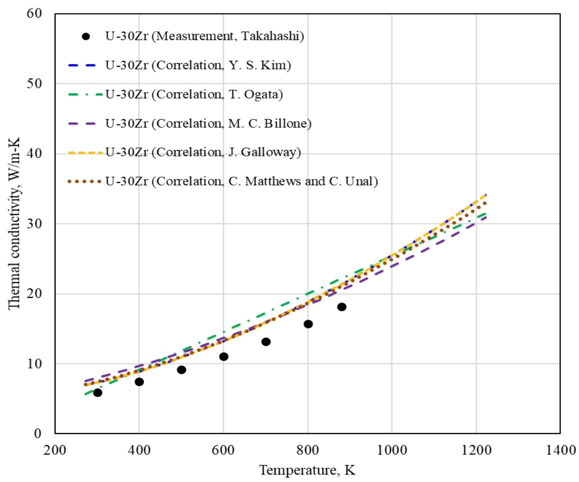

Fig. 2. Comparison between predictions of thermal conductivity models and measured data for U-30Zr.

In Fig. 3 and Fig. 4, thermal conductivity models were evaluated by comparing them with the measured data of TRU metallic fuels. We found that the correlation from Y. S. Kim aligns well with the measured data, and the model was integrated into the fuel performance analysis code "LIFE-METAL".

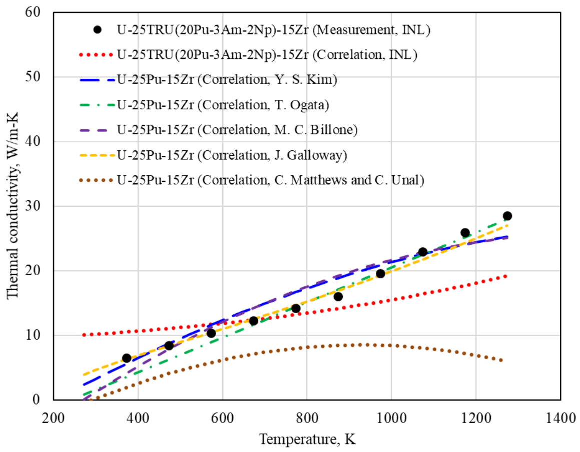

Fig. 3. Comparison between predictions of thermal conductivity models and measured data from AFC-A1.

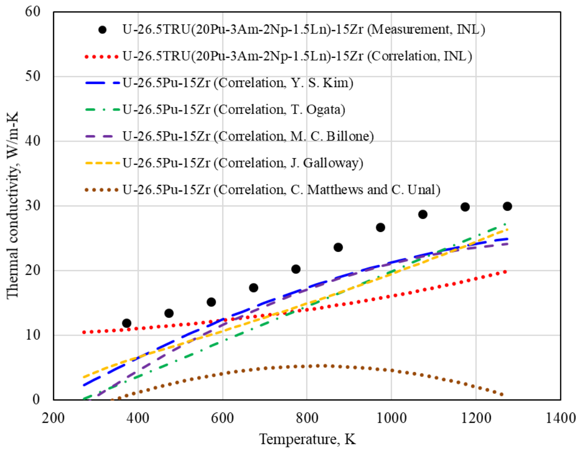

Fig. 4. Comparison between predictions of thermal conductivity models and measured data from AFC-A3

3. Fuel Performance Analysis

Temperatures of fuels during irradiation tests of X419 T179, X441A DP16, X501, Metaphix #1, Metaphix #2, and AFC-1H were evaluated, and the fuel performance analysis results were compared with the PIE results. The predicted fuel temperatures from the fuel performance code overpredicted when compared to the PIE results. We speculated that irradiation had some effect on the thermal conductivity of the fuels, and this irradiation effect was incorporated by implementing irradiation factors. As demonstrated in Fig. 5, after the revision, the temperature prediction from the fuel performance analysis code agreed well with the PIE results.

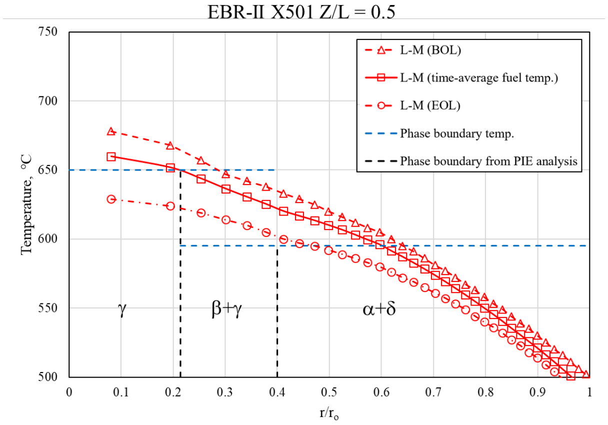

Fig. 5. Comparison between fuel performance analysis of X501 and PIE results.

4. Conclusions

Various thermal conductivity models for U-TRU-Zr metallic fuels were analyzed by comparing them with the thermal conductivity measured data of TRU metallic fuels. Based on the analysis, we determined that the correlation from Y. S. Kim agrees well with the measured data, and it was implemented in the fuel performance analysis code "LIFE-METAL". Subsequently, by utilizing several irradiation histories of TRU metallic fuels, fuel performance analyses were conducted, and the outcomes of the analyses were compared with the results from post-irradiation examination (PIE). It was found that the fuel performance code overpredicted when compared to the PIE results, hence the thermal conductivity model was revised to incorporate irradiation effects. After all, the revised fuel performance analysis code showed good agreement with the PIE results.

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