

## Preservation of Fuel Characteristics in the RPT Method

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### INTRODUCTION

Double-heterogeneity has been a challenge for a long time in the core design and analysis of the high-temperature reactors using the TRISO particle fuels.

Recently, a fundamentally different methodology has been proposed to handle the double-heterogeneity, the Reactivity-equivalent Physical Transformation (RPT) method.[1,2] In the RPT method, the original double-heterogeneous problem is transformed to a conventional single-heterogeneous one: fuel particles are dispersed in a smaller fuel zone with a higher packing fraction and the new fuel region is simply smeared. It is important to reduce the surface area of the new fuel zone. (See Fig. 1) The fuel radius (RPT radius) is determined such that the neutron multiplication factor is equivalent to the reference value. By using the RPT method, the complex double-heterogeneous problem can be easily analyzed with the well-matured conventional methodologies.

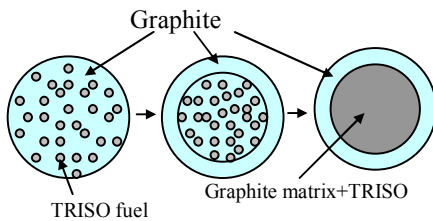


Fig. 1. The RPT concept.

In the previous paper, it has been shown that the RPT method works very well in the estimation of the reactivity and power distribution[1,2]. In this paper, the RPT method is further investigated from some microscopic view points.

### DESCRIPTION OF MODEL PROBLEM

As a model problem, a hexagonal unit cell is considered, which is shown in Fig. 2. The  $UO_2$  kernel diameter of the TRISO is  $350\mu m$  and coating thicknesses are as follows: buffer= $100\mu m$ , inner PyC= $35\mu m$ , SiC= $35\mu m$ , outer PyC= $35\mu m$ . The fuel packing fraction is 29% and the uranium enrichment is 10wt%. A helium gap of 0.0125 is also modeled between fuel compact and graphite block. All neutronic calculations are performed with the DRAGON[3] code, which can handle the double-heterogeneity with some limitations.

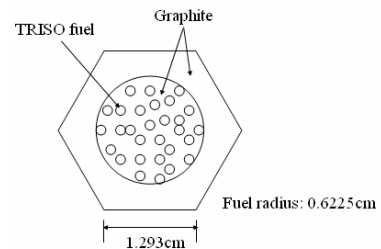


Fig. 2. Configuration of the Unit cell problem.

### SIMILARITY IN FINE-GROUP CROSS SECTIONS

The reference solution has been obtained by DRAGON and the RPT solution is compared with the reference one. For a comparison, the simple VWH (volume weighted homogenization) approach is also evaluated. The reference reactivity from DRAGON is used to determine the RPT radius. In the VWH method, the fuel zone is simply homogenized in a volume-weighted sense. In the DRAGON calculation, a 172-group cross section library is used in this study.

The reference neutron multiplication factor ( $k_{inf}$ ) is 1.44659 and the resulting RPT radius is 0.3854cm. Meanwhile, the VWH approach provides a much smaller  $k_{inf}$  value of 1.36827, thus double-heterogeneity is 3957 pcm. Note that the reference  $k_{inf}$  value is reproduced in the RPT method.

In order to investigate the physical similarity between the original and the RPT problems, the 172-group microscopic cross sections are compared for the model problem. Figs. 3 and 4 show the relative errors in the U-235 fission cross section and the U-238 capture cross section, respectively. One can clearly observe that the fine-group microscopic cross sections of the RPT solution is very close to the reference case throughout the whole energy range, while the errors are relatively large in the VWH case. As expected, the resonance cross sections are largely overestimated due to the reduced self-shielding effects in the VWH method. It is interesting to note that the fast neutron cross sections are substantially underestimated in the VWH method. For all the other types of cross sections, the RPT method turns out to preserve a high degree of similarity in the fine-group structure.

A similar analysis has been done for a TRU (transuranic) fuel, in which the TRU composition is

typical of the commercial PWR spent fuel. In this case, the kernel diameter is 200 $\mu$ m and the packing fraction is 12.38%. The coating layer thickness is the same as in the UO<sub>2</sub> case. The results are shown in Figs. 5 and 6. In this case, the double-heterogeneity effect is huge, 15992 pcm and the RPT radius is much smaller, 0.1911cm, relative to the UO<sub>2</sub> fuel.

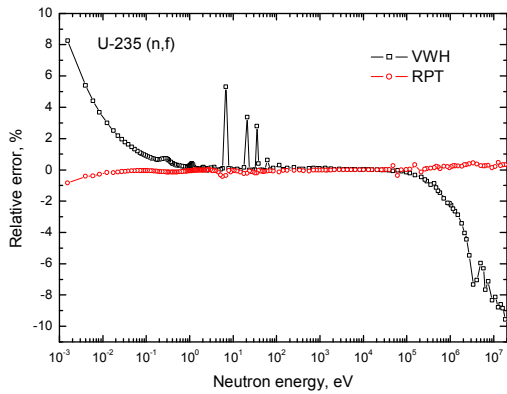


Fig. 3. Comparison of U-235 fission cross section.

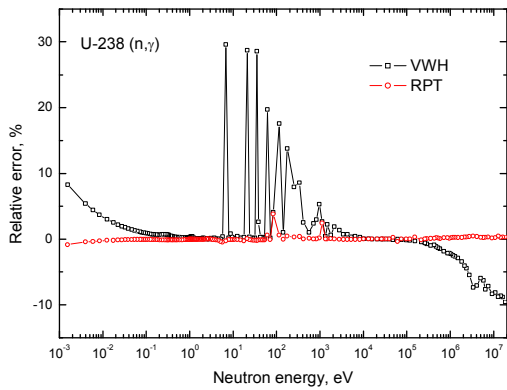


Fig. 4. Comparison of U-238 capture cross section.

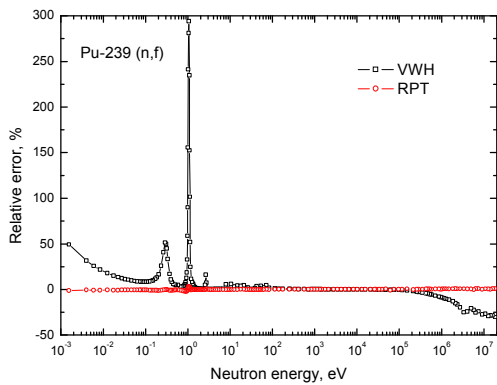


Fig. 5. Comparison of Pu-239 fission cross section.

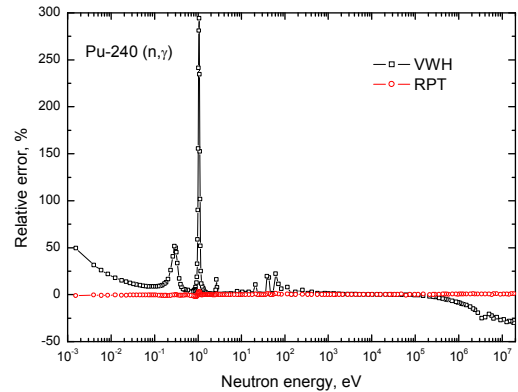


Fig. 6. Comparison of Pu-240 capture cross section.

In spite of the huge double-heterogeneity effect of the TRU fuel, the RPT method provides fine-group microscopic cross sections which are very close to the reference one. It is worthwhile to note that the VWH error is very large in the resonance energy around 1 eV.

## CONCLUSIONS

In the RPT method, the double-heterogeneous problem is transformed into a simple heterogeneous one by preserving the reference reactivity. Therefore, the microscopic group-wise equivalence is not guaranteed in the method. Nevertheless, it is shown that the fundamental physical properties are well preserved in the RPT process.

## Acknowledgement

This study has been carried out under the Long-Term Nuclear R&D Program supported by the Ministry of Science and Technology (MOST) of Korea.

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