Clad Treatment in KARMA Code and Library

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1. Introduction

KARMA is a transport lattice code to generate the few group constants for ASTRA, the reactor core design and analysis code of KEPCO Nuclear Fuel (KNF). KNF has developed advanced fuel for reactor, HIPER16 and HIPER17 and HANA clad material is introduced. This paper investigates the clad analysis model for KARMA whether current method is applicable to HANA clad material.

2. Evaluation of KARMA Zirconium Library

Zirconium alloys such as zircaloy-2 or ZIRLO are used as clad material. To evaluate current KARMA zirconium neutron library, the absorption cross sections of clad region are compared between KARMA and reference MCNP calculations. The geometry is typical PLUS7 fuel shown in Figure 1 and the composition of zircaloy-2 clad material is described in Table 1. The reference MCNP calculation was performed with LANL-provided ENDF/B-VII.0 neutron library and 50,000 particles for 50-inactive/500-active cycles.

Table 1. Nuclide Composition of zircaloy-2

Nuclide	NID	Composition (wt%)
Zr (nat)	40010	98.230
Sn (nat)	50000	1.500
Fe (nat)	26000	0.120
Cr (nat)	24000	0.100
N (7-N-14)	7014	0.050

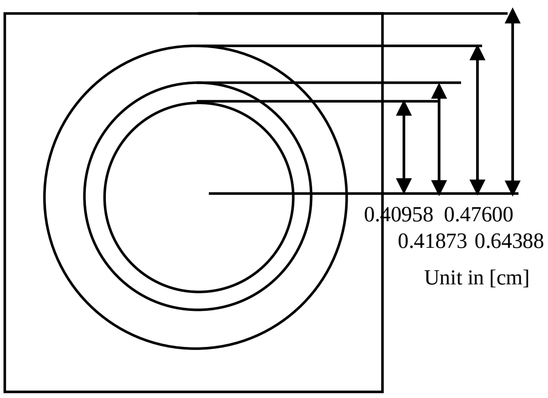

Figure 1. Geometry of PLUS7 Fuel

The multiplication factors are 1.38650 and 1.38732 from KARMA and MCNP calculation, respectively. The MCNP standard deviation was 0.00011. The difference is 82 pcm. Figure 2 shows absorption cross section in clad region.

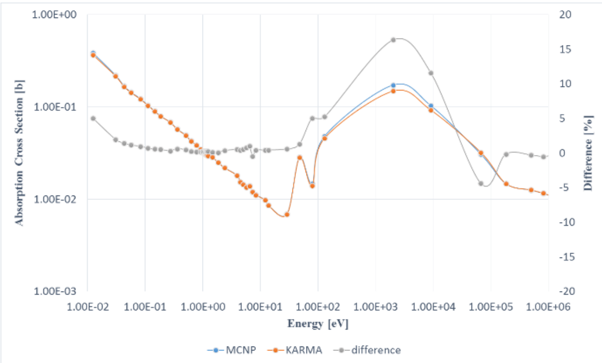

Figure 2. Absorption Cross Section of Clad Material (Zilcaloy-2)

The graph shows that effective absorption cross section agrees well along all energy group except for the specific resonance energy region. The energy region is where zirconium resonance presents as Figure 3 shows.

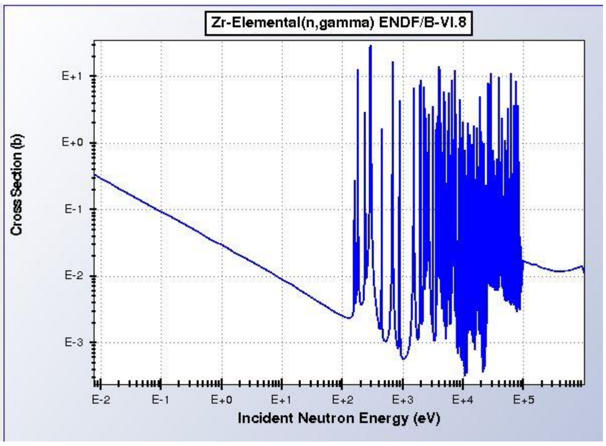

Figure 3. Absorption Cross Section of Natural Zr [1]

KARMA code uses subgroup method [2] for resonance treatment. Subgroup method uses subgroup parameters generated from effective cross section for resonance energy region. To reduce the cross section differences with reference MCNP calculation, effective cross section for resonance energy region and corresponding subgroup parameters for natural zirconium have been generated using KARMA library generation code system [3].

The effective cross section was obtained by using flux of clad region instead of fuel region. The idea is to obtain effective cross section with the same condition it is planned to be used. The subgroup parameters were also generated by using the effective cross section. When the new subgroup parameter was used for KARMA calculation, resonance absorption cross section was increased about 15% and showed better agreement with MCNP. Figure 4 shows the relative absorption reaction rate differences with MCNP along resonance energy group (10~25G). As shown in the graph, the large differences in Group 10 and 11 was reduced as well as small improvement in some energy groups.

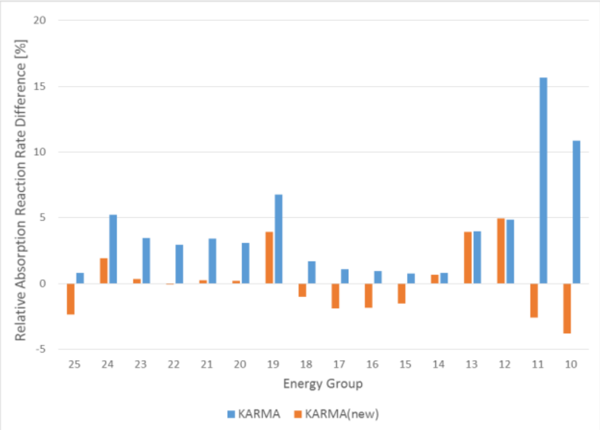

Figure 4. Relative Absorption Reaction Rate Difference in Clad Region with MCNP and KARMA

3. Use of Composite Nuclide

3.1. Composite Nuclide of Zircaloy-2

Instead of using explicit compositions of clad material, KARMA library provides the composite nuclide for clad material, namely 40002 nuclide for Zircaloy-2 alloy. Because 40002 nuclide is not a natural isotope, the cross section is obtained by using the KARMA output files [4]. It cannot be generated by editing the neutron library of each component due to resonance parameters.

The use of cross sections of 40002 could replace the use of cross sections of explicit nuclides of Zircaloy-2. The multiplication factor and the effective cross sections are very close. The multiplication factor is 1.38666 whose difference is 82 pcm with explicit Zircaloy-2 KARMA calculation. The maximum cross section difference is less than 3% in fast energy group.

The use of composite nuclide is generally acceptable when it is applied to the same composition such as 40002 nuclide instead of Zircaloy-2 composition. However it is not applicable to other clad materials such as ZIRLO or HANA. The Table 3 shows multiplication factors with different clad materials.

Table 3. Multiplication Factor Comparison

	KARMA	MCNP (std)	diff(pcm)
Zircaloy-2	1.38650	1.38732 (0.00011)	82
ZIRLO	1.38596	1.38681 (0.00012)	86
HANA	1.38623	1.38715 (0.00012)	92
40002	1.38666		

3.2. Composite Nuclide of HANA

The same procedures were taken to generate the composite nuclide of HANA clad material. The effective cross sections were obtained from KARMA calculation results and the atomic mass was calculated with given information. The new subgroup parameters of natural zirconium were used in this calculation. As a result, the use of composite nuclide of HANA clad material gives almost same result with the result when HANA clad material is used explicitly. The multiplication factor difference is only 9 pcm where it is increased to 115 pcm if the composite nuclide of Zircaloy-2 is used. The effective absorption cross section of clad region and the differences with reference MCNP results are shown in Figure 5. The cross section difference is much larger when other composite materials are used.

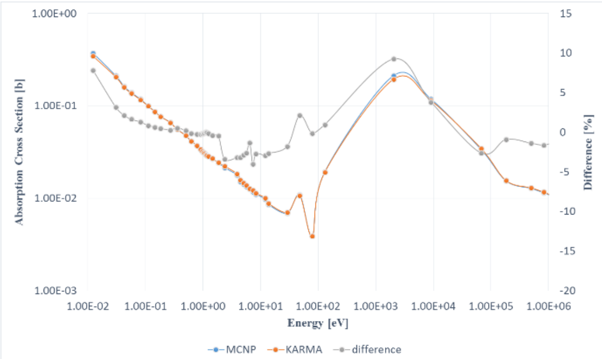

Figure 5. Absorption Cross Section of Clad Material (HANA)

4. Conclusion

Zirconium is the main components in clad materials. The subgroup parameters of zirconium were generated with effective cross section which obtained by using flux distribution in clad region. It decreases absorption reaction rate differences with reference MCNP results. Use of composite nuclide is acceptable to increase efficiency but should be limited to specific target composition. Therefore, the use of the composite nuclide of Zircaloy-2 should be limited when HANA clad material is used for clad. Either using explicit components or generating composite nuclide for HANA is suggested.

REFERENCES

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