The Difference between Flux Spectrums of WH-type Assembly and CANDU-type Lattice

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1. Introduction

Because of the thermal peak of the microscopic fission cross section of the U-235 which will be loaded into the reactor core as fuel material, the moderation process is very important in the neutron economy. It is natural that we can increase the fission rate by supplying neutrons with suitable spectrum shape. Sometimes, the nuclear reactors are categorized by the material of the moderator because of its importance. The representative materials as the moderator are light water (H_2O) and heavy water (D_2O). Also, it is well known that the slowing-down ratio of D_2O is hundreds times larger than that of H_2O while the slowing-down power of H_2O is several times larger than that of D_2O. It means that the H_2O sometimes plays a role of absorber such as the liquid zone controller (LZC) in the CANDU–type reactor. It can be thought that the flux spectrums in different reactors can differ from each other. In this research, two representative assemblies (the westing house (WH)-type fuel assembly of PWR and the CANDU-type fuel lattice of PHWR) are selected and the flux results for each group are extracted. Although there are many codes for the lattice transport calculation, the WIMS code and the HELIOS code are used for the calculation of the WH-type fuel lattice and the CANDU-type fuel lattice.

2. Problem Descriptions

There are two types of pin cell in a geometrical point of view as in Table I. But actually, we have three types of pin cell geometry, fuel rod, burnable poison rod (gadolinium rod) and guide tube rod for control devices. Among these three rod types, the dimensions of the fuel rod and burnable poison rod are same as each other as in Table I. The guide tube is empty because the variation about control rod insertion is not considered in this research. Because the there is no pin cell geometry in the lattice of CANDU-type, the pitch of the cell is not defined. Also, in the WIMS code, the gap between fuel pellet and cladding is not defined so the gap region is filled with fuel material.

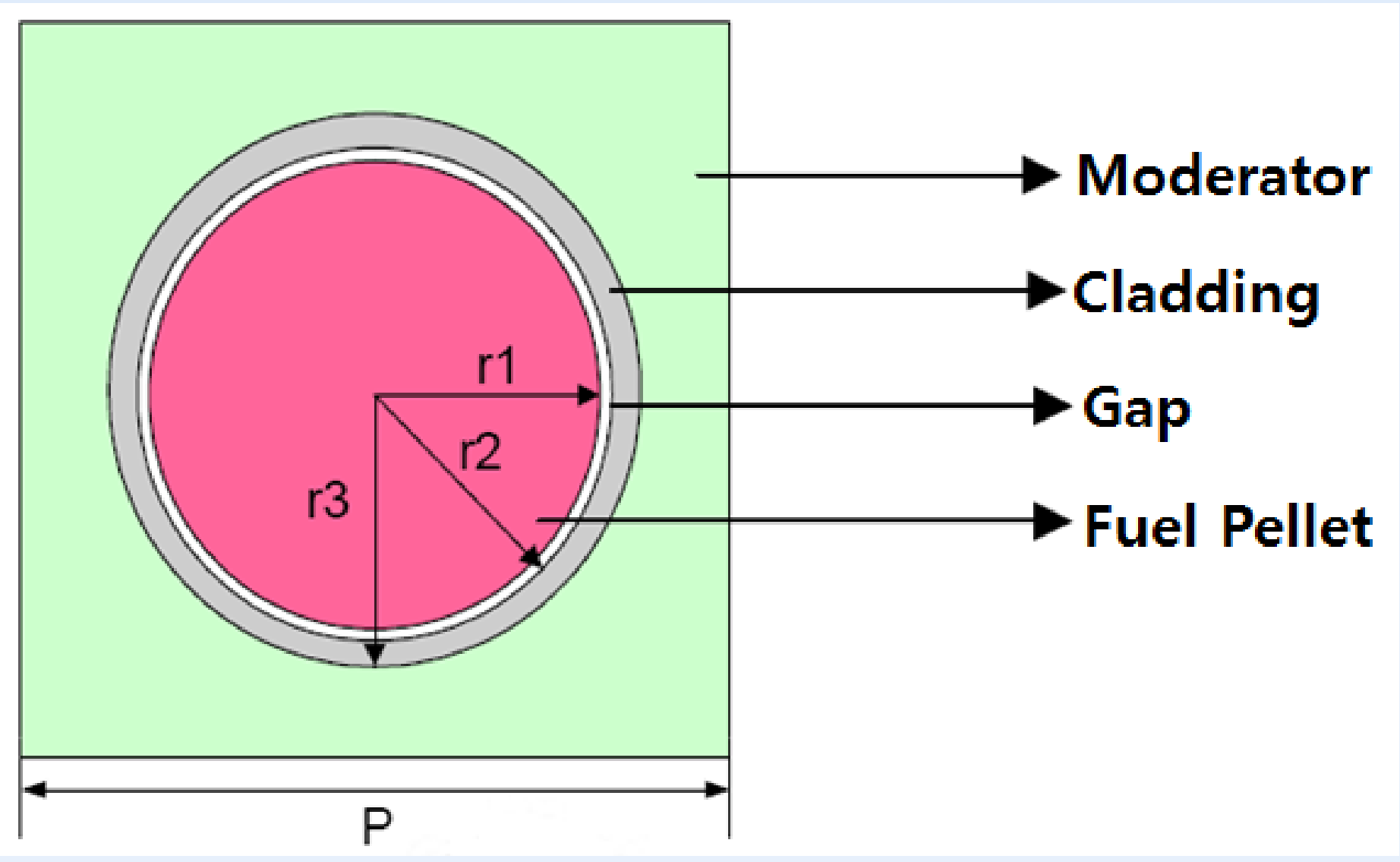

Fig. 1. Pin Cell Geometry of WH-type and CANDU-type Lattices

Table I. Pin Cell Parameters of WH-type and CANDU-type Lattices

	P	r1	r2	r3
Fuel and Gadolinium of WH-type Lattice	1.2660	0.4096	0.4188	0.4759
Guide Tube of WH-type Lattice	1.2660	0.0	0.5624	0.6130
Fuel of CANDU-type Lattice	N/A	0.429709	0.607700	0.648080

In Fig. 2., the WH 16GD-type assembly is depicted and the actual calculation domain is also marked with blue line. In the actual calculation domain 3.125 number of guide tubes, 2 gadolinium rods and 31 fuel rods are included. In Fig. 2., large volume of lattice cell in CANDU-type lattice is occupied with moderator while the relative small volume of lattice cell is occupied in the WH 16GD-type lattice. In Table VI., it can be verified that the lattice pitch of the CANDU-type is larger than that of WH 16GD-type.

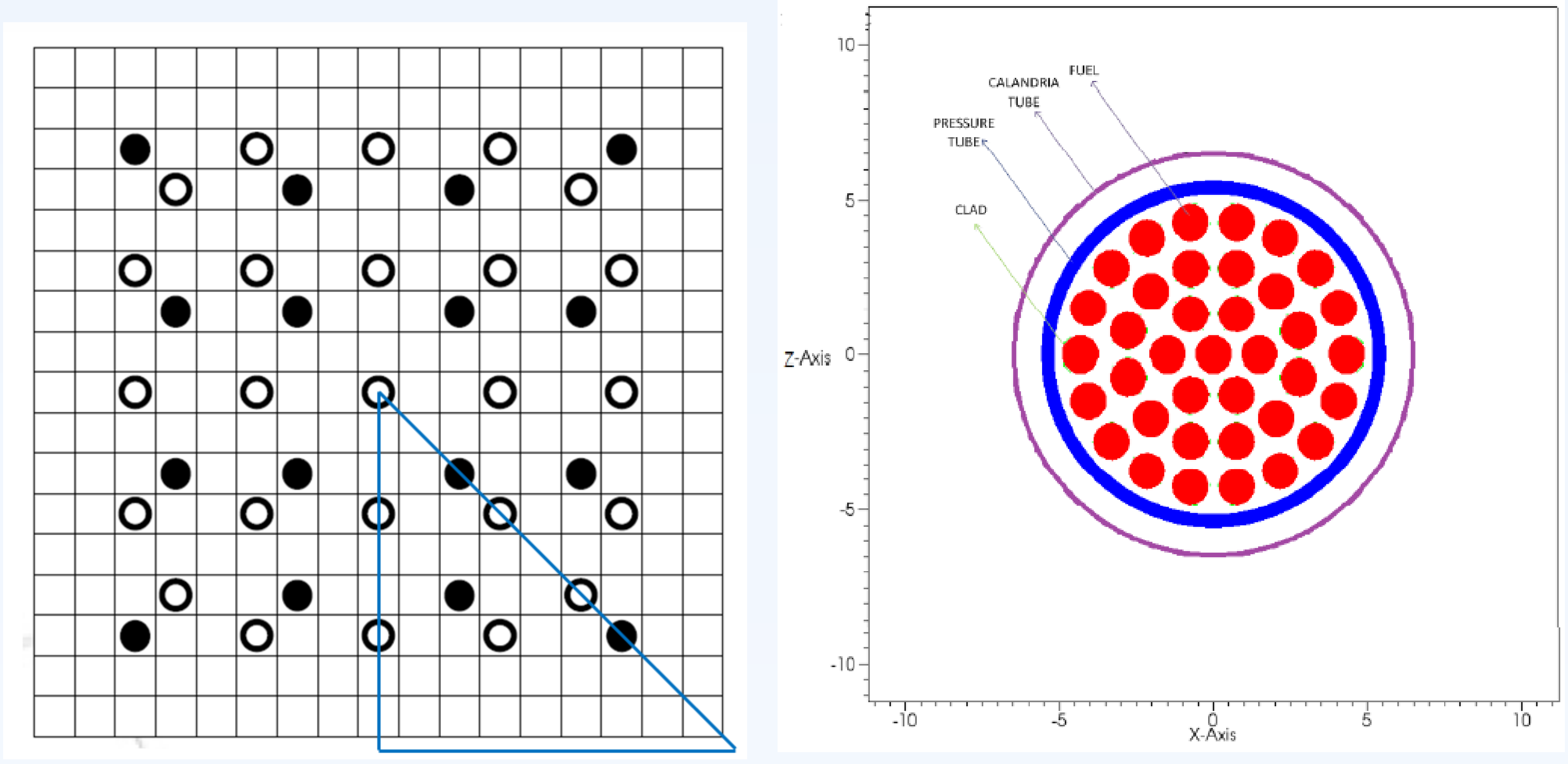

Fig. 2 Lattices of WH 16GD-type and CANDU-type

Note that the 33 groups are chosen for both simulations. Also, the 190 number of library is chosen for HELIOS running because of ambiguous points in the running. The coupling option of the asemblies is 2. The zicaloy-2 is used for the cladding material. For the computational convenience, CCS region is simplified. Various paths for the branch calculation is simplified. Finally, 147.959bar is used for the system pressure with given data in reference(from steam table with coolant density of 0.659g/cm at 600K)

3. Result

In Fig. 3., the it can be confirmed that the spectrum of WIMS Code is well match with that of McCARD Code(using infinite spectrum). The portion of fast flux and thermal flux($E\varphi(E)$) is almost same as each other for 17% and 83%.

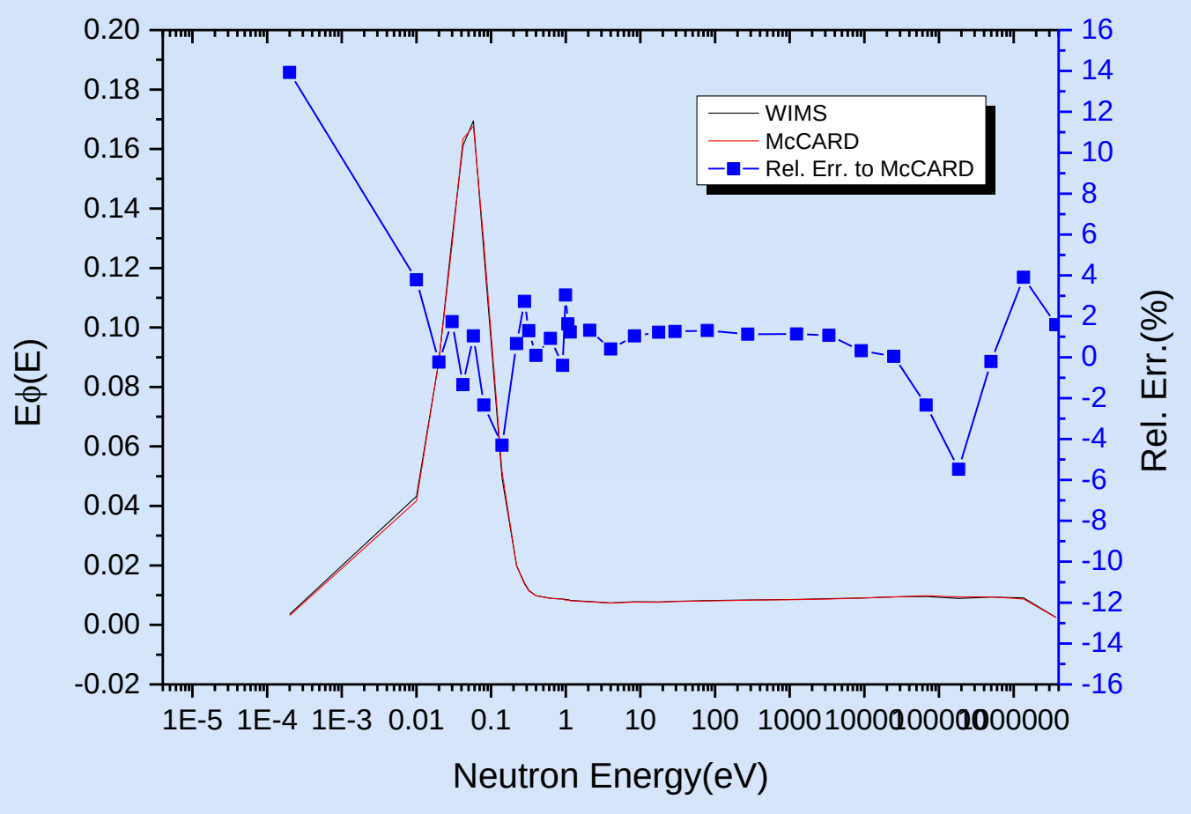

Fig. 3. Flux Spectrum Comparison between Results of WIMS and McCARD Codes

In Fig. 4., and Table II, it can be recognized that the effect of boron is to reduce the thermal flux because of the microscopic absorption cross section of the boron is decreasing with the incident neutron energy in log scale. In contrast with the case of PWR, the effect of the boron of the PHWR is much larger than that of the PWR because of the much more thermalized spectrum due to the heavy water.

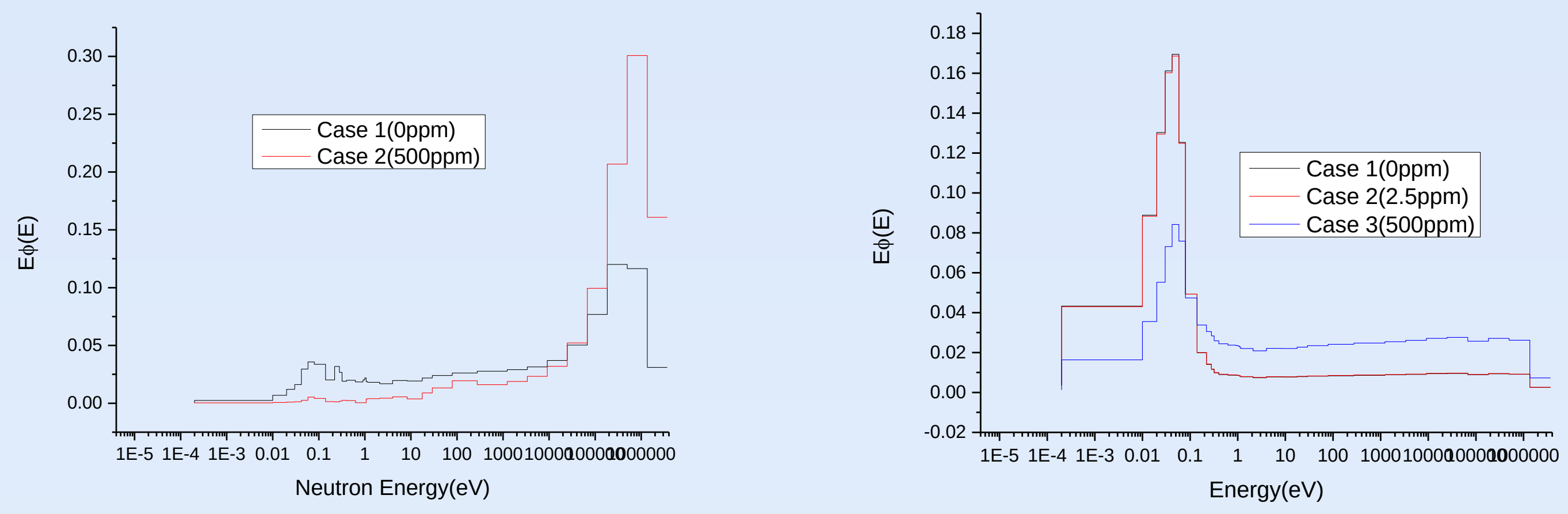

Fig. 4. Spectrum Change with Boron Concentration for WH 16GD-type and CANDU-type

Table II. Fast and Thermal Flux Portion Change with Boron Concentration for WH16GD-type and CANDU-type

(bound of 0.625eV)

		Case 1	Case 2	Case 3
WH 16GD-type	Fast(%)	76.52	97.71	N/A
	Thermal(%)	23.48	2.29	N/A
CANDU-type	Fast(%)	17.36	17.67	49.26
	Thermal(%)	82.64	82.33	50.74

In Fig. 5., the difference between spectrums of PWR and PHWR can be well verified through the WH 16GD-type and CANDU-type lattices. In spite of the zero boron in the WH 16GD-type, the portion of the thermal flux in CANDU is about four times more higher than that in PWR as 82.33%.

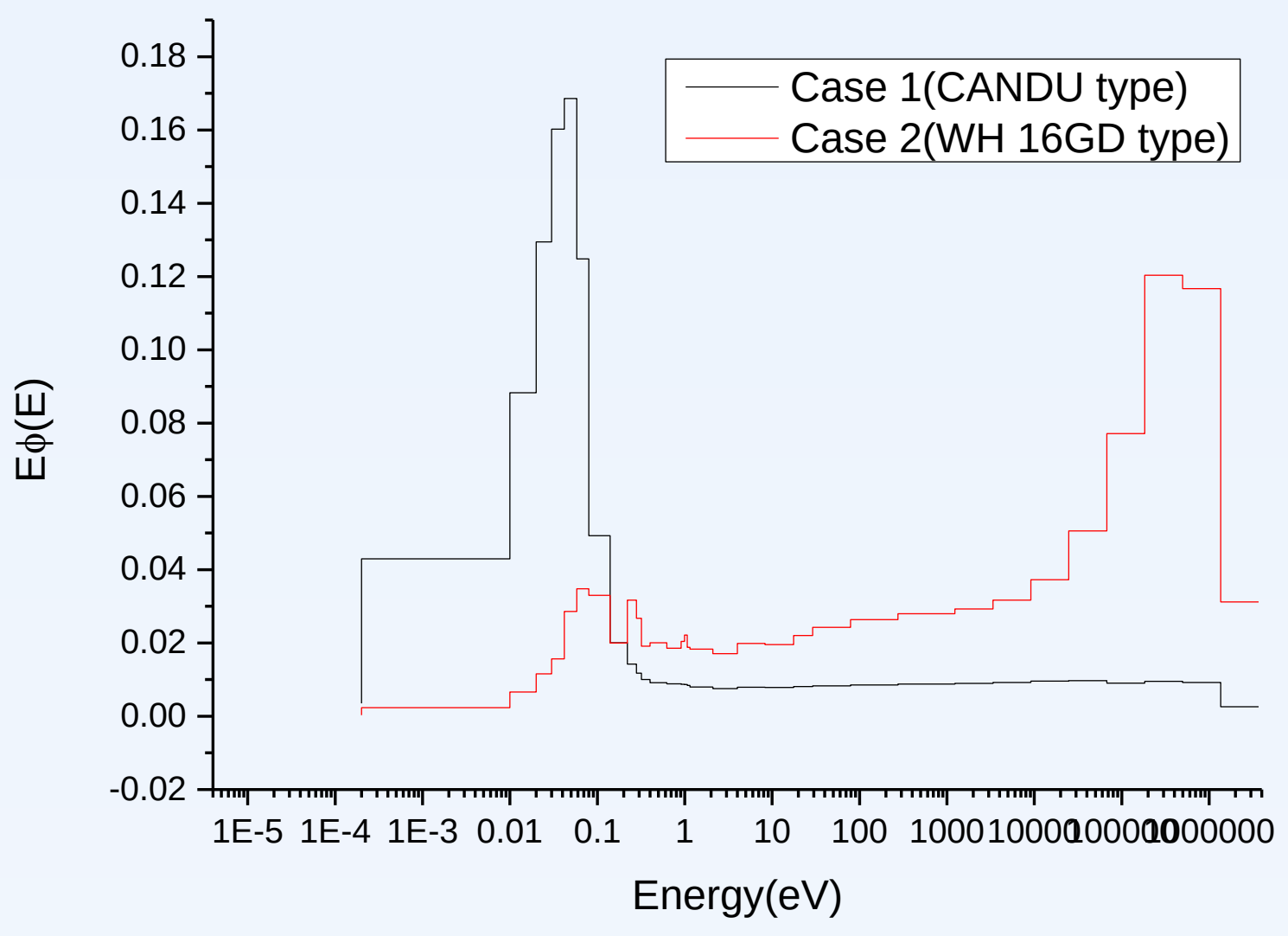

Fig. 5. Flux Spectrum Comparison between Results of WH 16GD-type and CANDU-type

4. Conclusions

Because of superior moderating ratio of the heavy water, the thermal flux ratio of the CANDU-type lattice is almost 82% while that of WH 16 GD-type lattice is around 23%.

Because of large portion of the thermal flux in CANDU-type lattice, the boron effect is maximized with the result of variations about boron. Thus it can be said that the spectrum largely depends on the moderator material, and the boron effect and sensitivity largely depends on the flux spectrum.

Because of dominant effect of the moderator material on flux spectrum in nuclear reactor, in the future, the comparison of spectrums of SFR, HTGR, PWR and PHWR is also an interesting subject to study. And it seems that utilizing the McCARD code can give us more accuracy with refined group spectrums about result and simplicity about inputs of cores because of using one code.

Also, over-moderation in PHWR lattice and under-moderation in PWR lattice can be explained by the investigation about flux spectrums with variations of moderator density in each lattice.