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Comparative Analysis of The Most Probable Moderation Condition for Different Nuclear Fuel Shapes

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1. Introduction

Rod-type nuclear fuel was mainly developed in the past, but recent study has been extended to plate-type nuclear fuel. The Plate-type fuel is popular in research reactors due to their outstanding thermo-hydraulic characteristics[1].

Therefore, this paper focused on the review of the most probable moderation condition according to different shapes of nuclear fuel types. The comparative analysis of the most probable moderation condition was performed using MCNP5. MCNP5 is well-known Monte Carlo codes for criticality analysis and a general-purpose Monte Carlo N-Particle code that can be used for neutron, photon, electron or coupled neutron / photon / electron transport, including the capability to calculate eigenvalues for critical systems[2].

2. Assumptions and Results

2.1 Assumptions

We performed the comparative analysis for different nuclear fuel shapes using MCNP5. Followings are assumptions about fuel and fuel assembly shapes.

- ◦ Fuel shape : Sphere, Cube, Cuboid and Cylinder
- ◦ Fuel shape of assembly : Rod-type and Plate-type
- ◦ Rod-type fuel assembly is composed of 37 cylinder type rods.
- ◦ Plate-type fuel assembly is composed of 37 plates.

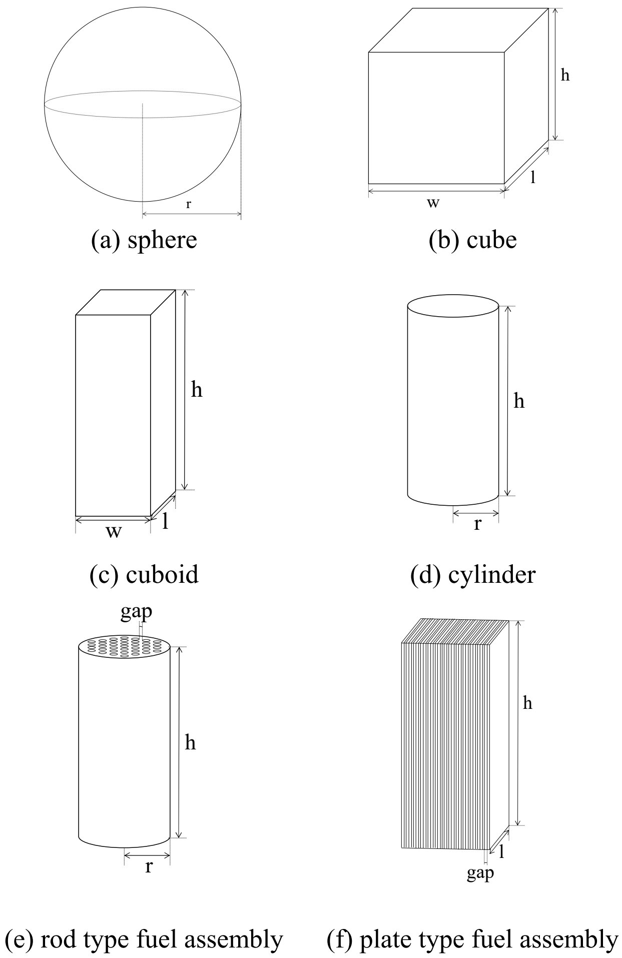
Followings are the analysis conditions.

- ◦ Flooding condition.
- ◦ Different shapes but same fuel mass and density.
  - Fuel mass : 67.87kg
  - Fuel density : 7.16 g/cm^3
- ◦ Different shapes but same nuclide component.
- ◦ Each shape is an infinite array of 30 cm intervals in the x and y axis directions.

The details of fuel shape are summarized in Table 1. Figure 1 shows the cross-section diagram of the two assembly models.

Table 1: Details of different fuel models

Fuel Shape	Size (cm)				
	r	h	w	l	gap
Sphere	13.13	-	-	-	-
Cube	-	21.17	21.17	21.17	-
Cuboid		70	11.65	11.65	-
Cylinder	6.57	70	-	-	-
Fuel rod of fuel assembly	1.08	70	-	-	0.29
Fuel plate of fuel assembly	-	70	0.25	14.58	0.14



(a) sphere (b) cube (c) cuboid (d) cylinder (e) rod type fuel assembly (f) plate type fuel assembly

Figure 1. Diagrams of different fuel shapes

2.2 Statistical reliability

In this criticality analysis, the number of source histories per cycle is used 10,000. This value was determined to ensure uniform distribution of the sources sampled from one cycle of criticality analysis throughout the calculation area and to decrease the calculation variation.

The number of active cycle was 100 and the number of inactive cycle was 50. One million sources, which are 10,000 (number of source histories per cycle) times 100 (number of active cycle), would give the statistically enough reliability on criticality analysis results.

2.3 Criticality of different fuel shapes

Table 2 shows the criticality results of different fuel shapes in the flooding condition. The maximum criticality occurs in the plate type fuel assembly and its values is 0.79428.

Table 2: Criticality of different fuel shapes in the flooding condition

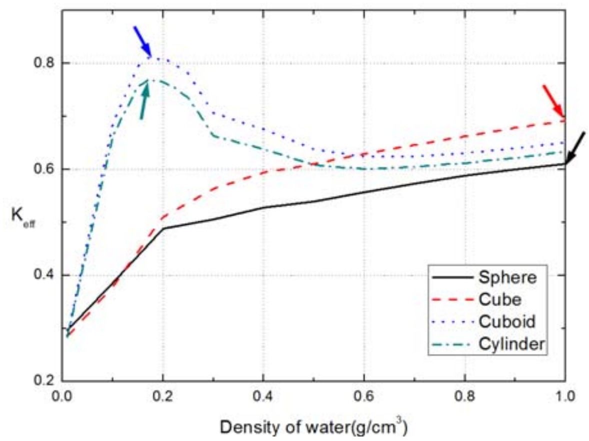
Fuel Shape	k_{eff}	σ	$k_{eff} + 2\sigma$
Sphere	0.60891	0.00083	0.61057
Cube	0.68958	0.00082	0.69122
Cuboid	0.64883	0.00092	0.65067
Cylinder	0.56947	0.00093	0.57133
Rod type fuel assembly	0.79018	0.00098	0.79214
Plate type fuel assembly	0.79200	0.00114	0.79428

2.4 The most probable moderation condition

We performed the analysis of the most probable moderation condition for different fuel shapes by changing the water density by 0.1g/cm^3. As shown in the Figure 2, the condition of optimum moderation was analyzed differently by fuel shape.

In the case of the case of sphere and cube shape, the most probable moderation condition did not occur at low water density but occurred at the water density of 1g/cm^3. However, in the cuboid and cylinder shape, the water density of 0.17 and 0.18 were respectively evaluated as the most probable moderation condition.

And the most probable moderation condition for plate-type and rod-type assembly is similar to the result of cuboid and cylinder shape because their structure is similar.



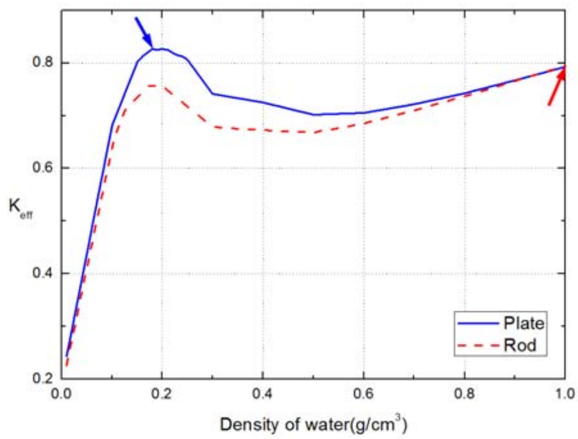


Figure 2. The most probable moderation condition of different fuel shapes

3. Conclusions

We performed the the most probable moderation condition analysis for different fuel shapes.

As a result, the condition of optimum moderation showed different results depending on the fuel shape, even if fuel mass and density are same. The most probable moderation condition occurs at a water density of about 0.2 g/cm^3 for the cuboid and cylinder type fuel and at a water density of about 1.0 g/cm^3. for the sphere and cube type fuel.

REFERENCES

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[2] X-5 Monte Carlo Team, LA-UR-03-1987/ LA-CP-03-0245, A general Monte Carlo N-Particle Transport Code, Version 5, Los Alamos National Laboratory, 2008.2.