STREAM Solutions for the Two-Dimensional C5G7 MOX Benchmark Problem

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1. Introduction

STREAM is a neutron transport code based on the method of characteristics (MOC) which has been developed at UNIST in Korea. In Korea, a project to design a boron free small modular reactor (SMR) started from July, 2013 through the cooperation of four nuclear companies. To design the boron free SMR, new types of fuel which can perform the role of boric acid need to be used. Current vendor codes such as HELIOS-2, DeCART, and CASMO-5 [1-3] are known to provide a good result for typical nuclear fuel in commercial reactors. However, they are not proven to be able to analyze an innovative fuel such as a fuel pin, including burnable poison inside cladding, because they were not designed to target such nuclear fuels. STREAM aims to have the capability to analyze such innovative fuel as well as typical fuel in commercial reactors. In this paper, two-dimensional C5G7 MOX benchmark problem [4] was used to verify the STREAM solver, and the results including eigenvalue and pin power distribution were compared with the MCNP reference solutions.

2. Description of work

For the C5G7 MOX benchmark problem, STREAM used 5 rings in the fuel, 10 rings in the coolant region, and 8 azimuthal divisions. Flat source regions in water reflectors were set to 0.126 cm x 0.126 cm mesh. The STREAM calculation used 128 azimuthal angles, 3 polar angles with the T-Y quadrature sets [5], and 0.048 cm of ray spacing with convergence criteria of 1 pcm.

3. Results

Table I summarizes the eigenvalues and pin powers from various codes [6-12], and Table II summarizes the comparison of assembly average pin powers to the reference solution by MCNP5. The root mean square error of STREAM pin power distribution is 0.248%, and there is an excellent agreement with the reference solution. Figures 1 and 2 show the pin power and pin power error distributions of the STREAM solution. The maximum pin power error of 0.928% occurs at the water reflector corner pin. It was confirmed that STREAM transport solver produce nearly exact solutions for a problem with given macroscopic cross sections when fine mesh and quadrature are used.

Table I. STREAM Solutions of C5G7 2-D Benchmark.

Code	Method	k-eff	Pin Power	
			Max.	Min.
MCNP (Reference)	**MC**	**1.18655**	**2.498**	**0.232**
STREAM	**MOC**	**1.18649**	**2.494**	**0.234**
DeCART	MOC	1.18660	2.492	0.235
CASMO	MOC	1.18660	2.497	0.233
CRX	MOC	1.18813	2.498	0.233
APOLLO2	MOC	1.18634		
LANCER02	MOC	1.18660	2.498	0.23
CRONOS	S8	1.18338		
ATTILA	S16	1.18658	2.494	0.231
PENTRAN	S16	1.18760		
PARTISN	S40	1.18632	2.503	0.232

Table II. Assembly Average Pin Powers.

Assembly	MCNP (Reference)	STREAM	Diff. (%)
Inner UO_2	1.867	1.864	-0.12
MOX	0.802	0.803	0.12
Outer UO_2	0.529	0.530	0.06

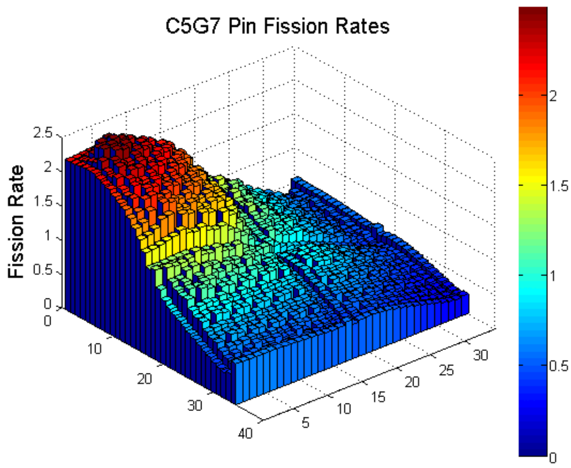

Fig. 1. STREAM Pin Power Distribution of C5G7 Benchmark.

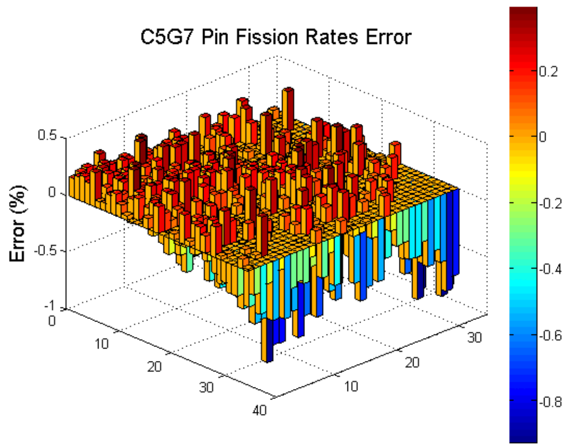

Fig. 2. STREAM Pin Power Error Distribution of C5G7 Benchmark.

4. Conclusions

A new MOC code named STREAM has been developed at UNIST. In order to verify the STREAM code, two-dimensional C5G7 benchmark was calculated. It is shown that pin power error is less than 1% and eigenvalue difference is 6 pcm in comparison with the MCNP5 solutions. Therefore, it was confirmed that the STREAM solution shows an excellent agreement with the MCNP5 reference solution. In the future, a depletion module will be implemented.

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