Verification of HELIOS-MASTER System through Benchmark of Halden Boiling Water Reactor (HBWR)

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1. Introduction

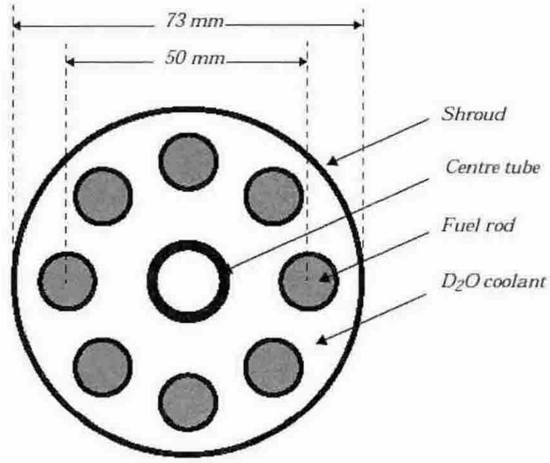
To verify the HELIOS-MASTER computer code system for a nuclear design, we have been performed benchmark calculations for various reactor cores. The Halden reactor is a boiling, heavy water moderated reactor. At a full power of 18-20MWt, the moderator temperature is 240℃ and the pressure is 33 bar. This study describes the verification of the HELIOS-MASTER computer code system for a nuclear design and the analysis of a hexagonal and D_2O moderated core through a benchmark of the Halden reactor core.

HELIOS[1], developed by Scandpower A/S, is a two-dimensional transport program for the generation of group cross-sections, and MASTER[2], developed by KAERI, is a three-dimensional nuclear design and analysis code based on the two-group diffusion theory. It solves the neutronics model with the TPEN (Triangle based Polynomial Expansion Nodal) method for a hexagonal geometry.

2. Description of Halden Boiling Water Reactor Core

2.1 Halden Driver Fuel Assembly

Standard driver fuel assemblies used in the Halden reactor consist of 8 UO_2 fuel rods inside a shroud. The rigs also contain a centre tube for stability. The initial fuel enrichment is 6.0 w/o of U^{235}. The active fuel length is 80cm and it is located 80 cm above the reactor bottom plate. The radial cross section and main dimensions of the driver fuel assembly are shown in Figure 1.



FUEL ROD:	*Pellet diameter*	=	*10.50 mm*
	Clad outer diam.	=	*12.25 mm*
	Clad inner diam.	=	*10.67 mm*
	Gap	=	*170 μm*
	Ring radius	=	*25 mm*
STAY ROD:	*Outer diameter*	=	*7.0 mm*
	Ring radius	=	*31 mm*
CENTRE TUBE:	*Outer diameter*	=	*17.0 mm*
	Inner diameter	=	*13.0 mm*
SHROUD:	*Outer diameter*	=	*73 mm*
	Inner diameter	=	*71 mm*

Figure1. Cross section and main dimensions of a standard Halden driver fuel assembly

2.2 Cross Section of the Core

The HBWR core has 331 channels within ring no. 10 located in a hexagonal lattice configuration with a pitch distance of 13 cm. Only the inner 6 rings and partly ring no. 7 are used for fuel assemblies. Normally, there are 80 ~ 110 fuel elements in the core. The reactor is controlled by 30 control rods inserted from the top of the core. When the control rods are withdrawn the channels are filled with the moderator. Figure 2 shows an idealized open hexagonal lattice configuration of 19 channels, only, to fit on this paper.

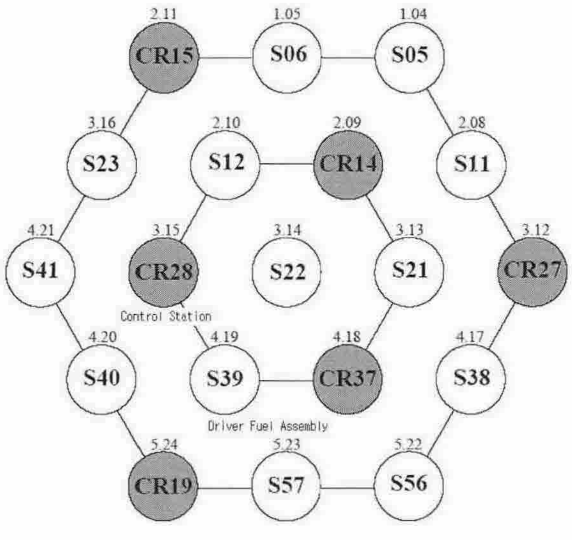


Figure2. Idealized open hexagonal lattice configuration of 19 channels only

3. Description of HELIOS Model and Generation of Cross Section

In order to generate a microscopic cross section set for MASTER, many calculation steps are required for the considerations of the fuel depletion, TH feedbacks and control rod description. Because the size of the water hole in the control station is moreover, the same as that of fuel assembly, the influence of the Assembly Discontinuity Factor(ADF) is large at the boundary. HELIOS models for all the FAs are simplified as in Figure 3, by considering water hole mixed FA arranges. This is because the boundary condition of the HELIOS model can be more realistic and the geometry size will be remarkably reduced. The three side FAs can be rotated appropriately so that the symmetry is maintained at the boundary. The effects of the rotation on the FA cross sections are negligible. All FAs can be modeled by half symmetry for the side FAs. The reflector cross sections were generated separately. A simple one-dimensional HELIOS calculation was adopted. From the results of the HELIOS calculation, a microscopic cross section set for MASTER was generated by using the HOPE and PROLOG code.

4. Result and Conclusion

A 3D Full Core calculation was performed by using MASTER. We compared the results of the MASTER core calculations with those of the MCNP that were provided by the OECD Halden Reactor Project Team in Norway. Figure 4 shows the comparisons of the radial power distributions and Table 1 lists the core eigenvalue differences. It can be seen that the difference of the core eigenvalue and the % difference of radial power distribution is less than 0.001 and 1.0 %, respectively which means HELIOS/MASTER system is fast and has enough accuracy for the HALDEN reactor core analysis.

Table1. Resultant k_{eff} of HBWR Core Calculation

MCNP	REBUS-HETERO* (Difference, pcm)	HELIOS-MASTER (Difference, pcm)
1.35432	1.2589(-9542)	1.35339(-93)

*Core Analysis Code System in OECD Halden Reactor Project Team in Norway

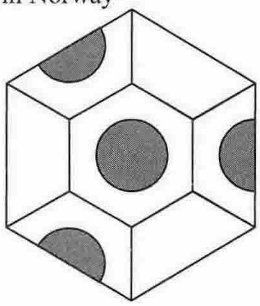


Figure3. Fuel assembly Arrange Model for HELIOS Calculation

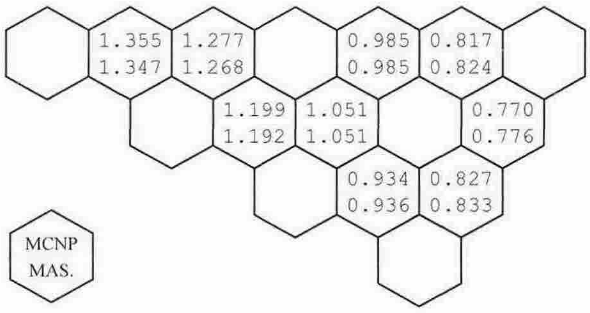


Figure4. Comparison of Radial Power Distribution

5. Acknowledgement

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6. Reference

[1] "HELIOS Program," Studsvik Scandpower, Nov. 2003.
[2] J. Y. Cho, et al., "MASTER 3.0 User's Manual," KAERI/UM-8/2004, KAERI, March 2004.