Assessment of SLTHEN code Estimation Capability for the coolant temperature distribution using the RANS based CFD analysis

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1. Introduction

KAERI provides steady-state TH design parameters by calculating flow and temperature distribution using the SLTHEN, the SFR core thermal hydraulic design code. For the efficiency of iterative calculations, the SLTHEN code uses a simplified ENERGY model by substituting an approximate model for the momentum equation. This model has the advantage of providing TH design variables as accurate as the result of the detailed model with a shortened calculation time for forced convection analysis under steady-state conditions.

Due to the wire-wrapped fuel structure, the flow has complicated characteristics, and since the SLTHEN code is a subchannel code, the design margin is applied by using a hot channel factor. For this reason, it is necessary to quantitatively evaluate the design margin of the calculation results in detail design. Verification of calculation results for flow distribution and mixing effect has already been performed through experiments, but additional verification is required due to the absence of experimental data for temperature data. Therefore, we assess the temperature distribution of SLTHEN code using the RANS based CFD methodology.

2. Methods and Results

2.1 Numerical analysis methodology

For CFD temperature analysis, SLTHEN code and CFD analysis results were compared for wire-wrapped fuel assemblies (61 pins) with geometrical similarity to PGSFR. A commercial CFD code, Star-CCM+, was used, and a grid was constructed using the polyhedral mesh and prism mesh provided in the code. As a numerical analysis method, 3-D, steady-state, segregated flow scheme, and all y+ wall treatment were set, and the analysis conditions are shown in Table 1 below.

Table 1 Numerical analysis conditions

Power	1.52 MW
Mass flow rate	15.02 kg/s
Coolant temperature	60℃
Density	983.4 kg/m^3
Viscosity	4.67E10-4 kg/m·s

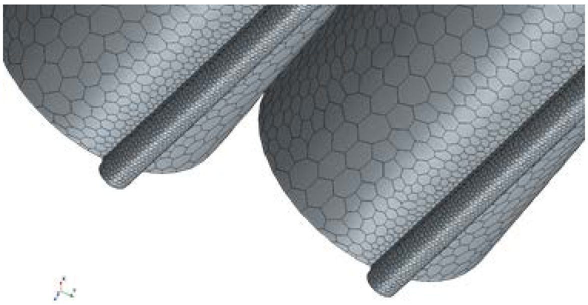

Figure 1. Polyhedral mesh

For the assemble power distribution, the cosine shape was applied used in the actual reactor design. In order to input the linear power according to the axial position, it was divided into six parts and applied by 4th polynomial fitting (Figure 2).

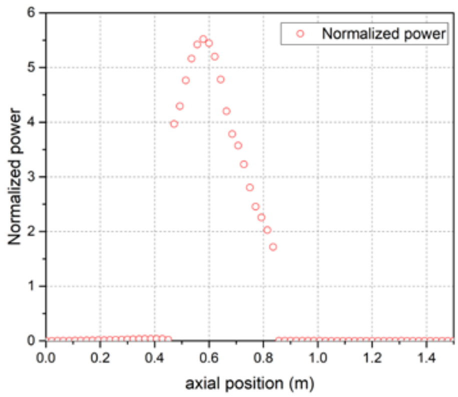

Figure 2. linear power shape (normalized)

2.2 Numerical analysis results

The mesh sensitivity evaluation was performed using a standard k-ε turbulence model, and the analysis results obtained as shown in Figure 4. The subchannels are numbered as shown in Figure 3. The average outlet temperature of SLTHEN prediction result was 1.4℃ lower in inner subchannels (No. 1 to 96) and 1.9℃ higher in outer subchannels (No. 97 to 126).

The SLTHEN outlet temperature compared with the CFD result for each subchannel is shown in Table 2 and Figures 5 and 6. The maximum temperature at the outlet was similar, and it was confirmed that, on average, SLTHEN predicted -0.8℃ lower and the minimum temperature was 2.3℃ higher.

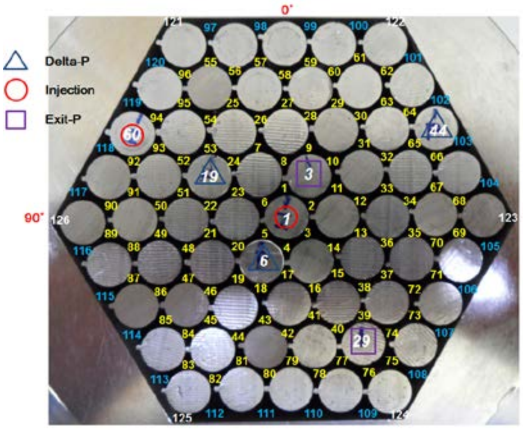

Figure 3. Subchannel numbering

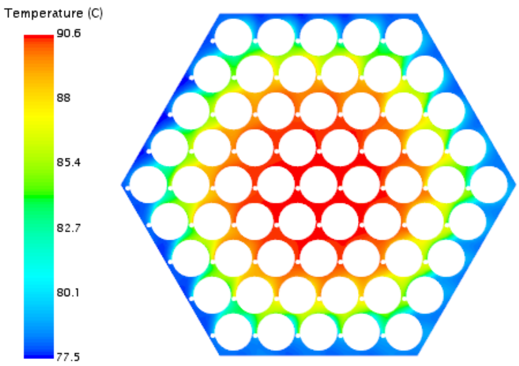

Figure 4. Outlet temperature distribution

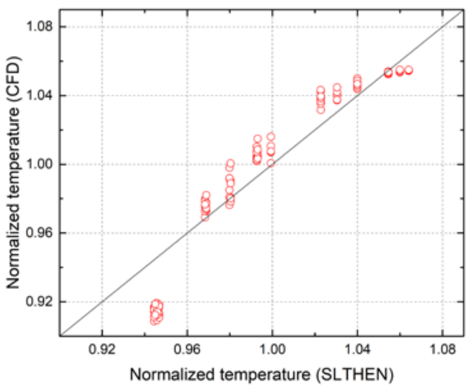

Figure 5. SLTHEN- CFD results comparison

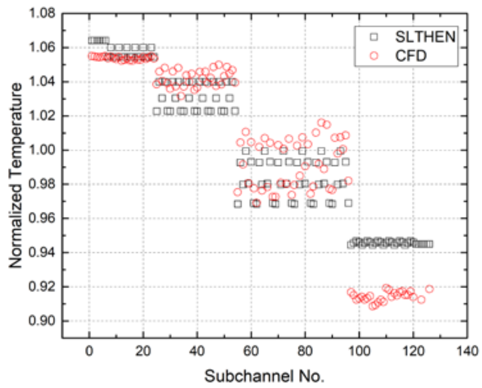

Figure 6. Outlet temperature of each subchannel

Table 2 Numerical analysis results

		Outlet temperature (℃)		
		Min.	Avg.	Max.
CFD		90.6	85.9	78.0
SLTHEN	Value	90.5	85.1	80.3
	Diff.	-0.1	-0.8	+2.3
	Error	-3.1%	0.7%	3.0%

3. Conclusions

In this study, the quantitative difference between the SLTHEN code and the CFD analysis result was investigated. It was confirmed that the temperature distribution of the SLTHEN code was wider and more evenly than that of the CFD, and this is thought to be due to the difference in the eddy effect between the subchannels. Based on the results of this study, we plan to verify the SLTHEN results by comparing them with overseas experimental data.

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