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Development of Heat Transfer Analysis Code for Heat Pipe Cooled Space Reactor Core

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1. Introduction

As SpaceX company succeed to launch reusable space rocket, the interesting for a space exploration has been concentrating. Recently, U.S.A announced long-term space project that human reside on the planet. One of the project is to develop the power source to the space base. A solar panel and radioisotope may provide the electric power in the space. However, the power with above sources is not sufficient to operate more than 1kWth system. After KRUSTY system test [1] has completed, the power using nuclear reactor become more realistic. The heat pipe components are used to cool down the reactor core in the KRUSTY system[1]. Therefore, it does not need pump system which increase weight, cost and complexity in the reactor system. Korea Atomic Energy Research Institute (KAERI) has also started the research and development project for the heat pipe cooled reactor. The project focuses on the design technology and the core concept development to analyze the reactor performance. Several technique are in demand to simulate the reactor system, a neutronics code, core heat transport code, heat pipe analysis code and reactor system analysis code. KAERI has been developing the core heat transport code, HEPITOS(Heat Pipe reacTor cOre Simulation) to predict the temperature distribution for a normal operation. On the present paper, the HEPITOS code with the heat pipe analysis code, LUHPIS(Lumped Heat Pipe Simulator)[2], are calculated and compared with the commercial CFD S/W results for two type reactor, fast and epi-thermal.

2. Numerical Method

The core concepts are drawn from the neutroncis code calculation[3]. Fig. 1 represents monolith type epi-thermal reactor. It uses U-Metal fuel and $ZrH_{1.5}$ moderator. The core height is 44. cm including the top and bottom reflector and the diameter of the outer reflector is 42.9 cm.

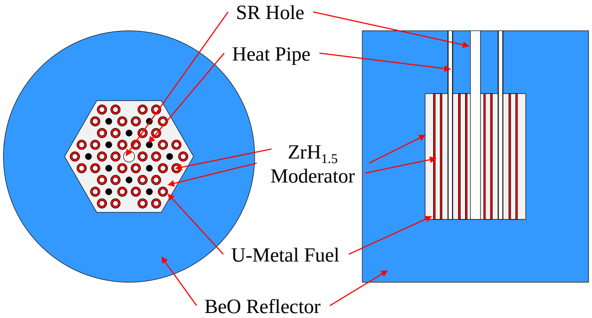


Fig. 1. Epi-thermal reactor

Fig. 2 shows homogeneous type fast reactor. It consist of U-7.5Mo fuel and BeO Reflector. The height of the core is 53.0 cm and the diameter of the outer reflector is 53.0 cm.

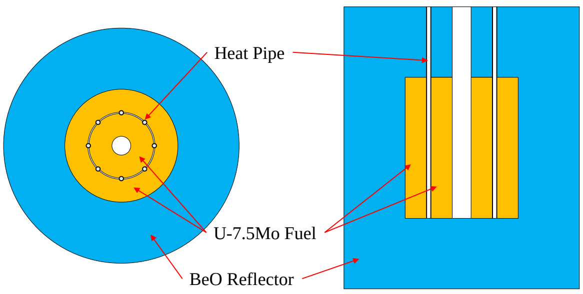


Fig. 2. Fast reactor

The core heat transfer analysis code, HEPITOS, coupled with the heat pipe analysis code, LUHPIS, was applied to predict the temperature distribution in the core.

The LUHPIS[2] code has been developing to analyze the heat pipe performance under the high temperature condition of ~600℃. A conventional water heat pipe can not be used on the prescribed temperature condition. Therefore, an alkali metal like sodium or potassium should be applied as a working fluid inside the heat pipe.

HEPITOS code has been developing by KAERI to investigate the heat transfer in the core. The CFD S/W may provide accurate and reliable solutions. However, the thermal analysis code will be calculated coupled with the neutronic code in the future. The code inherited a unit-cell approach of CORONA[4] to generate mesh and solve the three dimensional conduction problem like CFD tool. But, the CORONA code has developed based on the prismatic gas-cooled reactor. The unit cells had to be modified to analyze the homogeneous fast core. Also, the gas coolant channel algorisms replaced with the heat pipe analysis module. Considering the flexibility of the core, it is concluded that a new code is necessary. The user can solve the heat transport in the core using the unstructured grids by a combination of an already defined node geometry.

The code iteration procedure is below.

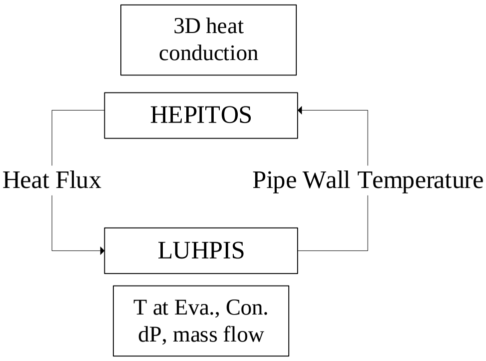
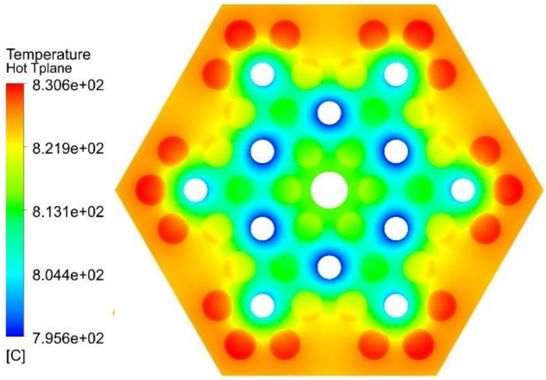


Fig. 3. Code iteration procedure

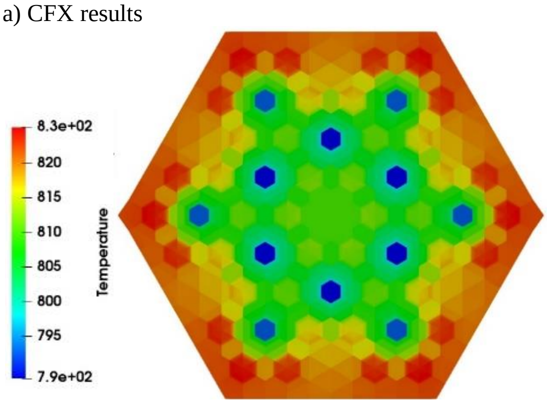
3. Numerical Results

It is important to predict temperature distribution accurately to assess the material integrity. Therefore, the computational results by the HEPITOS code are compared with the CFX[5] calculation results on the present study. The commercial CFD S/W ANSYS CFX was also coupled with the LUHPIS code using dll and user FORTRAN option. The core power was uniform. The ambient temperature on the side of heat pipe condensing region was 600℃ with 400 W/m^{2}K of heat transfer coefficient. The outer wall of the core block was assumed as an adiabatic condition for simple calculation.

The Fig. 3~5 show the comparison results. The maximum temperature difference is 6℃ (814℃ in CFX and 808℃ in HEPITOS).



a) CFX results



b) HEPITOS results

Fig. 3. Temperature distribution at the hottest plane

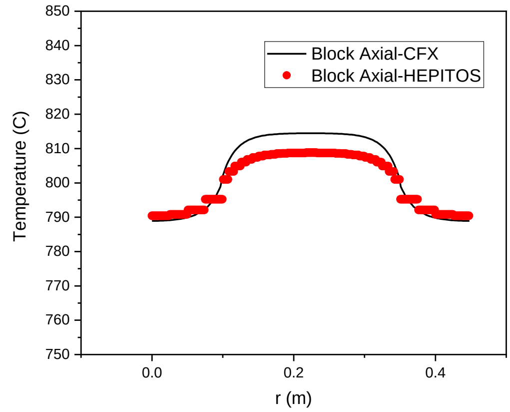


Fig. 4. Axial temperature comparison for epi-thermal reactor

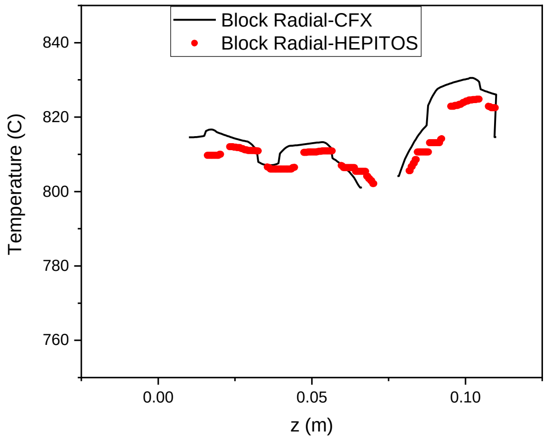
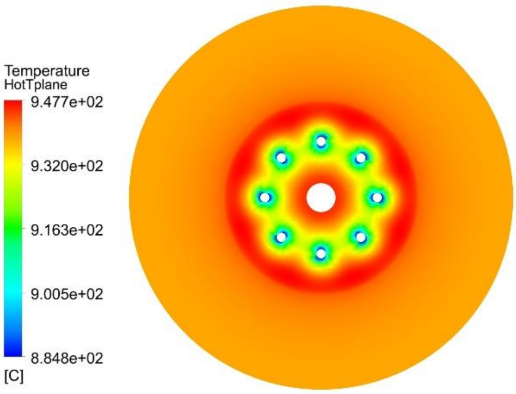
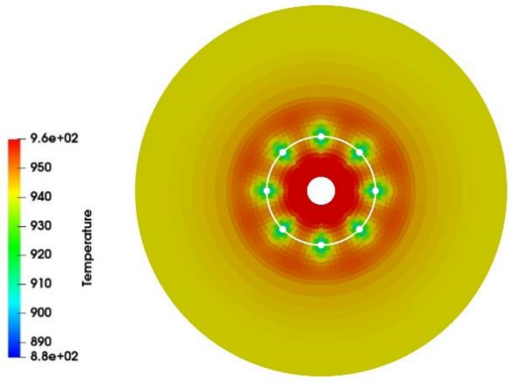


Fig. 5. Radial temperature comparison for epi-thermal reactor

The Fig. 6~8 show the comparison results. The temperature distribution at the hottest plane in Fig. 6 and 8 showed about 30℃ difference. The axial temperature profile in Fig. 7 showed slight difference between the active core and the bottom reflector. It is thought that there are slight differences between assembly connections filled with gas fluid. The proper process will be modified in the further research.



a) CFX results



b) HEPITOS results

Fig. 6. Temperature distribution of fast reactor

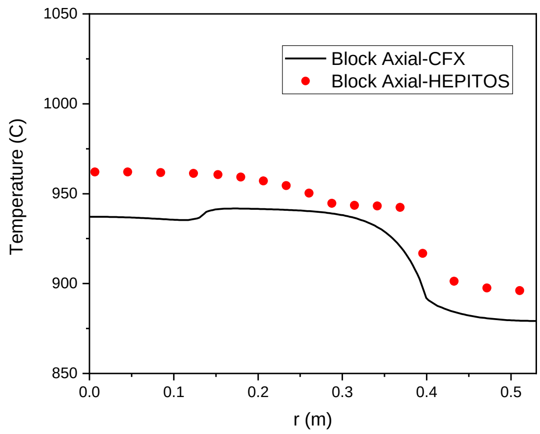


Fig. 7. Axial temperature comparison for fast reactor

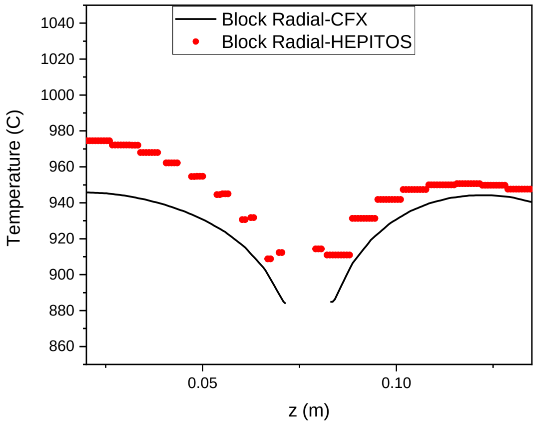


Fig. 8. Radial temperature comparison for fast reactor

4. Conclusion

The heat transport analysis code, HEPITOS, has been developing to predict the core temperature distribution for the heat pipe cooled space reactor coupled with the heat pipe analysis code, LUHPIS. Because it is necessary to assess the temperature distribution precisely, the calculation results of the developing HEPITOS code were compared with the commercial CFD S/W. The compared data showed well agreement each other for the different shape of reactor cores with a uniform power distribution. In the further studies, the more realistic power profile will be computed with the various boundary conditions.

Acknowledgements

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