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Verification of CORONA Code on a Transient Power Variation

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1. Introduction

Korea Atomic Energy Research Institute (KAERI) has been developing Core Reliable Optimization & thermo-fluid Network Analysis (CORONA)[1][2] Code to predict thermal-fluid phenomena in a prismatic High Temperature Gas-cooled Reactor(HTGR). HTGR has advantages of high efficiency, process heat, hydrogen production and inherent safety. However, the high temperature operating condition in the reactor core needs in-depth studies to use HTGR safely and efficiently. The key parameters to be considered in the HTGR are the hot spot temperature and the temperature distributions in the solid regions. A system code like GAMMA+[3] can be applied to predict temperature profile in the reactor core. However, most of system codes use the coarse mesh to reduce computational time. Therefore, it is not suitable to investigate the detailed temperature distributions in the active reactor core. A three dimensional Computational Fluid Dynamics (CFD) code might give realistic solutions to analyze the reactor core. However, the advanced CPUs and memories are still suffering from large computational domains. The CORONA code has been developed to take advantages of the CFD S/W and the system code. The CORONA code solves the fluid region as one dimension and solves the solid area as three dimensions. The previous studies with the CORONA code were concentrated on the steady-state conditions. However, the necessity to model a transient system was raised to predict temperature variation during short time power change like control rod ejection. On the present study, the transient algorithm implemented in the CORONA code was verified with a commercial CFD S/W, CFX Ver. 18.0[4].

2. Methods and Results

The CORONA code has developed to enhance a computational speed with reasonable accuracy. One dimensional network solver is implemented to solve the coolant channels. The solid regions of graphite, fuel and so on are solved with conventional three dimensional finite volume method[5][6].

2.1 Modeling

A fluid region is solved by the below one-dimensional steady-state governing equations.

$$\frac{\partial(\rho_f wA)}{A\partial z} = 0 \tag{1}$$

$$\frac{\partial p}{\partial z} + f\frac{\rho_f w|w|}{2D_h} = 0 \tag{2}$$

$$\frac{\partial(\rho_f wAC_f T_f)}{A\partial z} - \frac{1}{A}\frac{q_f^{conv}}{\partial z} = 0 \tag{3}$$

The transient term in a solid governing equation is added on the previous CORONA code to predict a temperature variation with regarding to a power change in Eq. (4).

$$\frac{\partial(\rho_s Cp_s T_s)}{\partial t} + \nabla\cdot(k\nabla T_s) = \dddot{q} \tag{4}$$

The transient term is only implemented in the solid governing equation to simulate a short term power change.

The heat transfer coefficient was calculated by the modified Dittus-Boelter correlation[7].

2.2 CFD model

ANSYS CFX, Ver. 18.0 is applied to verify transient temperature variation of single fuel column. The Shear Stress Transport (SST) turbulence model is used to simulate the coolant flows. The inlet temperature and pressure are assumed to 490℃ and 7 MPa. The inlet mass flow rate in the CFX was set to 0.1006 kg/s by considering one twelfth fuel column in Fig. 1.

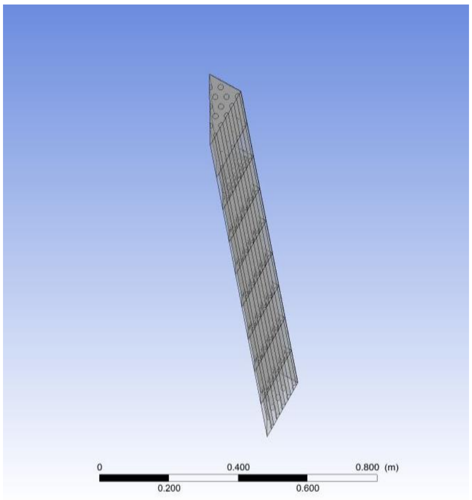


Fig. 1. One twelfth fuel column

Reference power profiles used on present study are shown in Fig. 2. The control rod ejection and withdrawal case were applied. Those profiles were used in the PBMR benchmark problems[8].

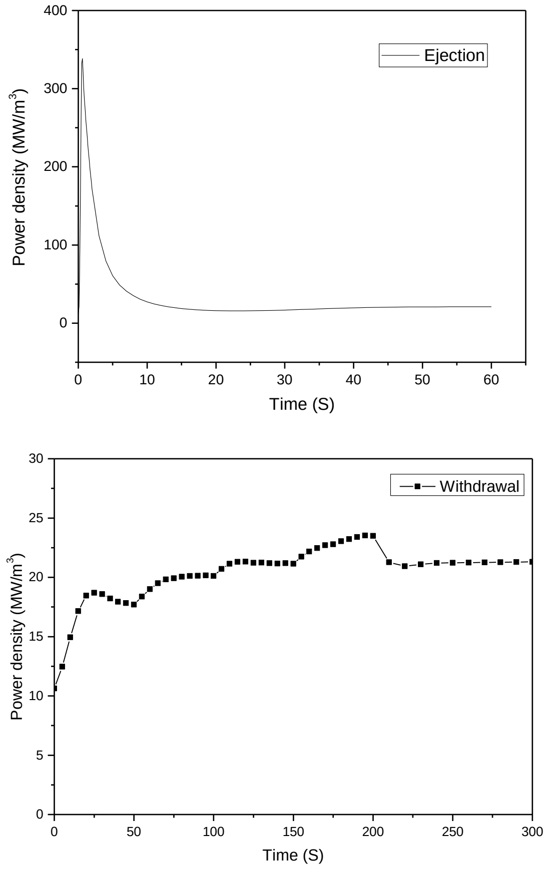
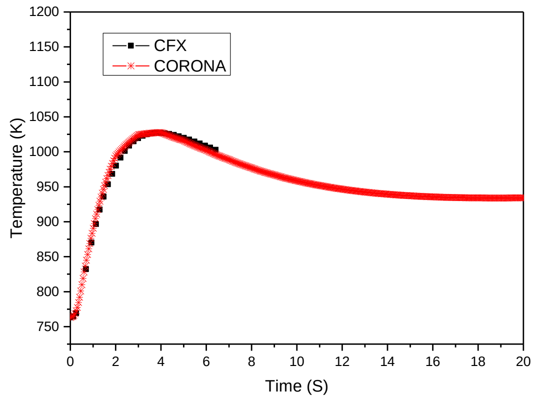


Fig. 2. Power variation according to control rod movement (Top : ejection, Bottom : withdrawal)

The calculated results by the CORONA code were compared with the obtained data by the CFX S/W in Fig. 3. The calculated data well matches each other. There are little differences because the CORONA code do not consider the transient term in the fluid equations.



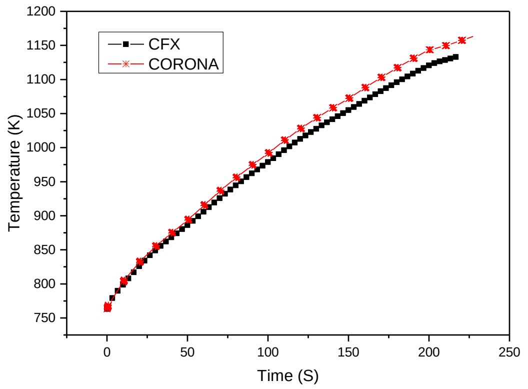


Fig. 3. Temperature comparison results(Top : ejection, Bottom : withdrawal)

3. Conclusions

The transient calculations by the CORONA code were verified with the CFX S/W. The transient algorithm was implemented to predict the detailed temperature distribution during short time power changes. It is confirmed that the calculated data by the CORONA code well agree with the data obtained by the CFX S/W.

Acknowledgements

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