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# Validation of Turbulence Models for Pool Natural Convection in CUPID Code

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## 1. Introduction

Thermal hydraulic power phenomenon prediction technique of nuclear reactor cooling system is a very important technique for performance and safety evaluation of nuclear power plant.

For this, system analysis codes based on one-dimension model have been developed for last several decades. In these codes, multi-phase flow phenomenon is estimated as one-dimension model, and they use flow regime map developed in fully developed flow condition of a stationary state, and have numerical sturdiness because of one-dimension differential time and space, but have difficulty to predict multi-phase phenomenon, big numerical spread [2].

Recently, to overcome these limits, multi-phase thermal hydraulic power analyzing code (CUPID) is being developed by Korea Atomic Energy Research Institute (KAERI). Therefore, it is necessary to verify performance of CUPID through comparison of analysis results among CUPID and FLUENT.

## 2. Methods

### 2.1. Mathematical model

The problem under consideration is depicted schematically in figure 1. The flow domain is the interior of a 2D square cavity of W=H. The horizontal walls of the cavity are assumed to be perfectly adiabatic, while the vertical walls are kept isothermal with the left wall at high temperature $T_H = 303\text{K}$ and the right wall at low temperature $T_C = 283K$. The interior of the cavity is filled with water. The water properties are calculated by using two methods in FLUENT. One is constant property, the other is variable property using piecewise-linear interpolation. The constant property is taken as the value of $T_m = 293K$. Density is calculated by using Boussinesq approximation for the fluid. On the other hand, all properties are calculated by table data in CUPID. We performed calculation at $\text{Ra} = 10^{10}$. In order to obtain Ra, we controlled the cavity size. TableⅠ shows the cavity size of water case and TableⅡ shows water properties. Figure 2 shows the uniform node distribution to use in this paper.

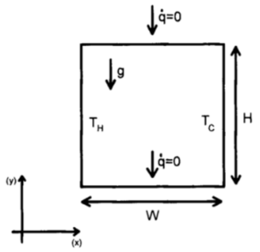

Fig 1. Schematic representation of cavity [3]

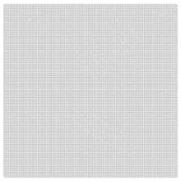

Fig 2. Uniform grids (80×80 nodes)

TableⅠ:Cavity size

| Ra | W |
|---|---|
| **$10^4$** | **0.00329m** |
| **$10^{10}$** | **0.329m** |

TableⅡ :Properties

| | 283K | 293K | 303K |
|---|---|---|---|
| **$C_p$** | 4196 | 4185 | 4180 |
| **μ** | 0.00131 | 0.00100 | 0.00080 |
| **k** | 0.5800 | 0.5982 | 0.6150 |
| **β** | 0.000088 | 0.000207 | 0.0003030 |
| **ρ** | 999.714 | 998.236 | 995.6966 |

### 2.2. Turbulent flow, k-$\varepsilon$ model

In this section, we calculated turbulent flow. We performed two different calculation by using constant and piecewise-linear properties. Figures 3,4 and 5 show the distributions of the temperature, u-velocity and v-velocity, respectively.

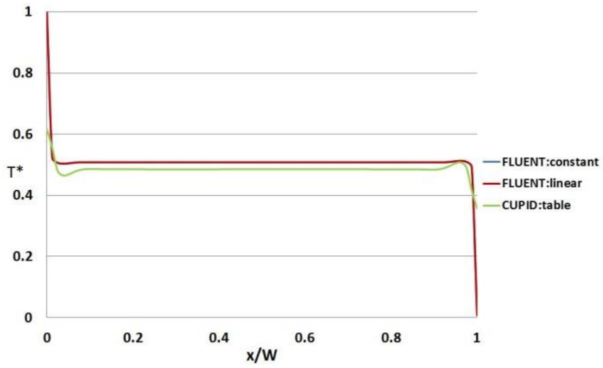

Fig 3. Temperature distribution (y/H=0.5)

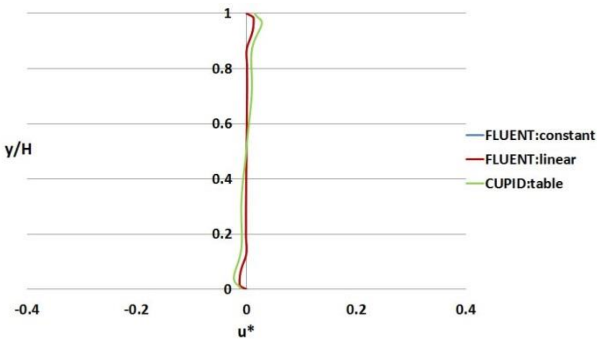

Fig 4. Distribution of u-velocity (x/W=0.5)

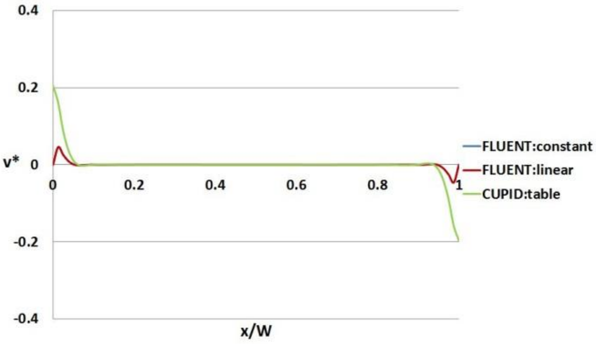

Fig 5. Distribution of v-velocity (y/H=0.5)

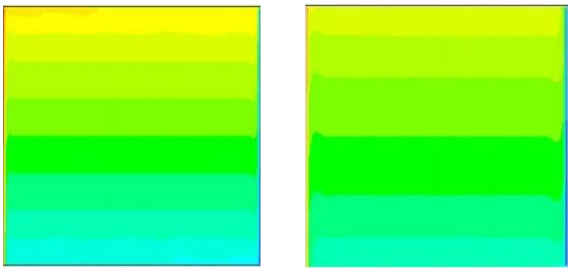

Fig 6. Fluent isotherms no model (left), k-ε model (right).

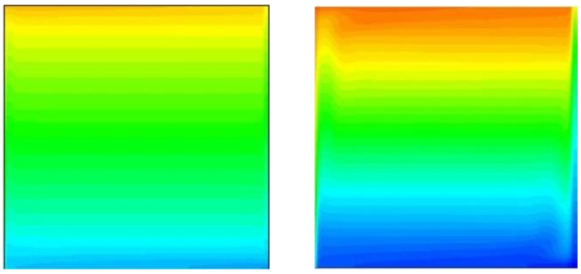

Fig 7. CUPID isotherms no model (left), k-ε model (right).

## 3. Conclusions

In this study, the prediction of CUPID code for pool natural convection problem was assessed against Fluent code results. Although some difference between CUPID and Fluent is seen near the walls, overall results for both codes are quite similar. In the final presentation, it would be discussed the similarity and difference between CUPID and Fluent results from a view point of turbulence models.

## APPENDIX: Nomenclature

| | |
|---|---|
| $T_c$ | temperature of cold wall (K) |
| $T_H$ | temperature of hot wall (K) |
| $T_m$ | reference temperature, $T_m = (T_H + T_c)/2$ (K) |
| $T^*$ | dimesnsionless temperature, $T^* = (T - T_c)/\Delta T$ |
| $u$ | horizontal velocity component (m $s^{-1}$) |
| $u^*$ | dimensionless horizontal velocity component, $u^* = u/\sqrt{g\beta\Delta TH}$ |
| $v$ | vertical velocity component (m $s^{-1}$) |
| $v^*$ | dimensionless vertical velocity component, $v^* = v/\sqrt{g\beta\Delta TH}$ |
| $C_p$ | specific heat (J/kg · K) |
| μ | viscosity (kg/$m^3$) |
| k | thermal conductivity (W/m · K) |
| β | coefficient of thermal expansion (1/K) |
| ρ | density (kg/$m^3$) |

## REFERENCES

[1] Yadigaroglu, G., Andreani, M., J. and Coddinggton, P., “Trends and needs in experimentation and numerical simulation for LWR safety.” Nuclear Engineering and Design, Vol.221, pp.205-223, 2003.

[2] I.K. Park, H.K. Cho, J.R. Lee, J.W. Kim, H.Y. Yoon, H.D. Lee and J.J. Jeong, “The Development and Assessment Strategy of A Thermal Hydraulics Component Analysis Code.” Korean Society for Computational Fluids Engineering, Vol. 16, No. 2, pp. 30-48, 2011.

[3] G.Barakos , E.Mitsoulis, D.Assimacopoulos, “Natural Convection Flow in a Square Cavity Revisitied : Laminar and Turbulent Models with Wall Functions”, International Journal for Numerical Methods in Fluids, vol. 18, pp. 695-719, 1994.