Evaluation of Two Different $k-\varepsilon-\overline{vv}-f$ Turbulence Models for Natural Convection in a Rectangular Cavity

S. K. Choi [1], ***E. K. Kim*** [2], ***S. O. Kim*** [3]
1. Fluid Engineering Division, Korea Atomic Energy Research Institute, Email)skchoi@kaeri.re.kr
2. Fluid Engineering Division, Korea Atomic Energy Research Institute ,Email)ekkim1@kaeri.re.kr
3. Fluid Engineering Division, Korea Atomic Energy Research Institute, Email)sokim@kaeri.re.kr

Corresponding author ***S. K. Choi***

Abstract

Two different $k-\varepsilon-\overline{vv}-f$ turbulence models together with the two-layer model are evaluated for natural convection in a rectangular cavity. The numerical problem and accuracy of the turbulence models are discussed. The original $\overline{vv}-f$ model suffers from the numerical stiffness problem when used with the segregate solution procedure like the SIMPLE algorithm, and a remedy for this problem is proposed. It is shown that original $\overline{vv}-f$ model best predicts the mean velocity, Reynolds stresses and the turbulent heat flux while the modified $\overline{vv}-f$ model (N=6) overpredicts the turbulent quantities.

Keyword: $k-\varepsilon-\overline{vv}-f$ *turbulence models, turbulent natural convection*

1. Introduction

A proper prediction of natural convection phenomenon is very important for investigating the fluid flow and heat transfer in the reactor vessel auxiliary cooling system adopted in the Korea advanced liquid metal reactor design. The present study is devoted to the test of turbulence models for prediction of natural convection phenomenon . The primary objective of the present study is the evaluation of the Durbin's $k-\varepsilon-\overline{vv}-f$ model [1] for the natural convection problem. The two-layer $k-\varepsilon$ model by Chen and Patel [2] is also considered for comparison. The original $k-\varepsilon-\overline{vv}-f$ model suffers from the numerical stiffness problem when used with the segregate solution procedure like the SIMPLE algorithm. Lien et al. [3] developed the "N=6 model" to avoid this problem. In the present study, we develop a source term linearization like treatment near the solid boundary to avoid the numerical stiffness problem of the original $k-\varepsilon-\overline{vv}-f$ model. We also compare the accuracy and convergence between two models for prediction of natural convection in a rectangular cavity.

2. Test Problem

The test problem considered in the present study is a natural convection of air in a rectangular cavity with aspect ratio of 5:1. The Rayleigh number based on the height of cavity is $Ra=4.5\times10^{10}$ and Prandtl number is $\Pr=0.7$. King [4] has made extensive measurements for this problem and experimental data are reported in Cheesewright et al. [5] and King [4].

3. Results and Conclusions

The Fig.1 to Fig. 4 show the comparisons of the predicted mean vertical velocity, velocity fluctuation, turbulent heat flux and Reynolds shear stress with the measured data. We can observe that the original $\overline{vv}-f$ model (N=0) best predicts all the variables and the modified $\overline{vv}-f$ model (N=6) fairly well predicts the mean velocity, but it overpredicts turbulent quantities. The two-layer model poorly predicts all the quantities when compared with those by the $\overline{vv}-f$ models. However, the original

$\overline{vv}-f$ model suffers from the numerical stiffness problem and we proposed a remedy of this problem. The modified $\overline{vv}-f$ model do not exhibits the numerical stiffness problem, but its accuracy is worse than the original model.

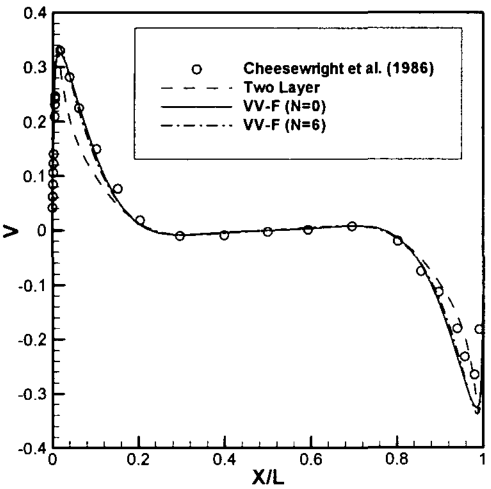

Fig.1 Vertical velocity profiles at y/H=0.5

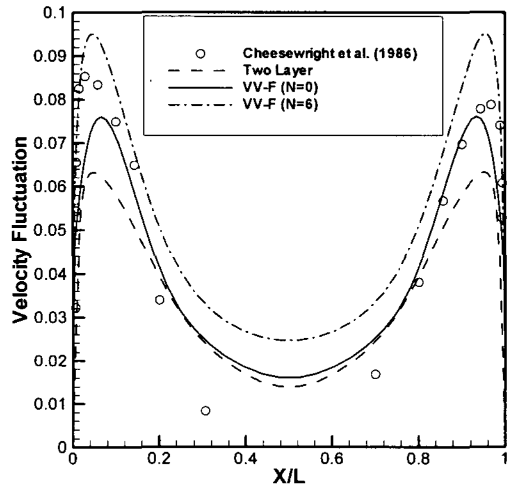

Fig.2 Vertical velocity fluctuation profiles at y/H=0.5

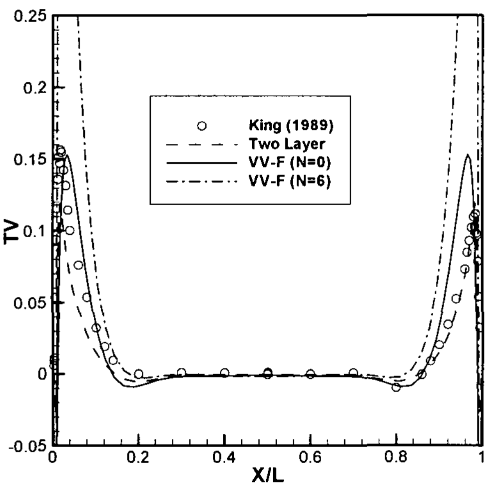

Fig.3 Vertical heat flux $\overline{\theta v}$ profiles at y/H=0.5

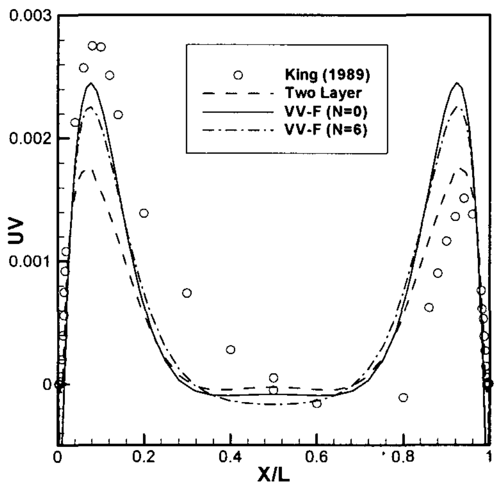

Fig.4 Reynolds stress $\overline{uv}$ profiles at y/H=0.5

References

[1] Durbin, P. A "Separated flow computations with the $k-\varepsilon-\overline{v^2}$ model," *AIAA J.* **33**, (1995), pp. 659-664.

[2] Chen, H. C. and Patel, V. C, "Near-wall turbulence models for complex flows including separation," *AIAA J.*, **26**, (1988), pp. 641-648.

[3] Lien, F. S., Kalitzin, G. and Durbin, P. A., "RANS modeling for compressible and transitional flows", Center for Turbulence Research, Proceedings of the Summer Program, (1998).

[4] King, K. V., "*Turbulent natural convection in rectangular air cavities,*" Ph.D Thesis, Queen Mary College, University of London, UK. (1989).

[5] Cheesewright, R., King K. J. and Ziai, S, "Experimental data for the validation of computer codes for the prediction of two-dimensional buoyant cavity flows," *Proceeding of ASME Meeting*, HTD, **60**, (1986). pp. 75-86.