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Natural Convection Analysis with Various Turbulent Models Using FLUENT

Yu sun Park
Korea Advanced Institute of Science and Technology, Daejeon, 305-701, Korea, Republic of.
Tel : +82-42-869-3856, Fax : +82-42-869-3810, Email : pink_0425@kaist.ac.kr

1. Introduction

The buoyancy driven convective flow fields are steady circulatory flows which were made between surfaces maintained at two fixed temperatures. They are ubiquitous in nature and play an important role in many engineering applications. Especially, in last decades, natural convection in a close loop or cavity becomes the main issue in the molecular biology for the polymerase chain reaction (PCR)[1]. Application of a natural convection can reduce the costs and efforts remarkably. This paper focuses on the sensitivity study of turbulence analysis using CFD for a natural convection in a closed rectangular cavity. Using commercial CFD code, FLUENT, various turbulent models were applied to the turbulent flow. Results from each CFD model will be compared each other in the viewpoints of flow characteristics. This work will suggest the best turbulent model of CFD for analyzing turbulent flows of the natural convection in an enclosure system.

2. Geometry Description

The cavity system is a closed hexahedron. Each edge has a length of 20 mm, 6 mm, and 4 mm as shown in Fig. 1. This cavity is filled with a PCR mix which will be replaced by water in this study. Then the cavity volume is heated from the bottom surface to 60^{o}C while the top surface is maintained cool at 20^{o}C so that the natural convection flow can be formed in the volume. Other surfaces consisting side of the rectangular cavity were set to the adiabatic condition so the heat goes out only through the top surface.

For this case, Rayleigh number is 9.95×10^4 and the flow in the cavity can be expected as turbulence[2].

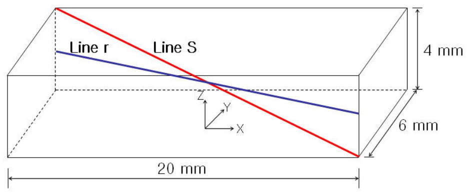

Fig. 1. Geometry description of a cavity system

3. Result and Conclusion

In this study, all seven models offered in FLUENT, Spalart-Allmaras model, κ-ε models, κ-ω models, and RSM, were used to predict flow characteristics of the natural convection of a rectangular cavity. As one can expect, hot fluid at the bottom surface goes up and cold fluid at the top surface goes down making a circular motion of fluid in all models. However, circular motions of fluid are different in detail between models. The difference of κ-ε models with others were shown definitely in Fig. 11 and Fig. 12 that show temperature and velocity distributions along line r, from (0.01, -0.003, 0.002) to (-0.01, 0.003, 0.002) in Fig. 1.

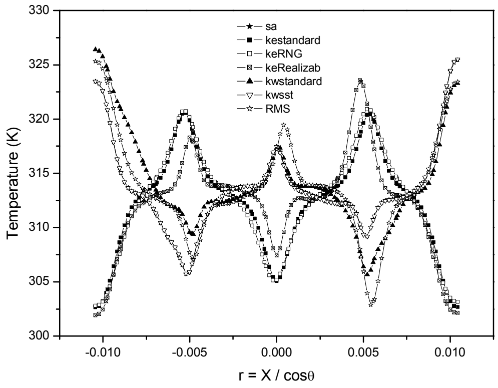

Fig. 11. Temperature distribution along line r

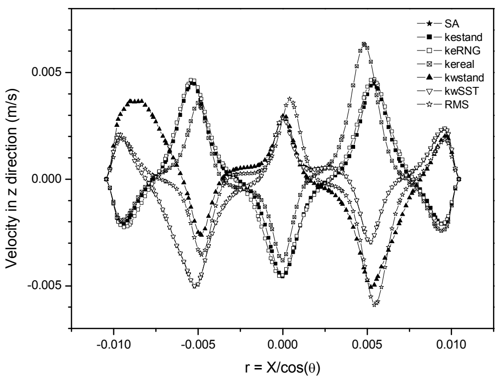

Fig. 12. Velocity distribution in z direction along line r

This difference of κ-ε models with others can be explained by the near wall region treatment. For modeling near-wall flow with a κ-ε model, it is necessary to use either a wall function or other strategies like two layer modeling scheme. The choice of one or the other option is governed by the analysis of y^+ parameter. For standard or non-equilibrium wall functions, the center of each wall-adjacent cell should be located within the log-law layer, $30 < y^+ < 300$. As much as possible, the mesh should be made either coarse or fine enough to prevent the wall-adjacent cells from being placed in the buffer layer ($y^+ = 5 \sim 30$). When the enhanced wall treatment is employed, y^+ at the wall-adjacent cell should be on the order of $y^+ = 1$ and a higher y^+ is acceptable as long as it is well inside the viscous sub-layer ($y^+ < 4$ to 5). So values of $1 < y^+ < 5$ allow the use of a two layer modeling scheme. On the other hand, two κ-ω models are available as low Reynolds number models (low y^+ values) as well as high Reynolds number models (high y^+ values).

However, values of y^+ in this rectangular cavity system for all used cases are smaller than 1, thus this is inadequate for κ-ε models with a wall function or two layer modeling. If y^+ value is increased to get a proper value for using κ-ε models, the size of control volumes will be increased in this fixed system condition resulting too coarse grid resolution. Thus, for this small rectangular cavity system, κ-ω models or RSM is proper than κ-ε models.

REFERENCES

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