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Numerical study of flow and heat transfer for incompressible flows past open cavity

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ABSTRACT

The fluid dynamic flow and heat transfer past open cavities have been the subject of extensive studies due to their importance in various engineering applications, such as in solar energy collectors and electronic components, see [2,3] and references therein. The presence of such type of geometry is of interest because of the convective heat transfer that occurs between the cavity and the forced flow stream. The thermal performance was found to be higher when the cavity experiences heat flux in the side opposing the inflow motion. The two-dimensional version of this problem has received considerable attention. However, to the best of our knowledge, very few results have been obtained for the three-dimensional case. In this work, a direct numerical simulation (DNS), using a three-dimensional finite volume solver [4], is undertaken to investigate the mixed convection for assisting and forcing incompressible flow past a three dimensional cavity that lies at the bottom of a horizontal channel. The cavity is assumed to be cubic in geometry and the flow is laminar. The Reynolds numbers based on the height of the cavity and the free-stream velocity are 100 and 1000, and the Richardson numbers are between 0.001 and 10. Two different heating modes are considered: (a) the vertical wall facing the opening (forced flow), or (b) the vertical wall in the inflow (assisting flow), are heated at constant temperature while all other walls are adiabatic. Three computations on three different meshes are made for each simulation in order to check the effect of the mesh resolution on the surface average Nusselt number at the heated wall. The fine and coarse meshes give similar results meaning that the results are mesh independent. Good agreement is obtained between bi-dimensional results of mixed convection in vertical open enclosure, see [1], and those predicted by Khanafer et Al. [1]. The DNS results show that the flow exhibits a three-dimensional structure and becomes steady for $Re = 100$ with Ri ranging from 0.01 to 10 and $Re = 1000$ with Ri ranging from 0.01 to 0.1. The forced flow dominates the flow transport mechanism and large recirculating zone forms inside the enclosure which results in heat transfer by conduction. In this case the Nusselt number increases slightly. For both high Reynolds and Grashof numbers, $Re = 1000, Gr = 10^6$, the natural convection comes into play and push the recirculating zone further upstream and the flow becomes unsteady with Kelvin-Helmholtz instabilities for forced flow mode at the shear layer. For $Re = 1000$ and $Gr = 10^7$ the isotherm lines remain parallel close

to the heated wall and form a thermal boundary layer. It is found that the average Nusselt number was high when the heated wall is in the opposite flow side. The work gives quantitative results for the velocity components resulting from various locations to give the idea of recirculating and ascending flow structure. We present also a picture of the unsteady flow and its instabilities in some constant plans at high Reynolds and Richardson numbers.

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