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NUMERICAL SIMULATIONS OF NATURAL CONVECTION FLOW IN A RECTANGULAR CAVITY UNDER TRANSIENT BOUNDARY CONDITIONS

*** D. Kizildag, C. D. Pérez-Segarra, A. Oliva, I. Rodríguez**

Centre Tecnològic de Transferència de Calor (CTTC)
Universitat Politècnica de Catalunya (UPC)
ETSEIAT, C. Colom 11, 08222 Terrassa (Barcelona), Spain
cttc@cttc.upc.edu, http://www.cttc.upc.edu

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ABSTRACT

This work is aimed at presenting numerical predictions regarding unsteady natural convection in a rectangular cavity. The flow in the buoyancy-driven cavity of $7:1$ aspect ratio is numerically analyzed for water $(Pr = 3.77)$ which is exposed to hot and cold vertical plates with periodic temperatures. The results are obtained for three different variable Rayleigh numbers sets whose maximum values are $1.58 \cdot 10^5$, $1.58 \cdot 10^8$, and $1.58 \cdot 10^{11}$. Outcome of the numerical experiment is of interest as it permits to estimate the unsteady heat transfer in a rectangular parellelepiped tank of an integrated solar collector [1].

Numerous correlations of the Nusselt number have been reported in the literature regarding laminar and turbulent natural convection flow in vertical cavities for steady state situations [2,3], which cannot necessarily predict the transient heat transfer rate with accuracy. This work allows to check the capability of the steady state correlations to provide reasonable predictions for transient situations.

Two-dimensional Navier-Stokes equations together with the energy equation assuming constant thermophysical properties, Newtonian fluid behaviour, and Boussinesq approximation, have been solved by means of finite-volume techniques on structured grids using a staggered arrangement [4]. Diffusive terms are evaluated by central differences, while convective terms are discretized by using high-order SMART scheme [5]. Second order fully implicit time integration has been applied [6] and the resulting system of algebraic equations is solved employing a pressure-based SIMPLE-like algorithm [7].

In dealing with turbulent flows, different RANS and LES models have been tested [8,9,10,11]. Parallel computing strategies have been employed in order to reduce the computational cost of the transient solutions.

Numerical solutions are verified by means of a transient post processing tool [12] based on the generalised Richardson extrapolation and the Grid Convergence Index [13], which determines the sensibility

of the simulation to the computational model parameters. Using the solutions obtained by individual and simultaneous refinement of the space and time mesh, the error band that contains the grid-independent solution is obtained together with the criteria on the credibility of the accuracy estimators.

In order to validate the simulations, in some cases, numerical experiments obtained by Direct Numerical Simulations are employed [14].

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