Simulation of Lid-Driven Cavity with Top and Bottom Moving Boundary Conditions using CFD

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KEYWORD

CFD; Lid-Driven Cavity; Forced Convection; Heat Generation; Rectangular Channel

ABSTRACT

CFD tools have a significant benchmark problem, and one of the most impressive tools is the lid-driven cavity. This study proposes a benchmark tool for CFD modeling of a lid-driven cavity with top and bottom changing boundary conditions. An unstable Navier-Stokes equation in a primitive variable formulation is employed as the governing equation. The implicit finite difference approach with fine meshing is used to solve the problem. As a result, a symmetrical vortex with half top and half bottom is formed. The Reynolds number was varied from 100, 500 and 1000. In this study, we also discuss the secondary vortex in particular situations. The velocity profile is also shown in quarter, half, and three-fourth full x and y axes.

1. Introduction

Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical analysis and data structures to analyze and solve problems that involve fluid flows. The fundamental basis of almost all CFD problems is the Navier-Stokes equations, which define many single- phase (gas or liquid but not both) fluid flows. In this phenomenon the lid driven cavity problem is the most standard CFD tools that has been examined for a long time. The issue occurs when fluid fills and flow through a confined chamber, and generally only one fluid component is involved. In this issue usually contained a rectangular two-dimensional capacity with two borders contained zero velocity and two (Top and Bottom) walls moving with a known velocity. The problem Lid-driven cavity model has long been recognized as a good model for assessing the numerical resolution of the standard equation.

In this phenomenon of grooved (closed) channels are two-sided movement of the lid-driven cavity (Top and Bottom wall).

In this paper, the structure of the present is the mathematics modeling and governing equation that is used, then the numerical and code that solves the mathematics model, then the result and discussion for conclusions that can be addressed in this research.

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2. Problem Formulation

This research focuses on the enthralling domain of computational fluid dynamics (CFD) within a rectangular channel. A rectangular channel having dimensions of 2m in height (H) and 2m in length (L). While going in the positive x-direction, the top wall of the channel maintains the no slip condition. Similarly, the bottom wall of the channel maintains the no slip condition while moving in the negative x-direction constantly. The other walls are immobile. The rectangular channel's upper and bottom walls are insulated, while the other two side walls are one heating wall and one cooling wall. The working fluid of Prandtl number (Pr) equals to 0.71 and 5.83 are utilized for this investigation. The walls are filled with water and air, and the walls are at a specified reference temperature. Except for the mass density, which varies according to the Boussinesq approximation, the thermo-physical parameters of the working fluid are considered to remain constant. The fluid is taken to be Newtonian and incompressible.

a. Mathematical Modeling & Governing Equations

Computational Domain & Boundary Conditions

The computational domain is a fluid-filled square box, with the configuration and boundary conditions described by the equations for the left-right side wall u = v = 0 and the top-bottom wall u = 1, v=0.

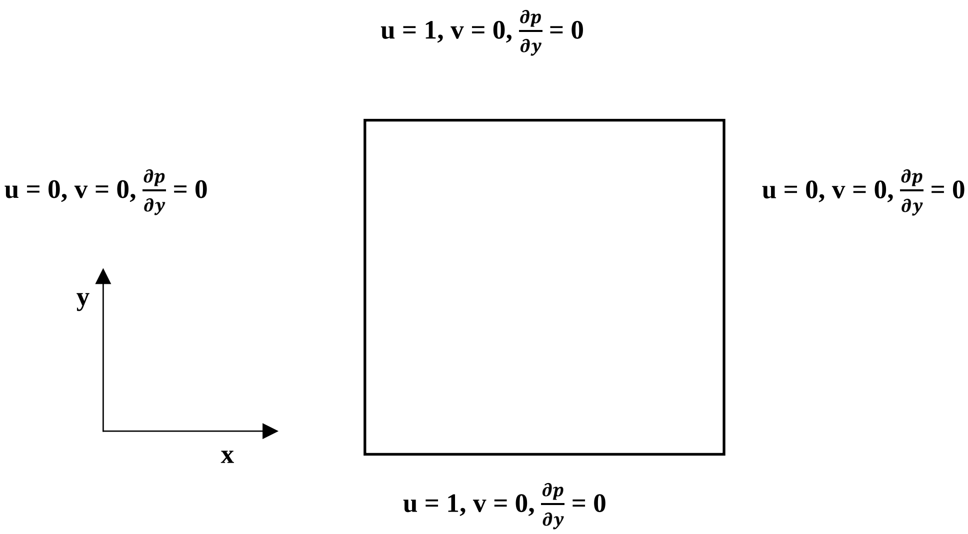

FIGURE.1: Computational Domain & Boundary Condition

Governing Equations

In this situation, the governing equations of Lid Driven Cavity are continuity and momentum equations. The governing equations for unstable and incompressible 2-D instances are as follows:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial x} = 0 \qquad (1)$$

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$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \frac{-\partial p}{\partial x} + \frac{1}{Re}\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) \quad (2)$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = \frac{-\partial p}{\partial y} + \frac{1}{Re}\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right) \quad (3)$$

Where: u and v are directional velocity components -x and -y,
p is pressure term

Re is Reynolds number

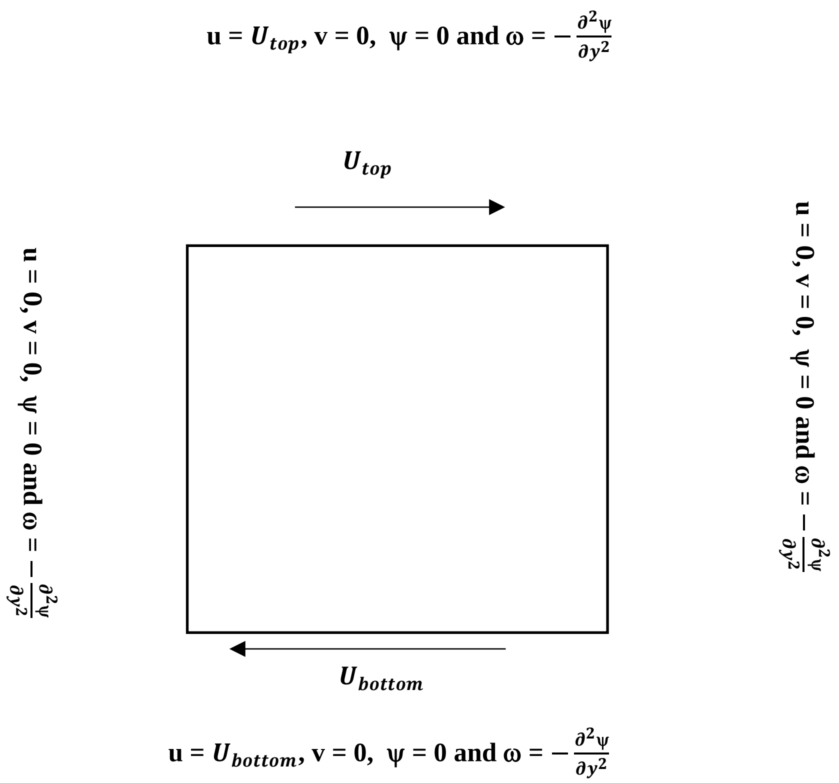

FIGURE.2: The dimensionless 2D symmetric two-sided lid-driven cavity.

3. Result & Discussion

The results obtained for Re = [100, 500 & 1000] are displayed in this paper. Basically, present works deals with the captivating domain of computational fluid dynamics and the study investigate for lid driven cavity on a rectangular channel with top and bottom wall moving simultaneously.

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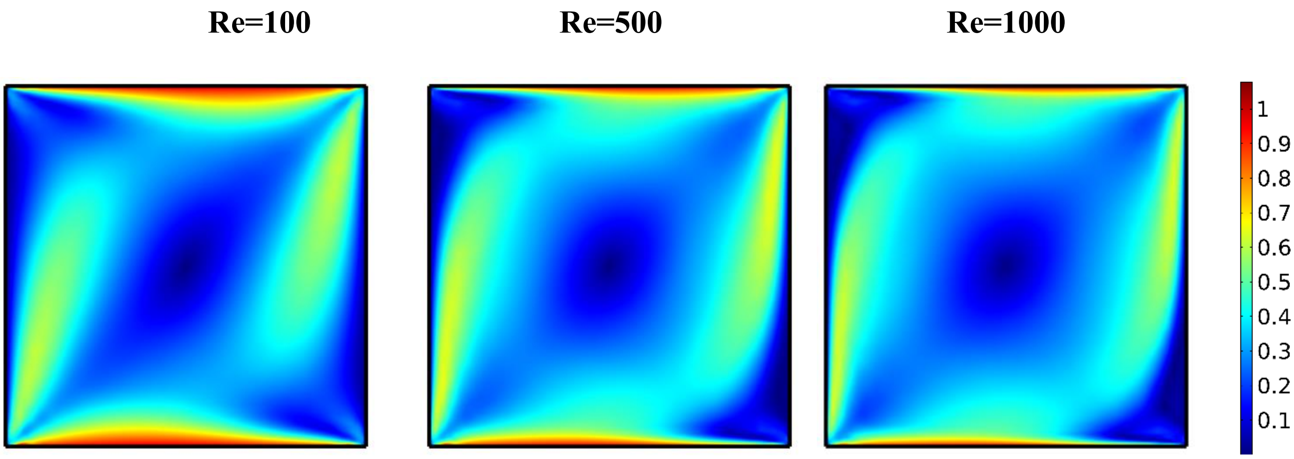

FIGURE.3: Color filled magnitude plot: Absolute velocity (**Pr= 0.71, 5.83**)

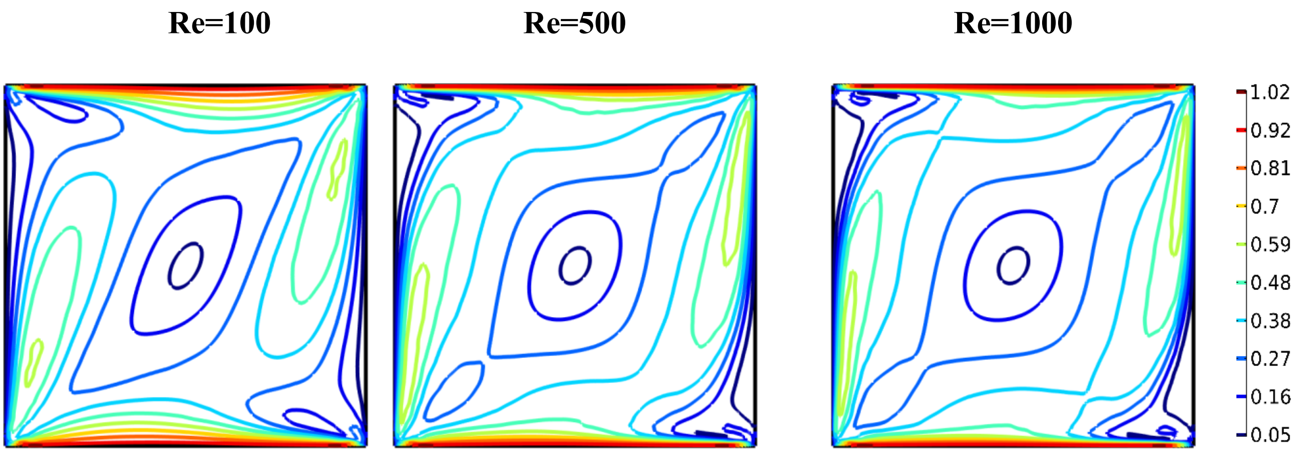

FIGURE.4: Absolute velocity contour plot

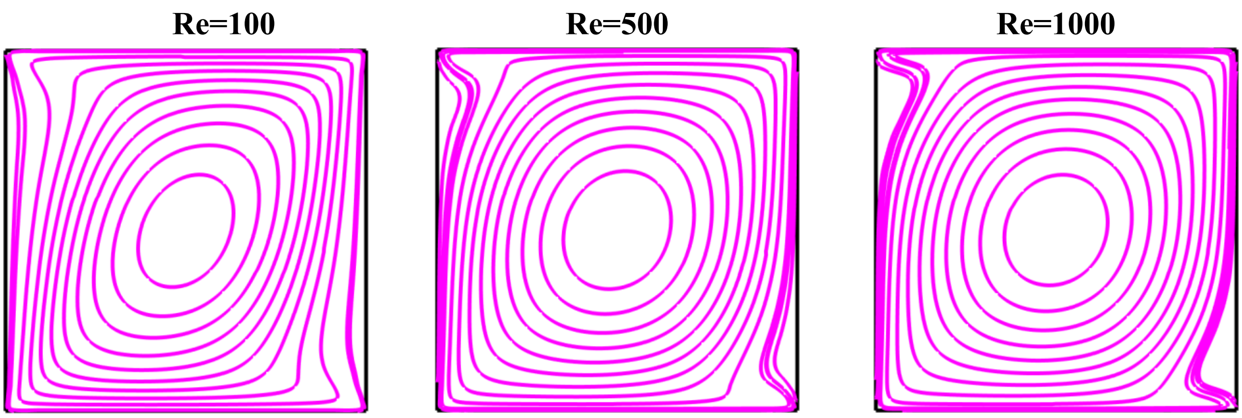

FIGURE.5: Streamlines contour plot

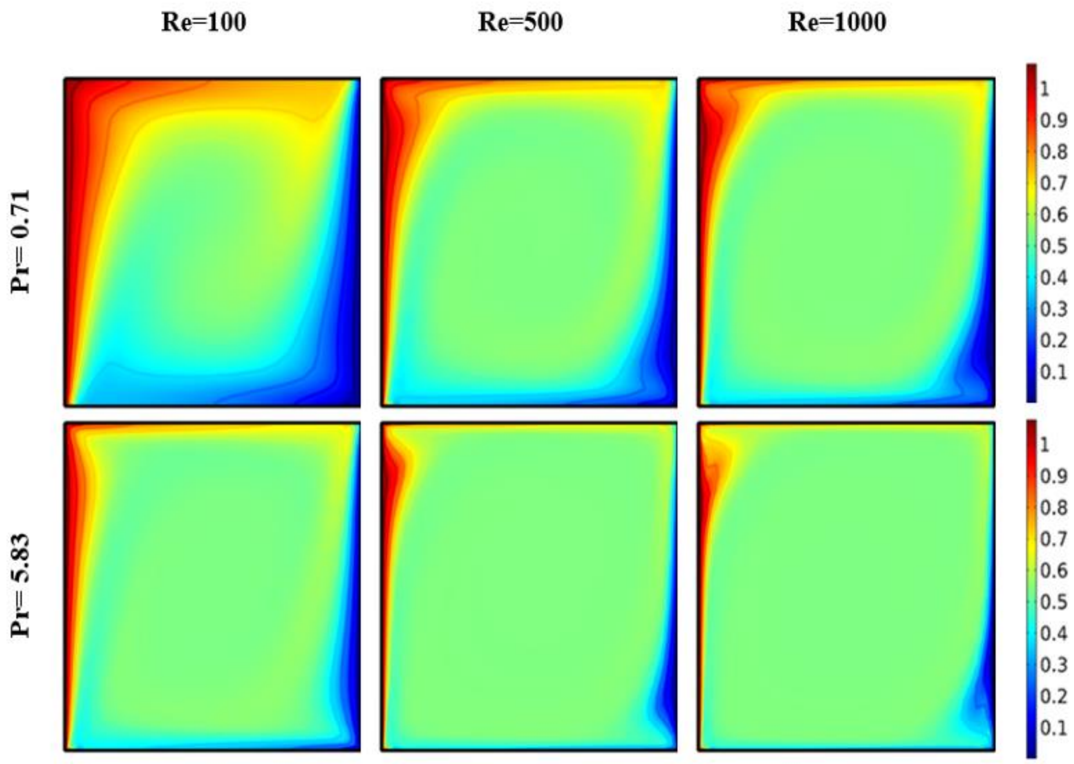

FIGURE.6: Temperature surface plot

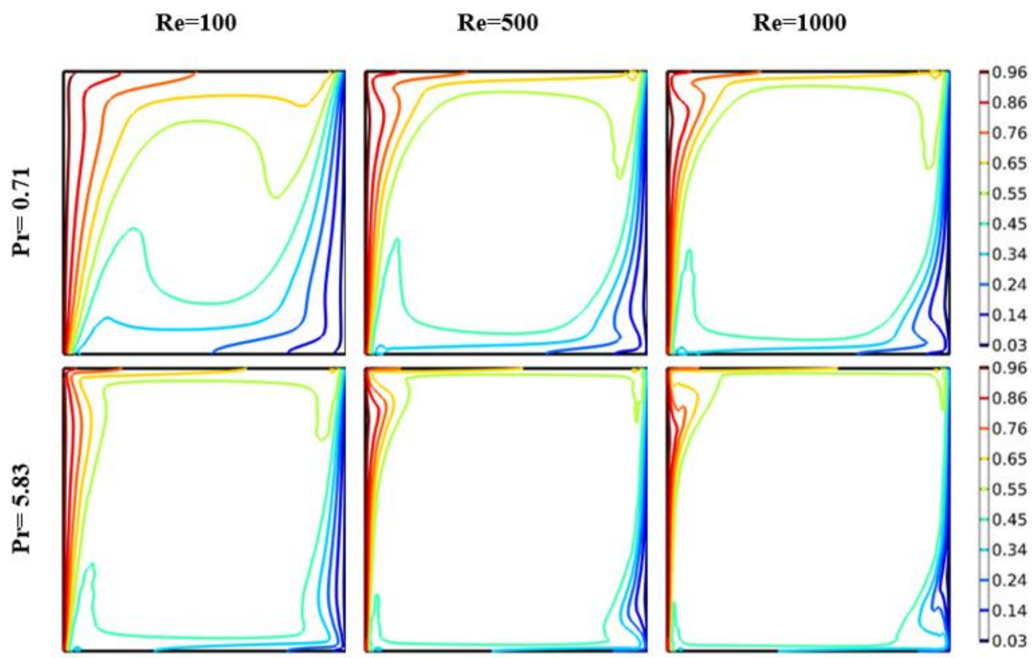

FIGURE.7: Isotherm plot (**Pr =0.71, 5.83**)

Under the result section the color filled magnitude plot, absolute velocity & streamlines contour plot are given. Figure 3 shows the color filled magnitude plot of absolute velocity where the plot of absolute velocity is same for both air (Pr= 0.71) and water (Pr= 5.83). Figure 4 shows the color filled magnitude plot of absolute velocity contour plot, Figure 5 shows the color filled magnitude plot of Streamline contour plot where the plot of absolute velocity is same for both air (Pr= 0.71) and water (Pr= 5.83). In case of temperature surface plot, we get different different color filled magnitude plot for air (Pr= 0.71) and water (Pr= 5.83). In Figure 7 we can see the isotherm plot in rainbow color where the different color shows different variations. For the whole study we are taking basically three types of Reynolds number (Re= 100, 500 & 1000). So, we are getting results according to Reynolds number.

Conclusion

The lid-driven cavity fluid flow with shifting boundary conditions at the top and bottom was solved using the implicit finite difference method and a staggered grid. The lid-driven cavity fluid flow with top and bottom moving boundary conditions may be solved using the implicit finite difference technique and a staggered grid up to Re = 1000. The pressure correction method and implicit finite difference were used to calculate numerical solutions to Navier-Stokes incompressible equations. The symmetrical solutions are found for Reynolds number values ranging from 100 to 1000. All of these answers are consistent. The symmetrical solutions are those that optimize the conversion of input energy into flow kinetic energy.

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