

Numerical Simulation of Two-Dimensional Constant Density Thick Flow in a Lid-driven Cavity

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Abstract – In this flow problem work, the Lid Driven Cavity prediction in rectangular using the stream function- vorticity formulation for the. The governing equations are discretised and the variation of flow is studied by using the simulation software. Graph of Variation of Local skin Friction coefficient along left and right wall of the Cavity is shown . Variation of local skin friction coefficient along top and bottom wall of the cavity is plotted. Flow simulation for Reynold number 200 is taken with a square cavity the bottom is not moving- top lid is moving.

Index Terms— CFD, lid driven cavity, stream function, skin friction coefficient, vorticity.

I. INTRODUCTION

I have used the FEA technology, now it is possible to analyse the fluid flow problem, in general any engineering problems. Now a days the CFD approach is becoming popular has come in this way. In the present work of flow analysis inside a square cavity with the top lid moving with low velocity is analyzed and resultof velocity contour is got with fluent software. Model is done first is created and then the fluid domain is discretized by grid. In the solver and postprocessor its solutions and result are obtained. Basically a theory of FEA and stream function-vorticity method is used and new software tool are applied. This technique may be used for designing of any fluid device by using the advantage of CAE. These phenomena are governed by sets of integral calculus equations which in most cases have no analytical solution. The boundary and initial conditions, material properties, and geometrical details are used in order to clearly describe the problem.

2.GOVERNING EQUATIONS AND NUMERICAL PROCEDURE

2.1Continuity equation

Physical principle: - Constant mass.

$$\frac{\partial}{\partial t} \iiint_V \rho \, dV + \iint_S \rho \, V \, dS = 0$$

2. 2 Momentum equation

Physical principle: - Newton’s second law (F=ma)

$$\frac{\partial(\rho u)}{\partial t} + \nabla \cdot (\rho u V) = -\frac{\partial p}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} + \rho f_x$$

$$\frac{\partial(\rho v)}{\partial t} + \nabla \cdot (\rho v V) = -\frac{\partial p}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{zy}}{\partial z} + \rho f_y$$

$$\frac{\partial(\rho w)}{\partial t} + \nabla \cdot (\rho w V) = -\frac{\partial p}{\partial z} + \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z} + \rho f_z$$

Equations are the momentum equations in x, y and z direction respectively in conservation form.

$$\rho \frac{Du}{Dt} = -\frac{\partial p}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} + \rho f_x$$

$$\rho \frac{Dv}{Dt} = -\frac{\partial p}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{zy}}{\partial z} + \rho f_y$$

$$\rho \frac{Dw}{Dt} = -\frac{\partial p}{\partial z} + \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z} + \rho f_z$$

2.3 Discretisation methods

The discretisation methods i.e. the numerical methods for solving PDEs include the finite difference methods (FDM), and the finite volume method (FVM) is used(Fig2.3).

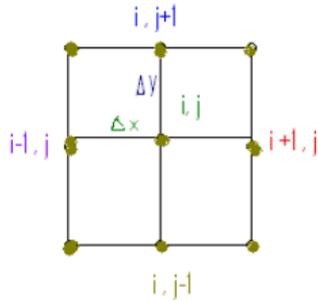


Fig.2.3.Mesh cell type

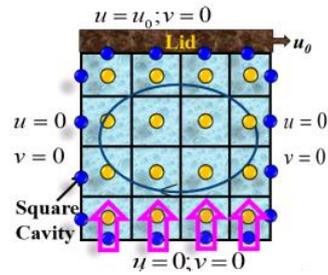


Fig.2.4.1.Boundary Condition

2.4 Stream Function Formulation

Flow prediction in Cartesian using the stream function- vorticity formulation

For two dimensional steady incompressible flow in a rectangular geometry, the governing equations for stream function and vortices are the following:

(i) Definition of vorticity:

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} = -\omega \quad \text{-----(1)}$$

Where ψ is the stream function and ω is the vorticity

(ii) Convective – diffusive transport equation for vorticity

$$\left(u \frac{\partial \omega}{\partial x} + v \frac{\partial \omega}{\partial y} \right) = \nu \left\{ \frac{\partial^2 \omega}{\partial x^2} + \frac{\partial^2 \omega}{\partial y^2} \right\} \quad \text{-----(2)}$$

Where the velocity components u and v are given by

$$u = \frac{\partial \psi}{\partial y}$$

$$v = -\frac{\partial \psi}{\partial x} \quad \text{-----(3)}$$

The boundary conditions for the lid-driven cavity problem are

$$u = 0, v = 0 \text{ at } x = 0; \quad u = 0, v = 0 \text{ at } y = 0;$$

$$u = 0, v = 0 \text{ at } x = L; \quad u = U_0, v = 0 \text{ at } y = H; \quad \text{-----(4)}$$

Where U_0 is the velocity of the lid.

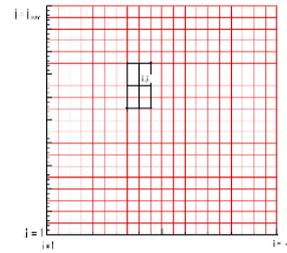


Fig.2.4.2.Grid,type cartesian 51 x51

$$\frac{\psi_{i+1,j} + \psi_{i-1,j} - 2\psi_{i,j}}{\Delta x^2} + \frac{\psi_{i,j+1} + \psi_{i,j-1} - 2\psi_{i,j}}{\Delta y^2} = -\omega_{i,j}$$

$$u_{i,j} \left[\frac{\omega_{i+1,j} - \omega_{i-1,j}}{2\Delta x} \right] + v_{i,j} \left[\frac{\omega_{i,j+1} - \omega_{i,j-1}}{2\Delta y} \right] =$$

$$\nu \left\{ \frac{\omega_{i+1,j} + \omega_{i-1,j} - 2\omega_{i,j}}{\Delta x^2} + \frac{\omega_{i,j+1} + \omega_{i,j-1} - 2\omega_{i,j}}{\Delta y^2} \right\}$$

3.RESULT

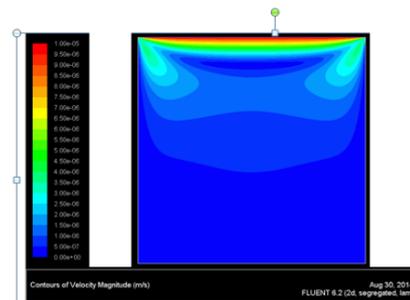


Fig.3.1 Velocity contour-1

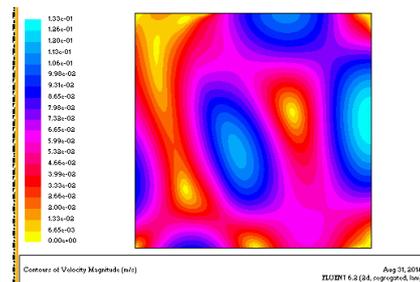


Fig.3.2 Velocity contour-2

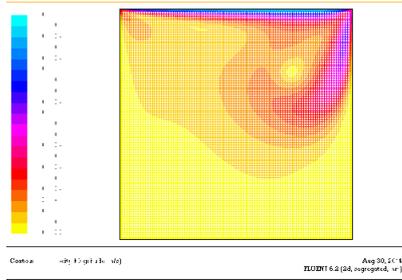


Fig.3.3 Velocity contour-3

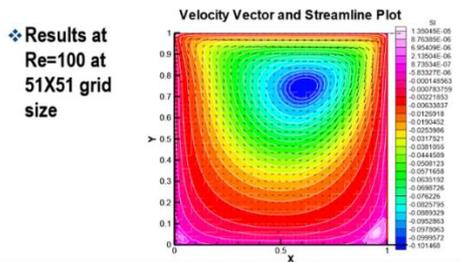


Fig.3.4 Velocity vector and stream line plot

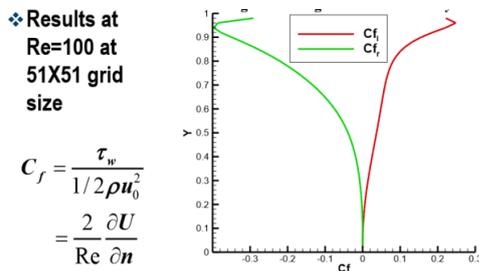


Fig.3.5 Variation of Local skin Friction coefficient along left and right wall of the Cavity.

In the below paragraph, the discussion about the graphs has been made.

Fig.2.3 shows the meshing ,type is uniform,51x51 grid.

Fig.2.4.1. shows the boundary conditions.

Fig.2.4.2.Grid,type cartesean 51 x51.

Fig.3.1 shows the Velocity contour-1. Eddy formation is shown at the top two corners, symmetrically, which causes the flow resistances. Max speed is obtained at the top.

Fig.3.2 shows the Velocity contour-2, when the Reynolds number is varied. Random Reynolds number is chosen ,reason is to check the velocity pattern variation.

Fig.3.3 shows the Velocity contour-3, when the Reynolds number is varied. Random Reynolds number is chosen , reason is to further check the velocity pattern variation.

Fig.3.4 shows the Velocity vector and stream line plot. The Reynolds number chosen is 100. Eddy formation has shifted to the center.

Fig.3.5 shows the Variation of Local skin Friction coefficient along left and right wall of the Cavity

4. CONCLUSION

In this present work the flow prediction in Cartesian using the stream function- vorticity formulation for the Lid Driven Cavity has been shown. On either side of the wall of the cavity the Local skin Friction coefficient varies in the same manner and found maximum between 0.9 and 1 on vertical and minimum at the vertically bottom.

Notations:

- P- pressure
- μ - viscosity
- τ - viscous stress
- U,V,W-free stream mean velocity
- u',v',w' - instantaneous velocity
- ρ - density
- f- body forces

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