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Simulation of fully developed laminar free convection flow between vertical parallel flat plates

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Abstract. This article presents a numerical simulation of the fully developed laminar free convection flow between vertical parallel plates with asymetric temperatures. The thermal boundary condition employed on the walls is of the type uniform wall temperature, with the left wall cooler and the right wall hotter. At the inlet, a uniform temperature is imposed, which is lower than or equal to the cooler (left) wall temperature. The simulation tool used is OpenFOAM v12. Three successively refined meshes where used to perform mesh sensitivity analysis and to show mesh convergence. The numerical solutions obtained approach asymtotically the analytical solution. The temperature profile, as the analytical solution is linear, is exactly reproduced by the numerical method even in coarse meshes. The velocity profile, as the analytical solution is cubic, is progresively reproduced by the numerical method as the mesh is refined.

Keywords. heat transfer, passive ventilation, solar chimney, CFD.

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1. Introduction

The motivation of this article is the simulation of solar chimneys. Free convection is the driving force that generates flow in a solar chimney. The steady-state, fully developed laminar free convection between parallel flat plates is one of the most basic cases of free convection. Additionally, it has analytical solution, which allows for a direct comparison and validation of the simulation results in terms of velocity, temperature, pressure and heat transfer.

Solar chimneys have been studied recently by [1].

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2. Results and discussion

Figure 1 shows the temperature profile obtained for the three meshes and the comparison with the analytical solution. As the analytical solution is linear, the numerical method reproduces it exactly for all the meshes, even for the coarsest mesh. As expected, the dimensionless temperature on the left wall ($X = 0$) is $\theta = 0.6$ and on the right wall ($X = 1$) is $\theta = 1$. This confirms the correct imposition of the temperature boundary conditions on the walls.

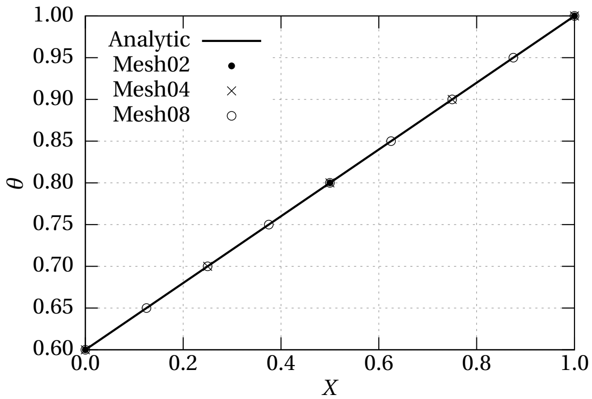

Figure 1. Temperature profile.

Figure 2 shows the vertical velocity profile obtained for the three meshes and the comparison with the analytical solution. As the analytical solution is cubic, the numerical method does not reproduce it exactly. Obiously, the finest mesh (Mesh08) reproduces the analytical solution the best. As expected, the dimensionless velocity on the left wall ($X = 0$) and on the right wall ($X = 1$) is $V = 0$. This confirms the correct imposition of the velocity boundary conditions on the walls. The maximum velocity, near $X = 0.5$ is captured very well even for the coarsest mesh. Even more, the numerical solution is almost nodally exact with respect to the analytical solution for all the meshes, which is very curious.

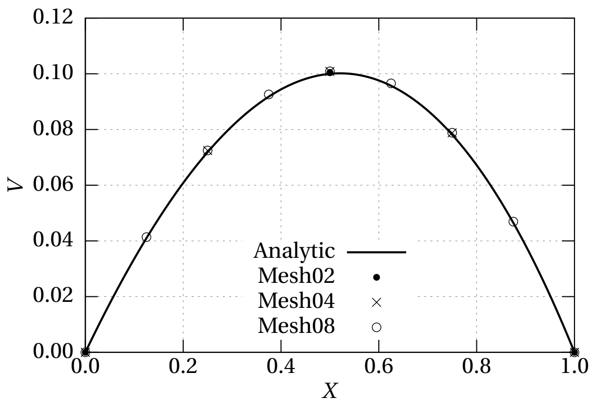

Figure 2. Vertical velocity profile.

3. Conclusion

The results obtained with the numerical simulation are in agreement with the analytical solution.

Conflict of interest

The authors declare no competing financial interest.

Dedication

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript.

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Research data availability

Data is available on request to the corresponding author. The research data is available on demand.

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