Natural Convection in a Square Cavity

Objective

This test problem is intended to test the buoyancy and viscous models and algorithms within the fluid flow section of Truchas.

Definition

Find the steady state solution to the problem posed in the de Vahl Davis Benchmark [1] in a very coarse mesh.

Metrics

The Benchmark solution contains a wealth of data for comparison. However, we will compare to only two velocity vectors at specific locations in the mesh. The points are the closest to the locations of the maximum horizontal velocity on the vertical midline of the cavity (Xh=0.5, Xv=0.813), and the maximum vertical velocity on the horizontal midline of the cavity (Xh=0.178, Xv=0.5). The benchmark values of these velocities are: Vh= 7.585×10^{-5} and Vv=7.685×10^{-5} respectively (scaled to the specifications used in the Truchas input file). These velocities should be sufficient to verify that Truchas results are not diverging from the correct solution without also checking on temperatures and heat fluxes.

Truchas Model

The problem domain is a unit square in the x-z plane divided into 5 mesh cells in each direction. (The y direction is a single cell of thickness 0.05). The left hand wall is held at T=1 and the right hand wall at T=0. The interior fluid is initially T=0.5. The fluid properties are approximately those of air (in MKS units), adjusted slightly to give the Prandtl number for the Benchmark solution. The acceleration due to gravity is adjusted to give the Rayleigh number 1000. The problem runs to t=60000 at which point the two monitored velocities are constant (to six significant figures). Viscous stress is treated implicitly to allow large time steps.

This problem is to begin from a restart file that contains the steady solution at t=60000. It is to run for 20 cycles to confirm that the steady solution is maintained by the current code version.

Variations: Change the plane of the simulation to investigate symmetry. Change the momentum and energy advection to donor higher order. Switch the initial liquid and gas volumes. Change the treatment of viscous stress to explicit. Change the mesh.

Results

To be added.

Critique

To be added.

References

G. de Vahl Davis, “Natural Convection of Air in a Square Cavity: A Bench Mark Numerical Solution,” IJNMF, v. 3, pp 249-264 (1983).