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Homeassignment # 4.

Buoyant convection a multiphysics problem

In this model coupling of heat transport and momentum transport is studied.
Assume that a fluid occupies a 2D rectangular region with solid walls as in the figure below. Gravity is in the negative y-direction. The temperature is higher on the right wall then the left wall. Under these circumstances a convective motion of the fluid is initiated and grows until a steady convective flow pattern is obtained.
The problem is defined by the equations heat conduction equation and Navier-Stokes equations

$$\frac{\partial T}{\partial t} + (\mathbf{u}\cdot\nabla)T = \kappa\nabla^2 T$$

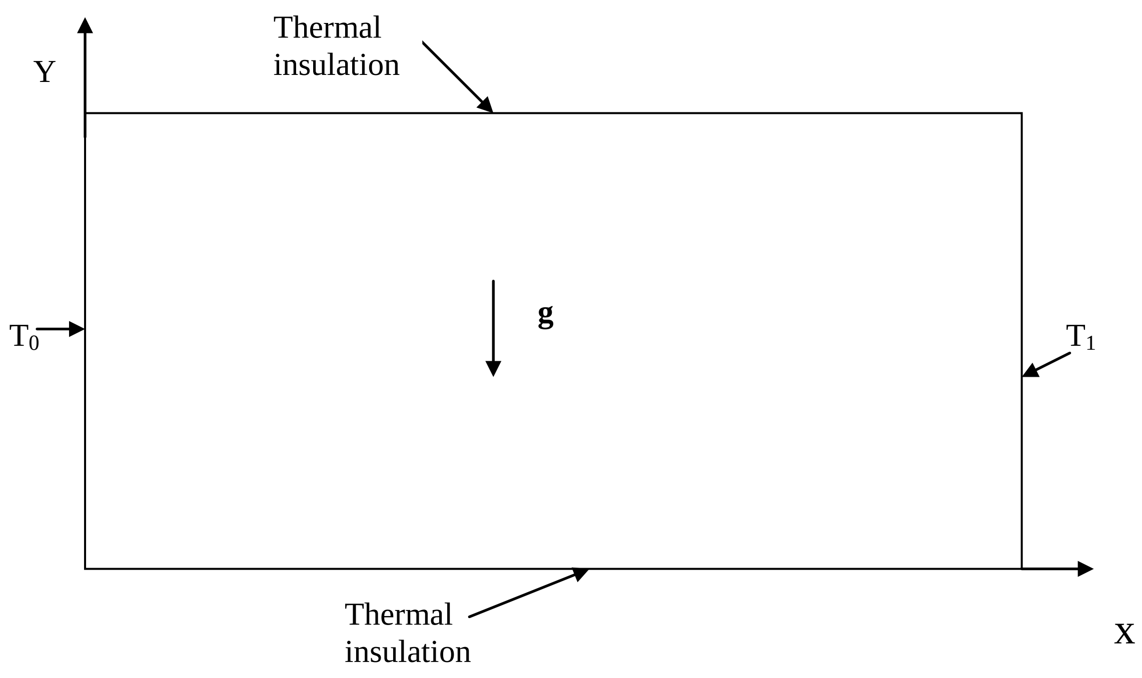
$$\rho(\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u}\cdot\nabla)\mathbf{u}) = -\nabla p + \mu\nabla^2\mathbf{u} + \rho(T)\mathbf{g}$$

$$\frac{\partial \rho}{\partial t} + \nabla\cdot(\rho\mathbf{u}) = 0$$

where the material parameters are defined as

g - the gravitational acceleration

κ – thermal diffusivity



Instructions

1. The assignment is first to find the steady solution so open Comsol and choose 2D Fluid dynamics, laminar flow. Add Heat transfer for fluids and under study choose steady flow.

2. Enter essential parameters T_0 and T_1 and g.
3. Choose a rectangular region with length 0.05[m] and height 0.01[m].

4. Open the materials browser and choose water as the fluid.

5. Click on laminar flow and choose Compressible flow(Ma<0.3). Under fluid properties model inputs choose temperature (ht). Under laminar flow fluid properties enter the volume force. Use spf.rho as the density. Add a pressure point constraint at point 1.

6. Under Heat transfer in fluids. Under absolute pressure choose “absolute pressure”. In velocity field choose “velocity field (spf)”. These conditions couple the heat transfer with the fluid flow. Enter the temperature boundary conditions and thermal insulation.

7. Choose the best mesh possible and compute.

8. Run the model for a series of different temperature differences. Start with temperature difference equal to zero. Increase the temperature difference and look what happens with the velocity field and temperature distribution. What is the direction of the velocity field? To find this consider Arrow surface under velocity. For large temperature differences there is no converged solution. Can you suggest a reason for that? Calculate the largest temperature difference that gives a converged solution.

9. Perform the same analysis for air instead of water. Calculate the value of the Rayleigh number for the case of largest temperature difference

$$Ra = \frac{\alpha g \Delta T h^3}{\nu \kappa}$$

$$\rho(T) = \rho_0(1 - \alpha(T - T_0))$$

10. Add a new study and run the same problem as a time dependent problem. Try to find the time scale of the evolution of the solution towards the steady state. Use the animation tool under results. Now start with initially uniform temperature T0 everywhere except at x=0.05 where the temperature is T1. Determine the time scale of the evolution towards steady state.

11. Write a report of your results.