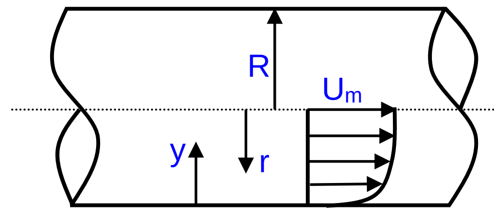
CE 580 COMPUTATIONAL TECHNIQUES FOR FLUID DYNAMICS

Homework 8

Finite Volume Solution to Turbulent Pipe Flow Using Wall Functions

Develop a computer program to obtain velocity distribution from an implicit FV solution to steady, uniform, turbulent flow in a circular pipe.



1. Use mixing length theory as the turbulence model.

2. Apply the boundary conditions

$$u = 0 \text{ at } y = 0 \qquad \text{and} \qquad u = U_m \text{ at } y = R.$$

3. Obtain initial data for velocity from the power law: $u(y) = U_m (y/R)^{1/7}$

4. Consider the steady momentum equation. Obtain a finite volume discretization for variable mesh size. Generate the computational grid using constant ratio method. Describe an implicit solution to the discretized FV equations.

5. Obtain the wall shear stress from the logarithmic law of the wall. Describe the percent change in shear velocity in two consecutive iterations as computational error and terminate iterations when this change is negligible.

6. Determine the Reynolds number and the friction factor (f_m) from the experimental formula. Compute the friction factor (f_c) using the computed average velocity and the wall shear stress in the Darcy's equation. Compute the percent error between the experimental and computed friction factors.

7. Run your program for the data given below:

   $U_m = 4$ m/s $R = 0.1$ m $N = 20$
   $\nu = 1\text{x}10^{-6}$ m^2/s $\rho = 1000$ kg/m^3 $\varepsilon_{max} = 1\text{x}10^{-5}$
   Grid ratio (G) = 1, 0.95, 0.90 and 0.86

8. Make logarithmic plots of the velocity profiles ($u^+ \sim y^+$) on the same page.

9. Prepare a table of results, presenting G, y_1^+, f_c, $100^*|f_c-f_m|/f_m$, and number of iterations.

10. Write a discussion on the results you obtained.