Laminar Pipe Flow - Exercises

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Problem Specification
Exercises (OLD)

Exercises

Exercise 1: Vertical Channel Flow

Problem Specification (pdf file)

Exercise 2: Laminar Flow within Two Rotating Concentric Cylinders

Contributed by Prof. John Cimbala and Matthew Erdman, The Pennsylvania State University

Problem Specification (pdf file)

The video below shows how to use ANSYS Fluent to set up and solve a problem like this.

Exercise 3: Laminar Pipe Flow

Consider developing ow in a pipe of length L = 8 m, diameter D = 0.2 m, = 1 kg/m3 , μ =2 × 10^3 kg/m s, and entrance velocity u_in = 1 m/s (the conditions specified in the Problem Specification section). Use FLUENT with the "second-order upwind" scheme for momentum to solve for the oweld on meshes of 100 × 5, 100 × 10 and 100 × 20 (axial divisions × radial divisions).

1. Plot the axial velocity proles at the exit obtained from the three meshes. Also, plot the corresponding velocity prole obtained from fully-developed pipe analysis. Indicate the equation you used to generate this prole. In all, you should have four curves in a single plot. Use a legend to identify the various curves. Axial velocity u should be on the abscissa and r on the ordinate.

2. Calculate the shear stress Tau_xy at the wall in the fully-developed region for the three meshes. Calculate the corresponding value from fully-developed pipe analysis. For each mesh, calculate the % error relative to the analytical value. Include your results as a table:

Mesh	τ_{xy}	% error

3. At the exit of the pipe where the ow is fully-developed, we can define the error in the centerline velocity as

$$\epsilon = \frac{|u_c - u_{\text{exact}}|}{u_{\text{exact}}}$$

where u_c is the centerline value from FLUENT and u_exact is the corresponding exact (analytical) value. We expect the error to take the form

$$\epsilon = K \Delta r^p$$

where the coefficient K and power p depend upon the order of accuracy of the discretization. Using MATLAB, perform a linear least squares t of

$$\ln \epsilon = \ln K + p \ln \Delta r$$

to obtain the coecients p and K. Plot vs. r (using symbols) on a log-log plot. Add a line corresponding to the least-squares t to this plot.

Hint: In FLUENT, you can write out the data in any "XY" plot to a le by selecting the "Write to File" option in the Solution XY Plot menu. Then click on Write and enter a lename. You can strip the headers and footers in this le and read this into MATLAB as column data using the load function in MATLAB.

4. Let's see how p changes when using a rst-order accurate discretization. In FLUENT, use "rst-order upwind" scheme for momentum to solve for the oweld on the three meshes. Repeat the calculation of coecients p and K as above. Add this vs. r data (using symbols) to the above log-log plot. Add a line corresponding to the least-squares t to this plot. In all, you should have four curves on this plot (two each for second- and rst-order discretization). Make sure you include an appropriate legend in the gure.

Contrast the value of p obtained in the two cases and briey explain your results (2-3sentences).

Hint: To interpret your results, you should keep in mind that the rst or second-order upwind discretization applies only to the inertia terms in the momentum equation. The discretization of the viscous terms is always second-order accurate.

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