Bifurcating Artery: Lecture Outline

BME 2000

Problem Specification

- Introduce bifurcating artery problem
- Geometry: carotid artery from GrabCAD
- Inlet: 0.315 m/s, outlets: 13332 Pa, no-slip walls
    - Real velocity is pulsatile, this is approximation
- ρ =1060 kg/m3, μ = 0.0035 Pa s (based on blood)
    - Approximate as Newtonian fluid for simplicity
- Reynolds number of 600 (based on inlet diameter)
- Engineering background

Pre-Analysis

- Governing Equations
- Boundary Conditions
- Assumptions and simplifications
- Expected results/trends
    - 70% of flow exits through larger outlet
    - Images from textbook for carotid artery
        - "Transport Phenomena in Biological Systems" by Truskey, Yuan and Katz.
    - Calculate expected maximum velocity and wall shear

Geometry

- We'll define the domain (show ppt)
- Carotid artery
    - Inlet ~ diameter of 6.3mm
    - Outlets ~ 4.5 and 3mm (larger and smaller respectively)
    - Ratio of areas (external/internal): 14.826mm2/7.2214mm2 ~ 2
    - Common carotid artery: 30.977mm^2
    - external/common = 50% (vs 50% in book)
    - internal/common = 32% (vs 25% in book)
- Start ANSYS
- Save in conventional format and wbpz
- Drag a Fluid Flow (Fluent) analysis system into Project Page
- Right-click on "Geometry" cell and import bif_artery1.STEP

Mesh

- Mesh > Details > Defaults > Element Size > 1.0 mm
- Insert > Body Sizing > Element Size > 1.0 mm
- Right-click on Coordinate Systems > Insert > Coordinate System
  - Change to Body Selection Filter and choose the artery
- Insert > Body Sizing > Sphere of Influence
  - Sphere Center: Coordinate System (what we just created)
  - Sphere Radius: 12.0 mm
  - Element Size: 0.5 mm (to capture effects near bifurcation)
- Insert > Inflation
  - Scope > Geometry: apply to entire body
  - Definition > Boundary: all 122 faces
    - Face Selection Filter, right-click, Select All
  - Inflation Option: Total Thickness
  - Number of Layers: 5
  - Maximum Thickness: 0.6 mm
- Named Selections
  - Inlet, outlet1 (larger), outlet2 (smaller), wall_artery, fluid_zone (the body)
- ***Note: All other settings are left as their defaults***
- ***Note: After exiting the mesher, you may need to right-click on Model and choose Update (if it shows the yellow lightning symbol instead of the green tick mark)***

Model Setup

- Double-click on Setup
  - Double Precision
- General Tab
  - Display mesh and mesh check
  - Enable Gravity
  - Solver Type: Pressure-based
- Material properties: ρ =1060 kg/m3, μ = 0.0035 Pa s
- Viscous model: Laminar
- GE are defined
- Boundary conditions
  - inlet = velocity inlet
    - Velocity Specification Method: Magnitude, Normal to Boundary
    - Velocity Magnitude: 0.315 m/s
  - Outlet1, outlet2 = pressure outlet
    - Gauge Pressure: 0 Pa
      - Operating Conditions > Operating Pressure > 13332 Pa
  - Wall_artery = wall
- BVP is completely defined at this point

Numerical Solution

- Solution Methods:
  - Make sure set to Second Order
- Reference Values: compute from Inlet
  - Area: 0.001324 m2
- Create report definitions to monitor quantities of interest
  - Cd on wall_artery in +z direction
- Monitors > Residuals > 1e-6
- Solution initialization
    - Standard: Compute from “inlet”
    - Click “Initialize”
- Run Calculation
    - Iterations = 2000

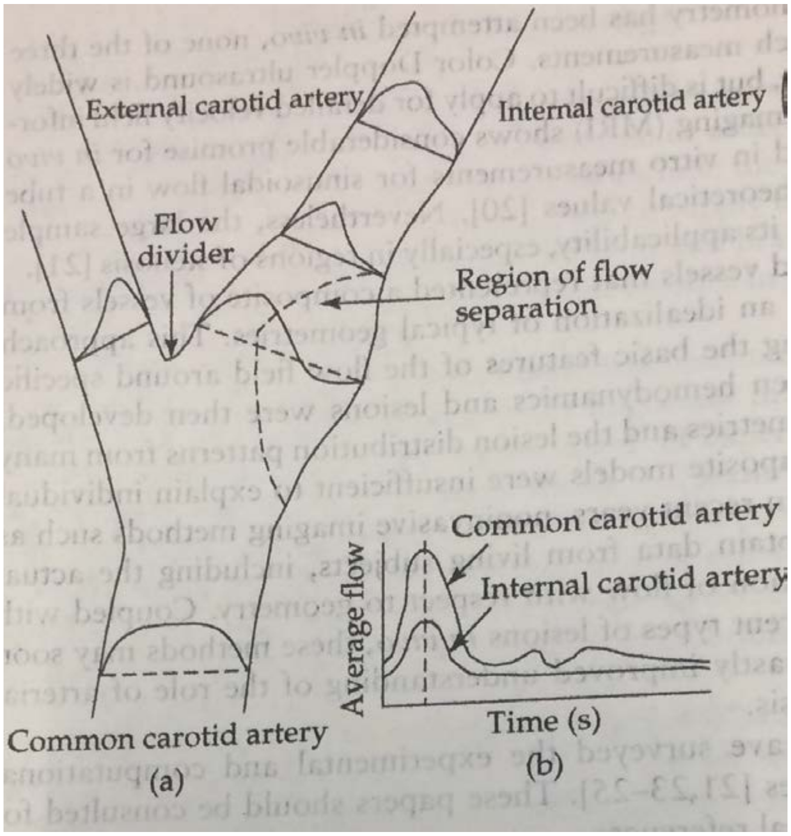
Numerical Results

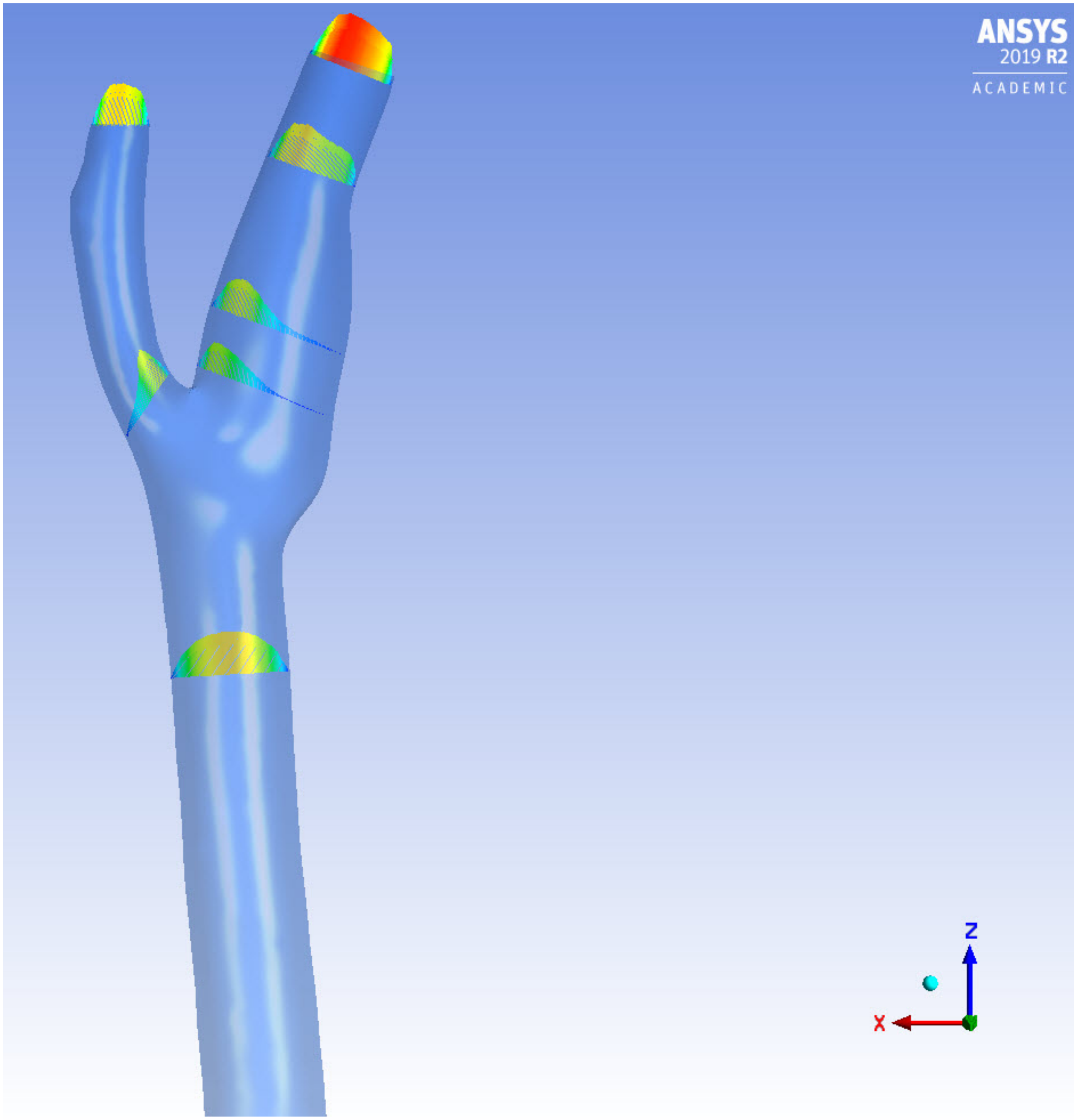
  - Before exiting Fluent
    - Check that Cd is constant between iterations
    - Check mass flow rate
      - Reports > Fluxes > Mass Flow Rate
      - Boundaries > inlet, outlet1, outlet2
      - Outlets should be 70% and 30% of inlet
    - Check inlet boundary condition
      - Reports > Surface Integral > Area-weighted Average
      - Velocity > Velocity Magnitude
      - Surfaces > inlet
- Change transparency of artery
    - Right-click on wall_artery
    - Render > Transparency > 0.7
  - Volume Renderings (side-by-side)
    - Velocity
    - Pressure
  - Velocity Vectors
    - Location: fluid_domain
- Velocity Vectors on planes
    - Locations: planes 1-3
      - Plane 1: XY Plane, Z = -0.02
      - Plane 2: XY Plane, Z = 0.005
      - Plane 3: XY Plane, Z = 0.015
    - Compare to vectors on lines (below)
- Velocity Vectors on cutsection
    - Location: Plane 4
      - Plane 4: 3 points
      - (0, 0.004, -0.02), (0.0075, 0.0002, 0.02), (-0.005, -0.0005, 0.02)

- Turn off wall_artery
- Wall Shear Contours
    - Location: wall_artery

Verification and Validation

- Compare to descriptions of flow in the carotid artery (Truskey-Yuan-Katz p. 235-236)
    - Reversed flow in bulge area
    - 70-30 split in the flow outlets


External carotid artery
Internal carotid artery
Flow divider
Region of flow separation
Common carotid artery
(a)
Common carotid artery
Internal carotid artery
Average flow
Time (s)
(b)


ANSYS
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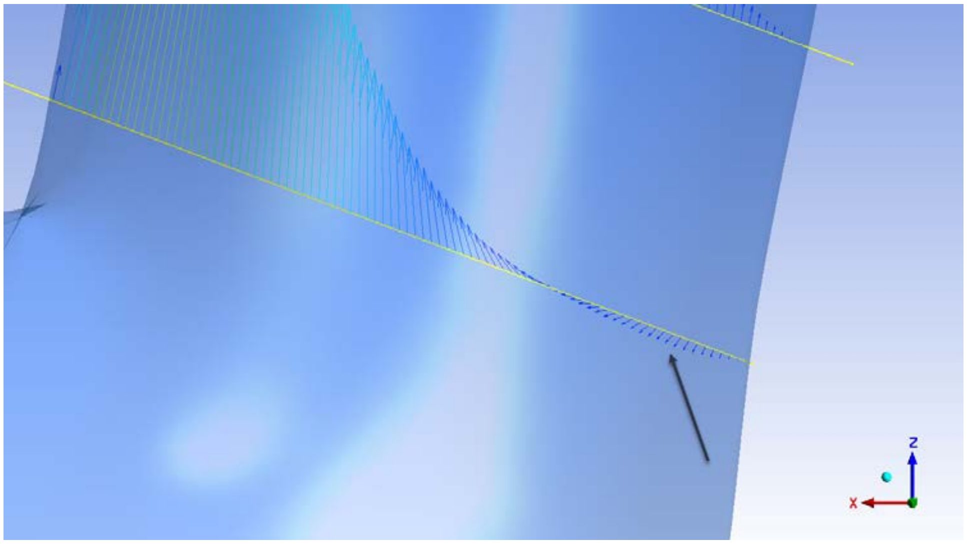

- Mesh refinement
    - What happens if we decrease cell count?
- Change velocity (to 0.21 m/s) to get Re = 400