Chemical Engineering 512

Nuclear Reactor Transient Modeling

Lecture 11

Numerical Stability

Spiritual Thought

"President Russell M. Nelson taught, 'Without the [Savior's] infinite Atonement, all mankind would be irretrievably lost.' Danny wasn't lost, and neither are we to the Lord. He stands at the door to lift us, to strengthen us, and to forgive us. He always remembers to love us!"

- Elder K. Brett Nattress

Pump Input

```
*                name         type
0540000      "rcpmpa"         pump
*                area       length          vol
0540101           1.0          0.0          1.0
*            az-angle    inc-angle           dz
0540102           0.0        -90.0         -1.0
*               flags
0540103             0
*                 ebt        press         temp
0540200           003       1.55e7       602.15
*                  to         area         kfor         krev     jefvcahs
0540108      52020002          0.0          0.0          0.0            0
*                flow          mfl          mfv       unused
0540201             1      3866.75          0.0          0.0
*                  to         area         kfor         krev     jefvcahs
0540109      56010001          0.0          0.0          0.0            0
*                flow          mfl          mfv       unused
0540202             1      3866.75          0.0          0.0
*        phase twophase tdiff mtorq tdvel ptrip rev
0540301      0        0     0    -1     0   550   0
*                pvel       pratio        rflow        rhead
0540302        155.51       1.0101      6.60833         97.2
*               rtorq      imoment        rdens        rmtor
0540303     3.79833e4      2949.81      740.741          0.0
*                 tf2          tf0          tf1          tf3
0540304           0.0       379.83       37.983          0.0
*                type       regime
0541100             1            1
*                 ind          dep
```

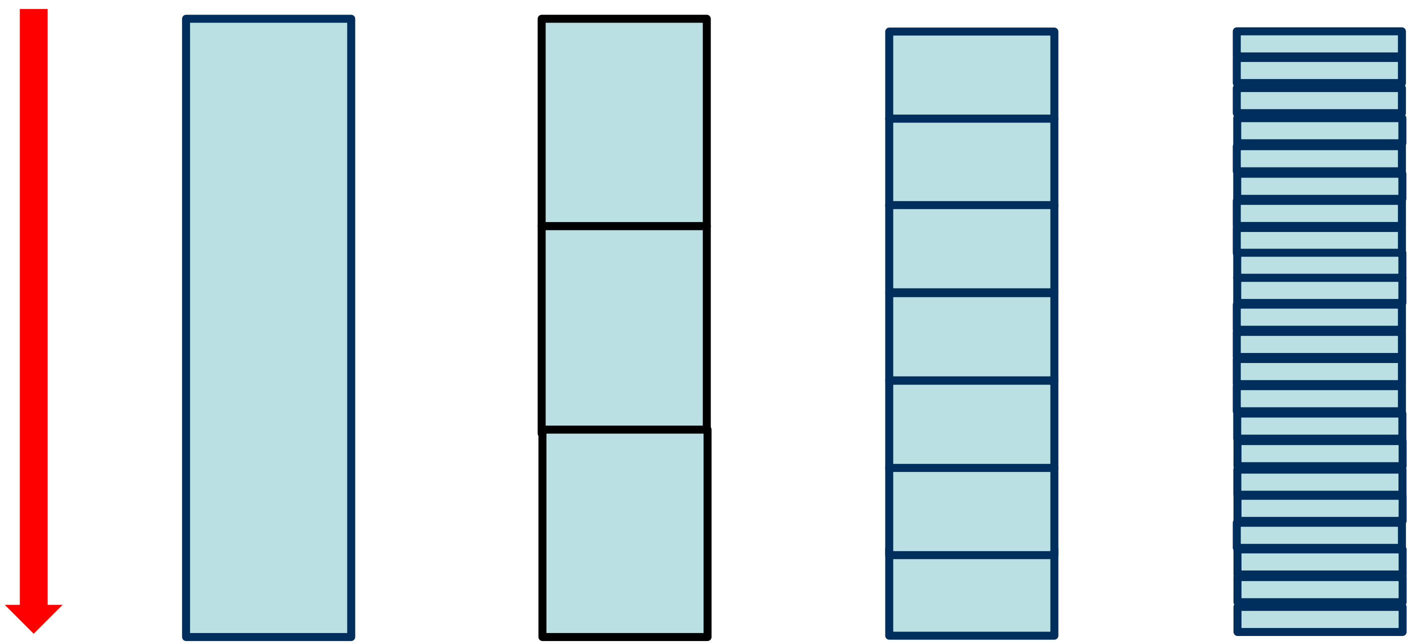
Pump Input

```
1040304          0.0       379.83        37.983          0.0
*               type       regime
1041100            1            1
*                ind          dep
1041101          0.0          1.8
1041102         0.15          1.7
1041103         0.22         1.65
1041104          0.3          1.5
1041105          0.4          1.4
1041106          0.5         1.35
1041107         0.62          1.3
1041108         0.75         1.31
1041109         0.87         1.22
1041110          1.0          1.0
*               type       regime
1041200            1            2
*                ind          dep
1041201          0.0        -1.55
1041202         0.15         -1.2
1041203          0.3        -0.85
1041204         0.53        -0.35
1041205         0.65          0.0
1041206          0.8         0.37
1041207          1.0          1.0
*               type       regime
1041300            1            3
*                ind          dep
1041301         -1.0          4.2
1041302         -0.8         3.65
1041303        -0.69          3.3
1041304         -0.5          2.8
1041305         -0.3          2.3
1041306        -0.17         2.05
1041307        -0.08         1.85
1041308          0.0          1.8
*               type       regime
1041400            1            4
*                ind          dep
1041401         -1.0          4.2
```

Objectives

- Nodalization
- Courant limit
- Practice numerical stability

Nodalization



Courant Limit

- The minimum time it takes for the fluid to pass through a volume is the Courant limit.
- The problem time step must be below this value or the fluid will “skip” volumes

$$(\Delta t_c)_i = \Delta x_i \frac{\max(\alpha_{fi}^n, \alpha_{gi}^n)}{\max(|\alpha_{fi}^n v_{fi}^n|, |\alpha_{gi}^n v_{gi}^n|)} \qquad i = 1, 2, \ldots, N \ .$$

$$\Delta t_c^1 \le \Delta t_c^2 \le \Delta t_c^3 \le \Delta t_c^4 \le \Delta t_c^5 \ .$$

Courant Limit Practice

- Pure water is flowing through a single volume at 10m/s. What is the Courant limit when the volume is 4m long and what should the maximum time step be (card 201)

$$(\Delta t_c)_i = \Delta x_i * \frac{\max\left(\alpha_{fi}^n, \alpha_{gi}^n\right)}{\max\left(\left|\alpha_{fi}^n v_{fi}^n\right|, \left|\alpha_{gi}^n v_{gi}^n\right|\right)} \qquad i = 1, 2, \dots, N$$

Skipping Cells

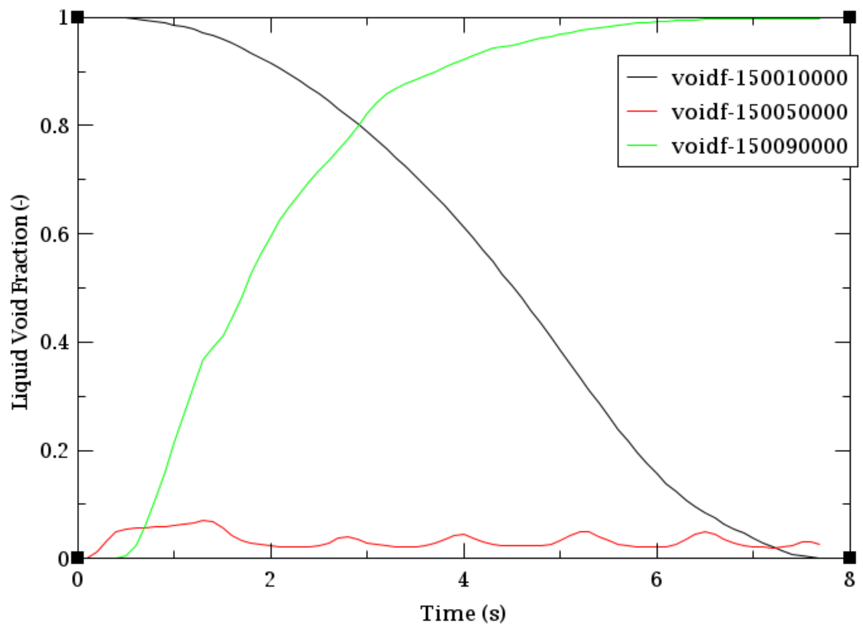
- When fluid is flowing fast through a pipe, if pipe volumes are too small, the courant limit will be less than the time step and the fluid will skip the volume.
- Why does this matter?

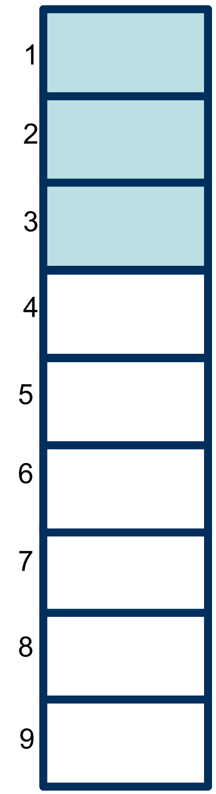
Computational Time

- Computational time = f(# of hydrodynamic cells)
- Number of heat structures generally increases with hydrodynamic cells
- Minimize number of mesh points in HS
- Subtraction of trips/control variables does little for computational time

Practice: Nodalization Study

- Remember HW 2?

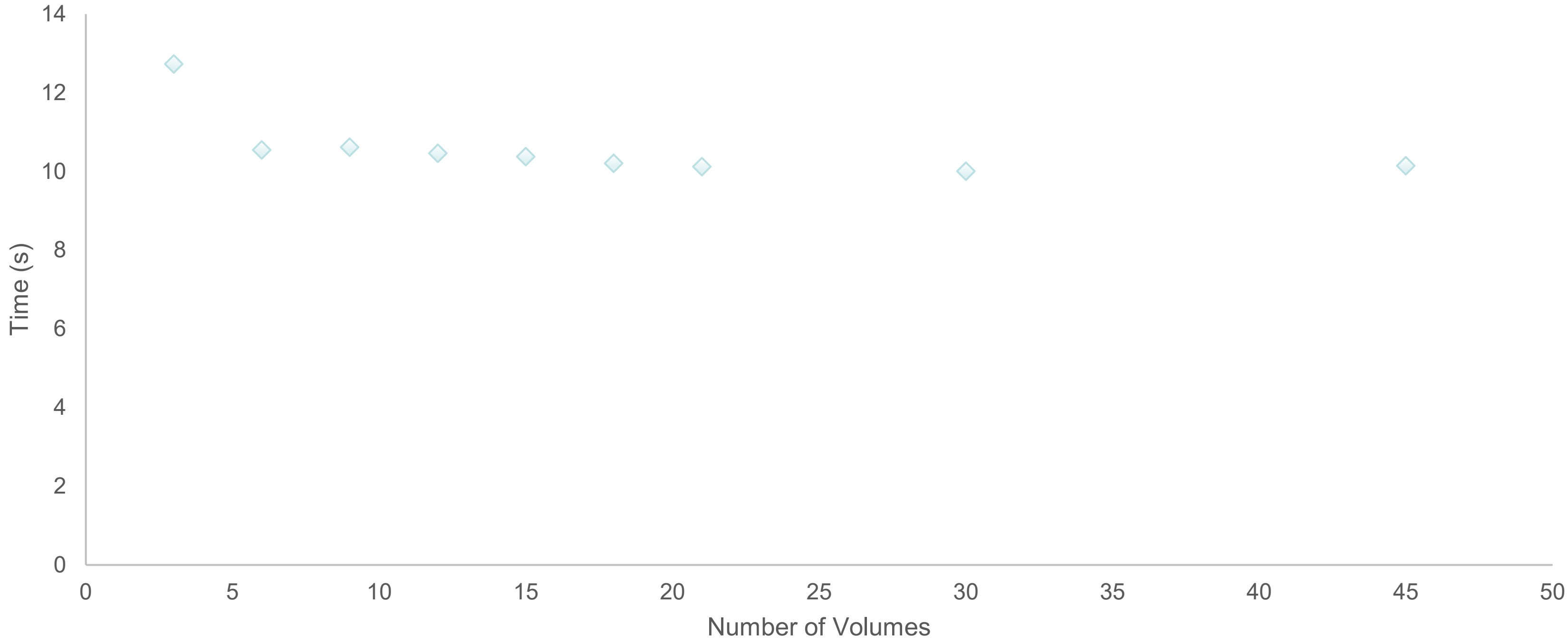




Practice: Nodalization Study

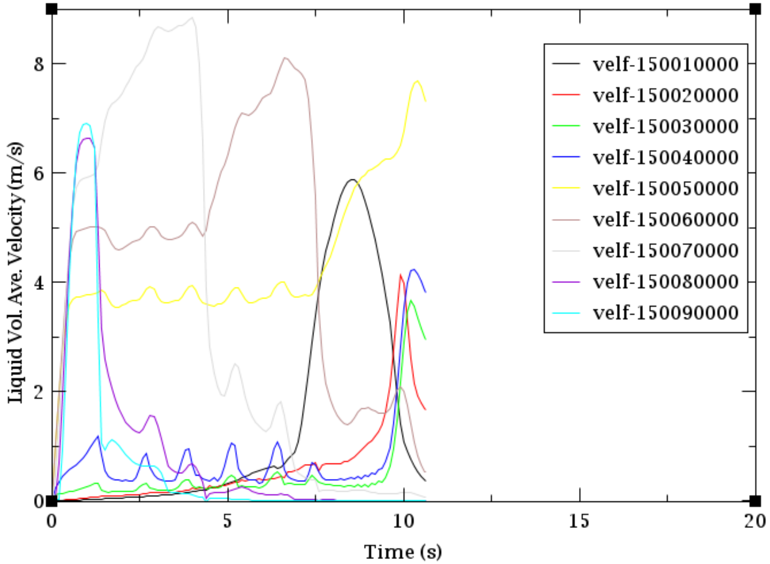
- What is the optimum number of volumes?
- Time step has already been set to be less than Courant limit
- To compare results we will plot the time it takes for 99.9% of the water to leave the top 1/3 of the pipe

Practice: Nodalization Study



Practice: Nodalization Study

- How many volumes can we have before changing the max time step of 0.01



$$(\Delta t_c)_i = \Delta x_i \frac{\max(\alpha_{fi}^n, \alpha_{gi}^n)}{\max(|\alpha_{fi}^n v_{fi}^n|, |\alpha_{gi}^n v_{gi}^n|)}$$

$$0.01 = \frac{\Delta x}{9}$$

$$\Delta x = 0.09$$

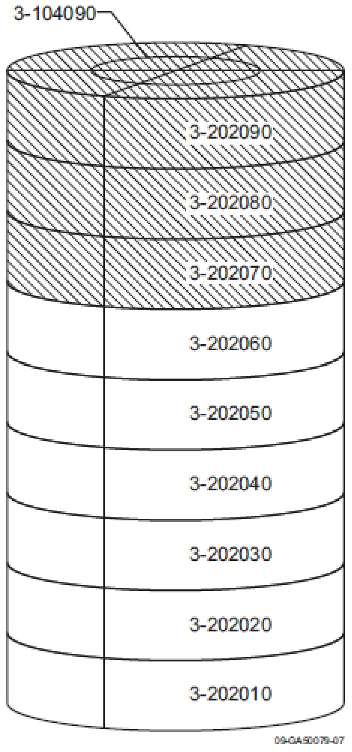
$$Volumes = \frac{4.5}{0.09} = 50$$

Why Proper Nodalization?

- Can change our results (the example changed by 25%)
- Can lower computation time (this will matter on a larger scale)
- Can lower complexity of deck (no one wants 10,000 volumes to keep track of)
- Ensures you are getting the most accurate answer possible

3D Component

- Basically CFD lite
- Can be helpful if you need to see more detailed 3D behaviors in a tank
- Refer to appendix for input description



Assignment

- Watch DVD sections 58-63 before next class
- HW 5 due next Tuesday (10/14)
- HW 6 due next Friday (10/17)