Chemical Engineering 512

Nuclear Reactor Transient Modeling

Lecture 13

Control Variables

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

Objectives

- Learn about control variables
- Learn about tables
- Practice making a control variable
- Practice making a table

Notes

- Remember to start working on gathering the data needed for your reactor
- One more day of watching videos
- Commenting looks better

Control Variables

- Provides the capability to evaluate simultaneous algebraic and ordinary differential equations
- Intended to simulate control systems typically used in hydrodynamic systems
- Also useful for auxiliary output quantities

Control Variables – Input Description

```
*               Card Format
20500000     999
*               Name     Type     Scaling     InitVal    InitValFlag
20510000     qdot     sum     1.0          0.0          1
*               Ao          A1          VariableCode     Parameter
20510001     0.0          1.0          cntrlvar               108
*               A2      VariableCode     Parameter
20510002    1.0       cntrlvar               109
```

$$Y = S(A_0 + A_1V_1 + A_2V_2 + \ \dots + A_jV_j)$$

Control Variables - Example

- *Example: Compute the volumetric flow rate at junction 110.*

Qdot = $\alpha_g v_g A + \alpha_f v_f A$ *where* $A = 1.0\ m^2$

SUM: $Y = S * (A0 + A1*V1 + A2*V2 + \ldots)$
MULT: $Y = S * V1 * V2 * \ldots$

```
20510800    qvap    mult 1.0 0. 1
20510801    voidgj  110010000   velgj  110010000
*
20510900    qliq    mult 1.0 0. 1
20510901    voidfj  110010000   velfj  110010000
*
20511000    qdot    sum 1.0 0. 1
20511001    0.0     1.0  cntrlvar  108
20511002      1.0  cntrlvar  109
```

Control Variables - Uses

- Model real control systems
  - Steam generator level control
  - Reactor power control
- Solve ODEs
  - Valve dynamics
  - Feedwater turbine
- Compute convenient auxiliary results
  - Water levels
  - Mass inventories

Control Variables - Practice

- Create a control variable input to make the following calculation:

$$W = \alpha_g \rho_g v_g A + \alpha_f \rho_f v_f A$$

- Do this for volume 105-01
- Assume the area is 0.55 m^2

Control Variables - Practice

```
20501010   vap.prod   mult   0.55  0.0  1
20501011   voidg 105010000   rhog 105010000
20501012   velg 105010000
20501020   liq.prod   mult   0.55  0.0  1
20501021   voidf 105010000   rhof 105010000
20501022   velf 105010000
20501030   vol.flow   sum   1.0   0.0   1
20501031   0.0   1.0 cntrlvar 101   1.0 cntrlvar 102
```

$$W = \alpha_g \rho_g v_g A + \alpha_f \rho_f v_f A$$

Tables

- Tables are used to input data into RELAP5-3D
- They are structured just as a normal tables with columns and rows
  - Rows are defined by card number
  - Columns are defined by spaces
    - Line up your data so it looks like a table
- Used to conveniently implement various numerical functions into a problem

Tables - Uses

- Thermal Property Data
  - Can input custom thermal conductivities and heat capacities for materials at different temperatures
- Power Table
  - Can help define reactor power output at different times
- General Tables
  - Many available

Tables - Input

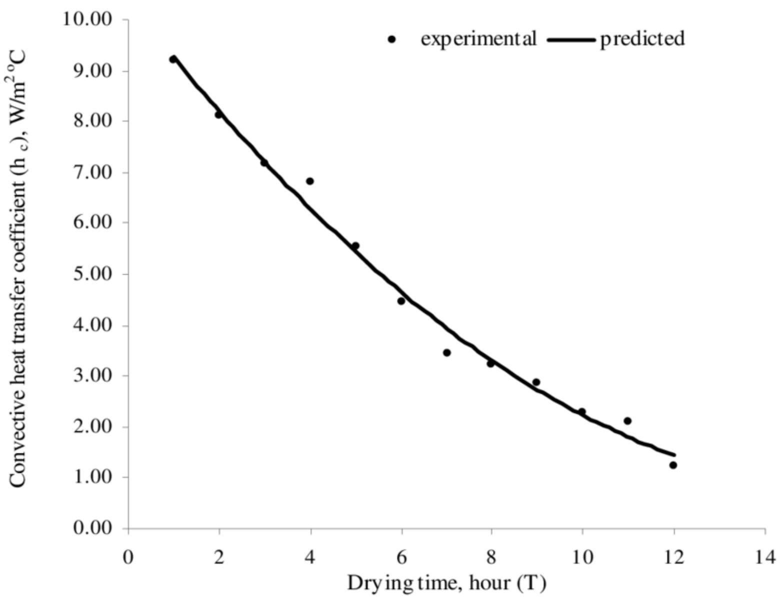
202TTTNN

- TTT – Table Number
- NN – Card Number within Table

```
*           table type    trip num    factor 1    factor 2
20290000    power         900         1.0         1200.e6
*           time          power
20290001    0.0           1.0
20290002    0.5           0.97
20290003    0.9           0.93
```

Tables - Practice

- Create a table to specify the heat transfer coefficient versus time and using the following plot.



Heat Structure Thermal Property Data

201MMMNN

- MMM – Composition Number
- NN – Card Number within Table

 * MaterialType k
cp

20110000 s-steel/tbl/fctn 1/2/3
1/-1/2

Heat Structure Thermal Property Data

201MMM01-201MMM49

- MMM – Composition Number
- NN = 01-49 – Thermal Conductivity

If tbl:

*	Temperature	k
20110001	500	500000
20110002	600	600000
20110003	…	…

Heat Structure Thermal Property Data

201MMM01-201MMM49

- MMM – Composition Number
- NN = 01-49 – Thermal Conductivity

$$k = A_0 + A_1(TX) + A_2(TX)^2 + A_3(TX)^3 + A_4(TX)^4 + A_5(TX)^{-1}$$

If fctn:

where TX = T - C, T is the temperature argument, and C is a constant. E

* LowT UpT A0 A1 A2 A3 A4 A5 C 20110001 300 5000 11.833 -.0065 .00002 0. 0. 0. 0.

Heat Structure Thermal Property Data

201MMM51-201MMM99

- MMM – Composition Number
- NN = 51-99 – Volumetric Heat Capacity

If tbl:

*	Temperature	density*cp
20110051	500	500000
20110052	600	600000
20110053	…	…

Heat Structure Thermal Property Data

201MMM51-201MMM99

- MMM – Composition Number
- NN = 51-99 – Volumetric Heat Capacity

If fctn: $\rho C_p = A_0 + A_1(TX) + A_2(TX)^2 + A_3(TX)^3 + A_4(TX)^4 + A_5(TX)^{-1}$

```
 *                LowT  UpT     A0
A1      A2  A3 A4 A5 C
20110051    300     5000   2305550.
2035.26  0.    0.   0.   0.   0.
```

Property Data – Practice

- Choose a material, find data for the material (either tabular or functional), create that material in RELAP
- My advice is pick one you may need for your project/homework

Homework Introduction

- Use tables to input Stainless Steel data
  - Do we expect results to be different than RELAPs built-in values?
  - Plot it and evaluate
- Use control variables to calculate:
  - Total mass in tubes
  - Total mass in shell
  - Water level inside shell
  - Break status

Next Class

- Learn about modeling a PWR reactor core
  - How to model a fuel rod
  - How to connect to cooling loops
  - Combining knowledge of many different components

Assignment

- Watch DVD Sections 72-78 before next class
- HW 7 due next Thursday 10/23