Chemical Engineering 512

Nuclear Reactor Transient Modeling

Lecture 8

Point Kinetics Introduction

Spiritual Thought

"There is nothing that has come or will come into your family as important as the sealing blessings. There is nothing more important than honoring the marriage and family covenants you have made or will make in the temples of God."

-Henry B. Eyring

Objectives

- Learn about kinetics input into RELAP
- Practice Combination of Volumes in Series

What is Point Kinetics?

- Used to compute reactor power behavior in a nuclear reactor
- Point kinetics is space independent and uses core-average fluid conditions, weighting factors, and feedback coefficients
- Nodal kinetics is the multidimensional neutron kinetics option

- Kinetics type
  - Point
  - Nodal
- Feedback type
  - Separabl
  - Table3
  - Table4
  - Table3A
  - Table4A

```
*****************************************************************************
*                                                                           *
*                              Kinetics                                     *
*                                                                           *
*****************************************************************************
*
*              KineticsType          FeedbackType
30000000       point                 separabl
*              Decay     Power       React   Nfrac
30000001       gamma     1200e+6     0.0     300.
*              ModeratorDensity         Reactivity
30000501       6.37250                  0.006
30000502       46.8710                  0.100
30000503       70.3065                  0.250
*              Temperature              Reactivity
30000601       32.0                     0.0
30000602       4500.0                   0.0
*              VolNum       Incr    WeightFact    LiqTempCoef
30000701       514010000    0       0.07391       0.0
30000702       514020000    0       0.18250       0.0
30000703       514030000    0       0.24359       0.0
*              HSNum        Incr    WeightFact    FuelTempCoef
30000801       5141001      0       0.07391       0.0
30000802       5141002      0       0.18250       0.0
30000803       5141003      0       0.24359       0.0
*
```

- Fission product decay type
  - No-gamma
  - Gamma
  - Gamma-ac
- Total Reactor Power
- Initial reactivity
- Delayed neutron fraction/prompt neutron generation time

```
*******************************************************************************
*                                                                             *
*                                  Kinetics                                   *
*                                                                             *
*******************************************************************************
*
*              KineticsType       FeedbackType
30000000       point              separabl
*              Decay   Power      React   NFrac
30000001       gamma   1200e+6    0.0     300.
*              ModeratorDensity       Reactivity
30000501       6.37250                0.006
30000502       46.8710                0.100
30000503       70.3065                0.250
*              Temperature            Reactivity
30000601       32.0                   0.0
30000602       4500.0                 0.0
*              VolNum       Incr   WeightFact   LiqTempCoef
30000701       514010000    0      0.07391      0.0
30000702       514020000    0      0.18250      0.0
30000703       514030000    0      0.24359      0.0
*              HSNum        Incr   WeightFact   FuelTempCoef
30000801       5141001      0      0.07391      0.0
30000802       5141002      0      0.18250      0.0
30000803       5141003      0      0.24359      0.0
*
```

- Moderator density vs reactivity table

- Fuel temperature vs reactivity table

```
******************************************************************************
*                                                                            *
*                               Kinetics                                     *
*                                                                            *
******************************************************************************
*
*           KineticsType        FeedbackType
30000000    point               separabl
*           Decay   Power       React   NFrac
30000001    gamma   1200e+6     0.0     300.
*           ModeratorDensity    Reactivity
30000501    6.37250             0.006
30000502    46.8710             0.100
30000503    70.3065             0.250
*           Temperature         Reactivity
30000601    32.0                0.0
30000602    4500.0              0.0
*           VolNum      Incr    WeightFact  LiqTempCoef
30000701    514010000   0       0.07391     0.0
30000702    514020000   0       0.18250     0.0
30000703    514030000   0       0.24359     0.0
*           HSNum       Incr    WeightFact  FuelTempCoef
30000801    5141001     0       0.07391     0.0
30000802    5141002     0       0.18250     0.0
30000803    5141003     0       0.24359     0.0
*
```

- Volume weighting factors
  - Increment same as heat structure increment
  - If WeightFact is non-zero, LiqTempCoef = 0
- Heat structure weighting factors
  - If WeightFact is non-zero, FuelTempCoef = 0

```
****************************************************************************
*                                                                          *
*                               Kinetics                                   *
*                                                                          *
****************************************************************************
*
*          KineticsType        FeedbackType
30000000   point               separabl
*          Decay   Power     React   NFrac
30000001   gamma   1200e+6   0.0     300.
*          ModeratorDensity      Reactivity
30000501   6.37250               0.006
30000502   46.8710               0.100
30000503   70.3065               0.250
*          Temperature           Reactivity
30000601   32.0                  0.0
30000602   4500.0                0.0
*          VolNum      Incr   WeightFact   LiqTempCoef
30000701   514010000   0      0.07391      0.0
30000702   514020000   0      0.18250      0.0
30000703   514030000   0      0.24359      0.0
*          HSNum       Incr   WeightFact   FuelTempCoef
30000801   5141001     0      0.07391      0.0
30000802   5141002     0      0.18250      0.0
30000803   5141003     0      0.24359      0.0
```

- Card 1CCCG701
  - Source type
    - If 1000-1004, then point kinetics is used

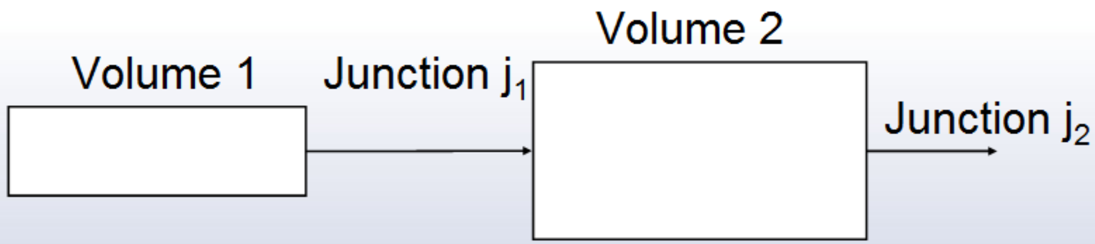
```
************************************************************************
*                                                                      *
*                         Heat Structures                              *
*                                                                      *
************************************************************************
*
*          AxialHS  RadMesh  GeoType  SSFlag  LeftBound  Reflood
11000000   6        8        2        1       5.74       0
*          MeshLocation     MeshFormat
11000100   0                1
*          NumOfIntervals   RightCoordinate
11000101   7                6.5
*          CompositionNum   IntervalNum
11000201   5                7
*          SourceValue      IntervalNum
11000301   0.0              7
*          InitialTemp      MeshPointNum
11000401   500.             8
*          BoundaryVol/Table  Incr  BCType  SACode  SA/Factor  HSNum
11000501   150010000          0     1       1       10.0       6
*          BoundaryVol/Table  Incr  BCType  SACode  SA/Factor  HSNum
11000601   0                  0     0       1       10.0       6
*          SourceType  Pf        LeftBoundMult  RightBoundMult  HSNum
11000701   1000        0.001791  0.0            0.0             6
*          WordFormat
11000800   0
*          HydDiam  HLFor  HLRev  GSLFor  GSLRev  GLCFor  GLCRev  Boil  HSNum
11000801   0.0      3.0    3.0    0.0     0.0     0.0     0.0     1.0   6
*          WordFormat
11000900   0
*          HydDiam  HLFor  HLRev  GSLFor  GSLRev  GLCFor  GLCRev  Boil  HSNum
11000901   0.0      3.0    3.0    0.0     0.0     0.0     0.0     1.0   6
*
```

Combining Volumes

- Reduce the number of control volumes
- Avoid having control volumes that are too small

- Can combine in series or parallel

Combining in Series



Hydrodynamic:				
Length:	Dx_1		Dx_2	
Elevation change:	Dz_1		Dz_2	
Hydraulic diameter:	D_{h1}		D_{h2}	
Area:	A_1	A_{j1}	A_2	A_{j2}
Volume:	V_1		V_2	
Form losses:		K_{j1}		K_{j2}
Heat structures:				
Inner radius:	R_{i1}		R_{i2}	
Thickness:	t_1		t_2	
Length:	L_1		L_2	

Combining Hydrodynamic

$Dx_m = Dx_1 + Dx_2$	

Combining Hydrodynamic

$Dx_m = Dx_1 + Dx_2$	$Dx_m = 2.0 + 2.0 = 4.0$
$Dz_m = Dz_1 + Dz_2$	

Combining Hydrodynamic

$Dx_m = Dx_1 + Dx_2$	$Dx_m = 2.0 + 2.0 = 4.0$
$Dz_m = Dz_1 + Dz_2$	$Dz_m = 0.0 + 0.0 = 0.0$
$V_m = V_1 + V_2$	

Combining Hydrodynamic

$Dx_m = Dx_1 + Dx_2$	$Dx_m = 2.0 + 2.0 = 4.0$
$Dz_m = Dz_1 + Dz_2$	$Dz_m = 0.0 + 0.0 = 0.0$
$V_m = V_1 + V_2$	$V_m = 0.00789*2+0.01863*2 = 0.05304$
$A_m = V_m/Dx_m$	

Combining Hydrodynamic

$Dx_m = Dx_1 + Dx_2$	$Dx_m = 2.0 + 2.0 = 4.0$
$Dz_m = Dz_1 + Dz_2$	$Dz_m = 0.0 + 0.0 = 0.0$
$V_m = V_1 + V_2$	$V_m = 0.00789*2+0.01863*2 = 0.05304$
$A_m= V_m/Dx_m$	$A_m= 0.05304/4.0 = 0.01326$
$D_{hm} = \left[\dfrac{\left(\dfrac{Dx_m}{A_m}\right)^{1.75}}{\dfrac{Dx_1}{D_{h1}^{1.25}A_1^{1.75}} + \dfrac{Dx_2}{D_{h2}^{1.25}A_2^{1.75}}}\right]^{0.80}$	

Combining Hydrodynamic

$Dx_m = Dx_1 + Dx_2$	$Dx_m = 2.0 + 2.0 = 4.0$
$Dz_m = Dz_1 + Dz_2$	$Dz_m = 0.0 + 0.0 = 0.0$
$V_m = V_1 + V_2$	$V_m = 0.00789*2+0.01863*2 = 0.05304$
$A_m = V_m/Dx_m$	$A_m = 0.05304/4.0 = 0.01326$
$D_{hm} = \left[\dfrac{\left(\dfrac{Dx_m}{A_m}\right)^{1.75}}{\dfrac{Dx_1}{D_{h1}^{1.25} A_1^{1.75}} + \dfrac{Dx_2}{D_{h2}^{1.25} A_2^{1.75}}}\right]^{0.80}$	$D_{hm} = \left[\dfrac{\left(\dfrac{4}{0.01326}\right)^{1.75}}{\dfrac{2}{0.102^{1.25} 0.00789^{1.75}} + \dfrac{2}{0.154^{1.25} 0.01863^{1.75}}}\right]^{0.80} = 0.0777$
$K_{jmf}=[(K_{j1}/A_{j1}^2)+(K_{j2}/A_{j2}^2)]A_{jm}^2$ $K_{jmr}=[(K_{j1}/A_{j1}^2)+(K_{j2}/A_{j2}^2)]A_{jm}^2$	

Combining Hydrodynamic

$Dx_m = Dx_1 + Dx_2$	$Dx_m = 2.0 + 2.0 = 4.0$
$Dz_m = Dz_1 + Dz_2$	$Dz_m = 0.0 + 0.0 = 0.0$
$V_m = V_1 + V_2$	$V_m = 0.00789*2+0.01863*2 = 0.05304$
$A_m = V_m/Dx_m$	$A_m = 0.05304/4.0 = 0.01326$
$D_{hm} = \left[\dfrac{\left(\dfrac{Dx_m}{A_m}\right)^{1.75}}{\dfrac{Dx_1}{D_{h1}^{1.25}A_1^{1.75}} + \dfrac{Dx_2}{D_{h2}^{1.25}A_2^{1.75}}}\right]^{0.80}$	$D_{hm} = \left[\dfrac{\left(\dfrac{4}{0.01326}\right)^{1.75}}{\dfrac{2}{0.102^{1.25}0.00789^{1.75}} + \dfrac{2}{0.154^{1.25}0.01863^{1.75}}}\right]^{0.80} = 0.0777$
$K_{jmf}=[(K_{j1}/A_{j1}^2)+(K_{j2}/A_{j2}^2)]A_{jm}^2$ $K_{jmr}=[(K_{j1}/A_{j1}^2)+(K_{j2}/A_{j2}^2)]A_{jm}^2$	$K_{jmf}=[(0.33/0.00789^2)]0.01863^2 = 1.840$ $K_{jmr}=[(0.29/0.00789^2)]0.01863^2 = 1.617$

Combining Heat Structures

$L_m = L_1 + L_2$	

Combining Heat Structures

$L_m = L_1 + L_2$	$L_m = 2.0 + 2.0 = 4.0$
$A_{im} = A_{i1} + A_{i2}$	

Combining Heat Structures

$L_m = L_1 + L_2$	$L_m = 2.0 + 2.0 = 4.0$
$A_{im} = A_{i1} + A_{i2}$	$A_{im} = 2\pi(0.0501*2+0.0770*2)=$ 1.597
$R_{im} = A_{im}/(2\pi L_m)$	

Combining Heat Structures

$L_m = L_1 + L_2$	$L_m = 2.0 + 2.0 = 4.0$
$A_{im} = A_{i1} + A_{i2}$	$A_{im} = 2\pi(0.0501*2+0.0770*2)= 1.597$
$R_{im} = A_{im}/(2\pi L_m)$	$R_{im} = 1.597/(2\pi 4) = 0.0635$
$V_{hs1} = \pi[(R_{i1}+ t_1)^2 - R_{i1}^2)]L_1$	

Combining Heat Structures

$L_m = L_1 + L_2$	$L_m = 2.0 + 2.0 =$ 4.0
$A_{im} = A_{i1} + A_{i2}$	$A_{im} = 2\pi(0.0501*2+0.0770*2)=$ 1.597
$R_{im} = A_{im}/(2\pi L_m)$	$R_{im} = 1.597/(2\pi 4) =$ 0.0635
$V_{hs1} = \pi[(R_{i1}+ t_1)^2 – R_{i1}^2)]L_1$	$V_{hs1} = \pi[(0.0501+ 0.0066)^2 – 0.0501^2)]2.0 =$ 0.00443
$V_{hs2} = \pi[(R_{i2}+ t_2)^2 – R_{i2}^2)]L_2$	

Combining Heat Structures

$L_m = L_1 + L_2$	$L_m = 2.0 + 2.0 =$ 4.0
$A_{im} = A_{i1} + A_{i2}$	$A_{im} = 2\pi(0.0501*2+0.0770*2)=$ 1.597
$R_{im} = A_{im}/(2\pi L_m)$	$R_{im} = 1.597/(2\pi 4) =$ 0.0635
$V_{hs1} = \pi[(R_{i1}+ t_1)^2 – R_{i1}^2)]L_1$	$V_{hs1} = \pi[(0.0501+ 0.0066)^2 – 0.0501^2)]2.0 =$ 0.00443
$V_{hs2} = \pi[(R_{i2}+ t_2)^2 – R_{i2}^2)]L_2$	$V_{hs2} = \pi[(0.077+ 0.0071)^2 – 0.077^2)]2.0 =$ 0.00719
$V_{hsm} = V_{hs1} + V_{hs2}$	

Combining Heat Structures

$L_m = L_1 + L_2$	$L_m = 2.0 + 2.0 =$ 4.0
$A_{im} = A_{i1} + A_{i2}$	$A_{im} = 2\pi(0.0501*2+0.0770*2)=$ 1.597
$R_{im} = A_{im}/(2\pi L_m)$	$R_{im} = 1.597/(2\pi 4) =$ 0.0635
$V_{hs1} = \pi[(R_{i1}+ t_1)^2 - R_{i1}^2)]L_1$	$V_{hs1} = \pi[(0.0501+ 0.0066)^2 - 0.0501^2)]2.0 =$ 0.00443
$V_{hs2} = \pi[(R_{i2}+ t_2)^2 - R_{i2}^2)]L_2$	$V_{hs2} = \pi[(0.077+ 0.0071)^2 - 0.077^2)]2.0 =$ 0.00719
$V_{hsm} = V_{hs1} + V_{hs2}$	$V_{hsm} = 0.00443 + 0.00719 =$ 0.01162
$R_{om} = \left[R_{im}^2 + \frac{V_{hsm}}{\pi L_m}\right]^{\frac{1}{2}}$	

Combining Heat Structures

$L_m = L_1 + L_2$	$L_m = 2.0 + 2.0 = 4.0$
$A_{im} = A_{i1} + A_{i2}$	$A_{im} = 2\pi(0.0501*2+0.0770*2)= 1.597$
$R_{im} = A_{im}/(2\pi L_m)$	$R_{im} = 1.597/(2\pi 4) = 0.0635$
$V_{hs1} = \pi[(R_{i1}+ t_1)^2 – R_{i1}^2)]L_1$	$V_{hs1} = \pi[(0.0501+ 0.0066)^2 – 0.0501^2)]2.0 = 0.00443$
$V_{hs2} = \pi[(R_{i2}+ t_2)^2 – R_{i2}^2)]L_2$	$V_{hs2} = \pi[(0.077+ 0.0071)^2 – 0.077^2)]2.0 = 0.00719$
$V_{hsm} = V_{hs1} + V_{hs2}$	$V_{hsm} = 0.00443 + 0.00719 = 0.01162$
$R_{om} = \left[R_{im}^2 + \frac{V_{hsm}}{\pi L_m}\right]^{\frac{1}{2}}$	$R_{om} = \left[0.0635^2 + \frac{0.01162}{\pi 4.0}\right]^{\frac{1}{2}} = 0.07045$
$t = (R_{om} – R_{im})/4$	

Combining Heat Structures

$L_m = L_1 + L_2$	$L_m = 2.0 + 2.0 = 4.0$
$A_{im} = A_{i1} + A_{i2}$	$A_{im} = 2\pi(0.0501*2+0.0770*2)= 1.597$
$R_{im} = A_{im}/(2\pi L_m)$	$R_{im} = 1.597/(2\pi 4) = 0.0635$
$V_{hs1} = \pi[(R_{i1}+ t_1)^2 – R_{i1}^2)]L_1$	$V_{hs1} = \pi[(0.0501+ 0.0066)^2 – 0.0501^2)]2.0 = 0.00443$
$V_{hs2} = \pi[(R_{i2}+ t_2)^2 – R_{i2}^2)]L_2$	$V_{hs2} = \pi[(0.077+ 0.0071)^2 – 0.077^2)]2.0 = 0.00719$
$V_{hsm} = V_{hs1} + V_{hs2}$	$V_{hsm} = 0.00443 + 0.00719 = 0.01162$
$R_{om} = \left[R_{im}^2 + \frac{V_{hsm}}{\pi L_m}\right]^{\frac{1}{2}}$	$R_{om} = \left[0.0635^2 + \frac{0.01162}{\pi 4.0}\right]^{\frac{1}{2}} = 0.07045$
$t = (R_{om} – R_{im})/4$	$t = (0.07045 – 0.0635)/4 = 0.00174$

Change Input Deck

- Start with the class example deck.
- Change pipe to represent 3 similar pipes the same values as the original.
- Talk with your group about how you could combine Heat Structures for this example

Combining in Parallel

- DVDs have another example you can work through
- I suggest you make yourself familiar with this process

Assignment

- Watch DVD sections 39-43 before next Class
- Homework 4 is due Thursday (10/2)