Exercise with a Simplified Reactor

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A simplified reactor: SR-11

Cylindrical reactor containing approximately 113,363 pebbles in an active core of 21.206 m^3.

The core is surrounded (axially and radially) by a graphite reflector.

The thickness of every reflector mesh is chosen in order to have the same volume in as many reflector batches as possible. On top of the pebble bed there is a void region with a height of 0.5m. The pebble bed is divided in 6x6 nodes. A SERPENT benchmark fuel is used.

The filling factor in the pebble bed is 0.6046 and in the reflector is 1.0.

The nuclide densities in the batches are set manually.

Fuel type: LEU-UO2-LTI-TRISO.

Particle batch: EUO 2308.


0/0 (cm)
61.237
86.602
106.066
122.474
136.930
150.0
173.206
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
550.0
Rod drive
Rod cavity
Pebble ped
Sink
Source
Cavity flow
Reflector

SS Task1

Calculate the fuel temperature coefficient of reactivity (800K – 1000K) and the moderator temperature coefficient of reactivity (800K – 1000K), respectively.

SS Task1

1. Go to the SS Task1 folder:

   cd /home/userXX/HCP/code/data/input/HCP2026/Case_SS/Task1

2. Modify the fuel or moderator temperature in “Model.xml”.

```
124          57 56 55 54 53 52 51
125        </Data>
126        <Data type="Temperature" kind="Fuel" calcDomainGrid="Fuel" unit="K">
127          900.0
128        </Data>
129        <Data type="Temperature" kind="Moderator" calcDomainGrid="Nuclear" unit="K">
130          900.0
131        </Data>
132        <Data type="FillingFactor" calcDomainGrid="Fluid">
133          1.0  1.0  1.0  1.0  1.0  1.0  1.0
```

3. Run the simulation and record k_{eff} after each change.

```
1121 EQUILIBRIUM CALCULATION  (%-INFORM. WITH RESPECT TO EQUILIBRIUM POWER  5.0000D+07 W)
1122             CPUS IFG      VFT IGS     VGT  DP21   P   TK1  TK2  TK3     MP1   WQK  BZEM
1123             (S)      ITF  (K)     IMX  (K)  (MB)  (B)  (C)  (C)  (C)     (KG/S) (%)  (C)
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145 *** Equilibrium calculation converged ***
1146
```

ITN	VNL (%)	WQNT (%)	KEFF	max. changes in Mat. Mesh Solid.-,	Mat. Mesh Gas-Temp.,	Mat. Mesh nucl.Pow.	Mesh-CS-Generation It	Spect-C	CS-Approx
10	1.26	100.00	1.14828196104			4 1 6 1	1	57	6
10	-0.01	100.00	1.14835062339			1 1 3 1			
20	1.27	106.33	1.14835062339			1 1 3 1			
10	-0.07	100.00	1.13891520994			28 5 6 1	1	57	6
11	-0.00	100.00	1.13890192479			1 1 3 1			
21	0.07	99.62	1.13890192479			1 1 3 1			
10	0.00	100.00	1.13884027164			11 2 7 1	1	57	6
11	-0.00	100.00	1.13884012240			13 3 3 1			
21	0.00	100.02	1.13884012240			13 3 3 1			
4	-0.00	100.00	1.13883745410			34 6 6 1	1	57	6
11	0.00	100.00	1.13883732691			31 6 3 1			
11	-0.00	100.00	1.13883732875			31 6 3 1			
26	0.00	100.00	1.13883732875			31 6 3 1			
5	0.00	100.00	1.13883703974			17 3 7 1	1	57	6
11	0.00	100.00	1.13883703051			31 6 3 1			
7	-0.00	100.00	1.13883703039			1 1 3 1			
23	0.00	100.00	1.13883703039			1 1 3 1			
5	-0.00	100.00	1.13883699458			34 6 6 1	1	57	6
9	0.00	100.00	1.13883699361			13 3 3 1			
14	0.00	100.00	1.13883699361			13 3 3 1			

4. Calculate the temperature coefficients.

SS Task2

Perform both a pure neutronics simulation and a coupled multiphysics simulation (with “FluidDynamics” activated) for the steady-state case of the simplified reactor. Then, plot and compare the resulting power distributions.

SS Task2

1. Go to the SS Task2 folder:

   cd /home/userXX/HCP/code/data/input/HCP2026/Case_SS/Task2

2. Pure neutronics simulation: this case is already prepared for you. Run the simulation and then rename the output file from “output.txt” to “output_neutronics.txt”

3. Coupled multiphysics simulation: uncomment the “FluidDynamics” section in “Scenario.xml”. Run the simulation and then rename the output file from “output.txt” to “output_coupled.txt”

```
63      <Setting type="Switch" kind="Capture"> 1 </Setting>
64      <Setting type="Switch" kind="CondensedBurning"> 1 </Setting>
65    </Settings>
66
67    <!--Settings type="FluidDynamics">
68      <Setting type="Value" kind="MaxStepWidth" unit="s"> 5.0 </Setting>
69      <Setting type="Value" kind="MinStepWidth" unit="s"> 0.0001 </Setting>
70      <Setting type="Mode"  kind="KernelModel"> 0D </Setting>
71      <Setting type="Value" kind="ParticleOverheat"> 1 </Setting>
72      <Setting type="Switch" kind="ModFuelTemp" boundaryCond="extrapolated"> 1 </Setting>
73      <Setting type="Value" kind="MaxSolidTemp" unit="K"> 2.0 </Setting>
74      <Setting type="Value" kind="MaxGasTemp" unit="K"> 5.0 </Setting>
75      <Setting type="Value" kind="MaxRelPower" unit="W"> 0.5 </Setting>
76      <Setting type="Value" kind="SolidTemp" unit="K"> 0.2 </Setting>
77      <Setting type="Value" kind="FuelTemp" unit="K"> 0.2 </Setting>
78      <Setting type="Value" kind="GasTemp" unit="K"> 0.2 </Setting>
79    </Settings-->
80
81    <Settings type="Neutronics">
82      <Setting type="Value" kind="Power" unit="MW"> 50.0 </Setting>
83      <Setting type="Mode" kind="HeatProduction"> MGT </Setting>
```

SS Task2

4. Run the Octave script to extract the data and plot the power profile:

   octave

   plotpower

5. Check the figures as pdf files. Why are they different?

SS Task3

Modify the enrichment and the number of TRISO particles in the fuel pebble, observe their effect on the keff. Reduce the number of TRISO particles to 2500, find the enrichment value to reach criticality.

SS Task3

1. Go to the SS Task3 folder:

   cd /home/userXX/HCP/code/data/input/HCP2026/Case_SS/Task3

2. Change the number of TRISO particles to 2500 in “Model.xml”.

```
374   <ParticleCompositions n="1">
375     <ParticleComposition id="1" type="CoatedParticle" label="CPComp1">
376       <Property type="NumberOfParticles"> 15000 </Property>
377       <Property type="Fraction" unit="norm1" particle="1"> 1.0 </Property>
378     </ParticleComposition>
379   </ParticleCompositions>
380
```

3. Adjust the enrichment in “Model.xml” and run the simulation.

```
422   <Material id="UO2">
423     <Compound label="UO2">
424       <Property type="Element" proportion="1"> U </Property>
425       <Property type="Element" proportion="2"> O </Property>
426     </Compound>
427     <Properties type="Common">
428       <Property type="Density" unit="g/cm^3"> 10.4 </Property>
429       <Property type="Enrichment" nuclide="U-235" base="U" unit="w%"> 8.2 </Property>
430       <!--in case no base, it refers to whole material -->
431       <Property type="Impurity" element="B" base="U" unit="ppm"> 24.953 </Property>
432       <Property type="HeatCapacity" kind="value" unit="Ws/cm3K" factor="1.0"> 3.526041 </Property>
433       <Property type="HeatConductivity" kind="value" unit="W/cmK" factor="1.0"> 0.03163283 </Property>
434     </Properties>
435   </Material>
```

4. Repeat Step 3 until $k_{eff} = 1$.

TR Task1

Perform the transient simulation with the coolant inlet temperature increased from 250.0°C to 300.0°C in 120s, observe the system responses.

TR Task1

1. Go to the TR Task1 folder:

   cd /home/userXX/HCP/code/data/input/HCP2026/Case_TR/Task1

2. Add the transient action by modifying “Scenario.xml”:

```
<TimeLine nActions="3">

  <Action begin="0.0" end="0.0" unit="s">
    <Calculation type="Stationary" mode="manual">
      <Ramp type="SteadyState" from="Recalculation"/>
    </Calculation>
  </Action>

  <Action begin="0" end="120" unit="s" >
    <Calculation type="Transient">
      <Ramp duration="120" unit="s" type="Gas">
        <Gas type="InletTemp">
          <InletTemp type="TempValue">
            <TempValue material="3" value="300" unit="C"/>
          </InletTemp>
        </Gas>
      </Ramp>
    </Calculation>
  </Action>

  <Action begin="120" end="3000" unit="s" >
  <Preferences scope="persistent">
      <Settings type="FluidDynamics">
        <!-- For all settings, a default value must be given -->
        <Setting type="Value" kind="MaxStepWidth" unit="s"> 10.0 </Setting>
      </Settings>
  </Preferences>
    <Calculation type="Transient">
      <Ramp type="FreeTransient"/>
    </Calculation>
  </Action>
</TimeLine>
```

3. Run the simulation and then run the following command to export the transient data to “output.csv” (Row 3: thermal power; Row 5: maximum fuel temperature; Row 8: average moderator temperature; Row 9: average fuel temperature): readptr data.ptr output.csv

4. Use Octave to visualize the result.

TR Task2

Change the power to 25MW and 100MW, adjust the coolant mass flow rate to achieve the same outlet temperature. Then perform the transient simulation in “TR Task1”.

TR Task2

1. Go to the TR Task2 folder:

   cd /home/userXX/HCP/code/data/input/HCP2026/Case_TR/Task2

2. Change the power and coolant mass flow rate:

```
81    <Settings type="Neutronics">
82      <Setting type="Value" kind="Power" unit="MW"> 50.0 </Setting>
83      <Setting type="Mode" kind="HeatProduction"> MGT </Setting>
84      <Setting type="Value" kind="MaxStepWidth" unit="s"> 60.0 </Setting>
```

```
317   <Component id="4" type="CavityFlow" label="Sink">
318     <Property type="SolidTemperature" unit="C"> 750.0 </Property>
319     <Property type="GasTemperature" unit="C"> 750.0 </Property>
320     <Property type="HeatCapacity" kind="rule" factor="1.0"> G01 </Property>
321     <Property type="HeatConductivity" kind="rule" factor="0.01"> R08 </Property>
322     <Property type="VolumeOverSurfaceRatio" unit=""> 4.0 </Property>
323     <Property type="Massflow" unit="kg/s"> -25.0 </Property>
324   </Component>
```

3. Run the simulation and then run the following command to export the transient data to “output.csv”:

   readptr data.ptr output.csv

4. Use Octave to visualize the results.

TR Task3

Perform the transient simulation with the coolant mass flow rate variation of ±30% in 20s, observe the system responses.

TR Task3

Add the transient action by modifying “Scenario.xml”:

```
<TimeLine nActions="4">

  <Action begin="0.0" end="0.0" unit="s">
    <Calculation type="Stationary" mode="manual">
      <Ramp type="SteadyState" from="Recalculation"/>
    </Calculation>
  </Action>

  <Action begin="0.0" end="20.0"  unit="s">
    <Preferences scope="persistent">
      <Settings type="FluidDynamics">
      <Setting type="Value" kind="MaxStepWidth" unit="s"> 5.0 </Setting>
      </Settings>
    </Preferences>
    <Calculation  type="Transient" mode="manual">
    <Ramp duration="20.0" unit="s" type="Gas">
        <Gas type="MassFlowSource">
          <MassFlowSource material="4" value="-17.5" unit="kg/s"/>
        </Gas>
    </Ramp>
    </Calculation>
  </Action>

  <Action begin="20.0" end="1000.0" unit="s">
    <Preferences scope="persistent">
      <Settings type="FluidDynamics">
        <Setting type="Value" kind="MaxStepWidth" unit="s"> 10.0 </Setting>
      </Settings>
    </Preferences>
    <Calculation type="Transient">
    </Calculation>
  </Action>

 <Action begin="1000.0" end="6000.0" unit="s">
    <Preferences scope="persistent">
      <Settings type="FluidDynamics">
        <Setting type="Value" kind="MaxStepWidth" unit="s"> 20.0 </Setting>
      </Settings>
    </Preferences>
    <Calculation type="Transient">
    </Calculation>
  </Action>

</TimeLine>
```

TR Task4

Perform the PLOFC transient simulation (coolant mass flow rate reduced to 0 in 60s), observe the system responses.