The study of CFD Simulation for Air Ingress Accident with HTGR

Reporter: Joy Chou
Author: Ming-Jui Chang
        Yuh-Ming Ferng prof.
        Bau-Shei Pei prof.

National Tsing Hua University, Hsinchu city, Taiwan

E-mail : vilasofe@gmail.com
Outline

- Introduction
- Description of the GT-MHR600
- Numerical results and discussion
- Boundary conditions
- Conclusion
Introduction (1/2)

- High temperature gas-cooled reactor (HTGR) is a helium cooled thermal reactor using graphite as a moderator. The core keeps at very high temperature under normal operating. For the HTGR design, it has increased the features of an inherent safety, high thermal efficiency, a high temperature process heat potential, and a hydrogen production.
Introduction (2/2)

- The air ingress accident is that air enters the reactor system through a break in the primary circuit. This air reacts with hot graphite at temperatures ranging from 500 to 1100 °C resulting in chemical reactions that produce both CO and CO₂.
## Description of the GT-MHR600

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Power (MW)</td>
<td>600</td>
</tr>
<tr>
<td>Core height (m)</td>
<td>7.93</td>
</tr>
<tr>
<td>Core dimension (m)</td>
<td>4.83</td>
</tr>
<tr>
<td>Core pressure (MPa)</td>
<td>7</td>
</tr>
<tr>
<td>Inlet He temperature (°C)</td>
<td>490</td>
</tr>
<tr>
<td>Average He outlet temperature (°C)</td>
<td>950</td>
</tr>
<tr>
<td>He mass flow rate (kg/s)</td>
<td>320</td>
</tr>
</tbody>
</table>
Boundary conditions

- This figure shows the simulation model of the GT-MHR 600. The simulation region contains the steam generator and core region.
- The red part is the core area and uses the porous media model. The steam generator is the blue area.
Boundary conditions

- Upper plenum
- Fuel
- Lower plenum
- Reactor bottom
- Coolant riser
- Coolant riser
- Hot gas duct
- Cold gas duct
- Reflector
- Fuel
Boundary conditions

- The basic assumptions at steady state:
  - All the wall conducted at thermal isolation conditions.
  - The power density was 6.6 MW/m³
  - A porous media condition was applied to the core blocks.
  - The volume porosity was 0.185.
## Boundary conditions

<table>
<thead>
<tr>
<th></th>
<th>Core and hot duct region</th>
<th>Steam generator region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure (Pa)</td>
<td>101325</td>
<td>0</td>
</tr>
<tr>
<td>Temperature (K)</td>
<td>Same as the full power condition</td>
<td>300</td>
</tr>
<tr>
<td>Mass fraction of He (%)</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Mass fraction of O₂ (%)</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>Mass fraction of N₂ (%)</td>
<td>0</td>
<td>78</td>
</tr>
</tbody>
</table>

![Diagram of boundary conditions](image)
Numerical results and discussion-temperature

- This figure shows the temperature contour of the core at the steady state.
- Coolant inlet temperature is 763K.
- The maximum temperature of coolant is located at lower plenum. And the maximum temperature of coolant is 1330K.
- The heated helium stream out from the crack of the hot gas duct and the outlet temperature is 1221K, same as the data provided from reference[1], which is 1223K.
Numerical results and discussion

0.2 sec
Numerical results and discussion—graphite corrosion

![Graphite corrosion graph]

- Point 1
- Point 2
- Point 3
- Point 4
Numerical results and discussion - graphite corrosion
Numerical results and discussion - graphite corrosion
Numerical results and discussion: graphite corrosion

30s

50s

100s

200s
Numerical results and discussion

- Graphite corrosion
Conclusion

1. After using FLUENT, we can predict the hot gas duct outlet temperature (1221K) of the GT-MHR600 reactor in full power. And the maximum temperature of the fuel region is 1330K and it will not exceed the safety limit of 1873K. This proves that the fuel region of the GT-MHR600 reactor in full power is safe.

2. With the time of the accident, the density curve difference between air and helium is smooth. This proves that the air into the core by diffusion.

3. Because oxygen diffuses more easily into the reactor core from the lower plenum, the corrosion of the fuel are concentrated in the lower region of the core.
References


Thank you for attention