22.313J, 2.59J, 10.536J THERMAL-HYDRAULICS IN POWER TECHNOLOGY

Homework Set 5

Simplified Thermal Analysis of the PWR Hot Channel

The fuel pin geometry for a standard Westinghouse PWR is shown in Figure 1. The heated length is 3.66 m. Consider the following operating conditions, which apply to the hot channel:

Pressure: 15.5 MPa
Inlet temperature: 285°C (corresponding to an inlet enthalpy of 1263.4 kJ/kg)
Mass flux: 3,500 kg/m^{2}s
Linear power: 30 kW/m

1) Assuming axially constant linear power, develop a numerical model to calculate the following parameters in the hot channel:

- Axial distribution of the coolant enthalpy
- Axial distribution of the bulk temperature
- Axial distribution of the equilibrium quality
- Axial location of the onset of nucleate boiling (*Hint:* use the Davis-Anderson model, and verify that the size of the nucleation sites is reasonable, i.e., <10 μm).
- Axial distribution of the wall temperature (*Hint*: use the Dittus-Bolter correlation for single-phase heat transfer, the Thom correlation for fully-developed boiling and the Bergles-Rosenhow superposition method for partial boiling)
- Axial location of the onset of significant voids (*Hint:* use the Saha-Zuber correlation)
- Axial distribution of the flow quality (*Hint:* use the Levy model)

2) Are the flow and equilibrium qualities different at the hot channel outlet? If so, why?

3) If the mass flux is increased somewhat, while keeping all other operating conditions identical, do the axial locations of the onset of nucleate boiling and onset of significant voids shift towards the inlet or the outlet?

Assumptions:

- Treat the channel as a round tube of equivalent diameter
- Use the properties in Table 1. Neglect the dependence of the properties on temperature and pressure.
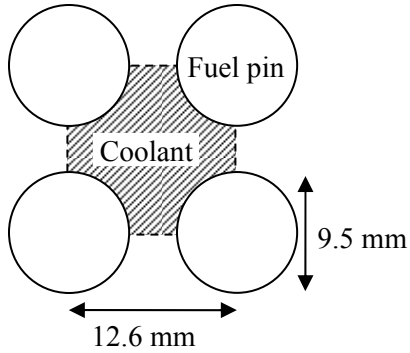
Figure 1. Cross-sectional view of the PWR hot channel

Table 1. Properties to be used in this homework set.

Parameter	Value
Subcooled liquid properties	
$C_{p,\ell}$	6.3 kJ/(kg°C)
μ_ℓ	8.6×10^{-5} Pa·s
k_ℓ	0.516 W/(m°C)
Saturation properties	
T_{sat}	617.8 K (344.6°C)
ρ_f	593 kg/m^3
ρ_g	101 kg/m^3
h_f	1,631 kJ/kg
h_g	2,596 kJ/kg
$C_{p,f}$	9.1 kJ/(kg°C)
$C_{p,g}$	13.7 kJ/(kg°C)
μ_f	7.3×10^{-5} Pa·s
μ_g	2.3×10^{-5} Pa·s
k_f	0.448 W/(m°C)
k_g	0.123 W/(m°C)
σ	0.0048 N/m
Molecular weight	0.018 kg/mol