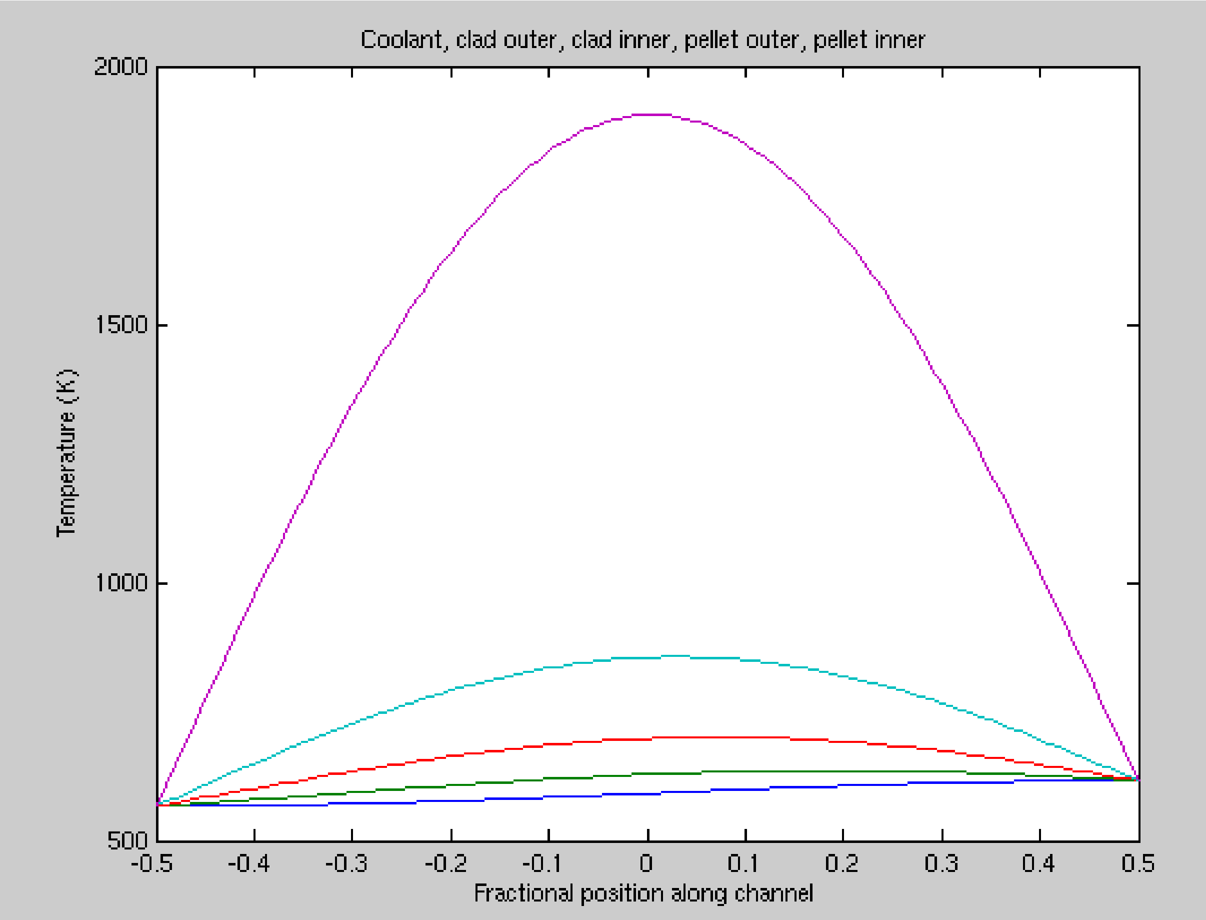
Nuclear Thermal-Hydraulics

PWR Question

(a)

Typical PRW temperature distributions



(b)

$$\dot{m}C_p \frac{dT}{dz} = \dot{q}'(z)$$

So the coolant temperature at any location is given by:

$$T(z) - T_{in} = \frac{1}{\dot{m}C_p} \int_{\frac{-L}{2}}^{z} \dot{q}'(z)\,dz$$

For a cylindrical reactor

$$\dot{q}'(z) = \hat{\dot{q}}' \cos\left(\frac{\pi z}{L}\right)$$

so using this

$$T(z) - T_{in} = \frac{\hat{\dot{q}}'}{\dot{m}C_p} \int_{\frac{-L}{2}}^{z} \cos\left(\frac{\pi z}{L}\right) dz$$

or

$$T(z)-T_{in}=\frac{\hat{q}'}{\dot{m}C_p}\frac{L}{\pi}\left[\sin\left(\frac{\pi z}{L}\right)-\sin\left(\frac{-\pi\frac{L}{2}}{L}\right)\right]=\frac{\hat{q}'}{\dot{m}C_p}\frac{L}{\pi}\left[\sin\left(\frac{\pi z}{L}\right)-\sin\left(\frac{-\pi}{2}\right)\right]$$

or

$$T(z)-T_{in}=\frac{\hat{q}'}{\dot{m}C_p}\frac{L}{\pi}\left(\sin\left(\frac{\pi z}{L}\right)+1\right)$$

At any location z the *difference* between clad surface temperature T_c and the bulk coolant temperature T is proportional to the local surface heat flux: That is

$$\left(T_c(z)-T(z)\right)2\pi r_c h=\dot{q}'(z)$$

where h is the heat transfer coefficient and r_c the clad outer radius.

So

$$T_C(z)=T(z)+\frac{1}{2\pi r_C h}\dot{q}'(z)$$

Using $T(z)$ from above, and $\dot{q}'(z)$, we can write

$$T_C(z)=T_{in}+\frac{\hat{q}'}{\dot{m}C_p}\frac{L}{\pi}\left(\sin\left(\frac{\pi z}{L}\right)+1\right)+\frac{1}{2\pi r_C h}\hat{q}'\cos\left(\frac{\pi z}{L}\right)$$

or

$$T_C(z)=T_{in}+\frac{\hat{q}'}{\pi}\left(\frac{L}{\dot{m}C_p}\left[\sin\left(\frac{\pi z}{L}\right)+1\right]+\frac{1}{2r_C h}\cos\left(\frac{\pi z}{L}\right)\right)$$

Differentiating the above we get:

$$\frac{\partial T_C(z)}{\partial z}=\frac{\hat{q}'}{\pi}\left\{\frac{L}{\dot{m}C_p}\frac{\pi}{L}\cos\left(\frac{\pi z}{L}\right)-\frac{1}{2r_C h}\frac{\pi}{L}\sin\left(\frac{\pi z}{L}\right)\right\}$$

Setting to zero we have at the maximum-temperature location:

$$\frac{z}{L}=\frac{1}{\pi}\arctan\left(\frac{2r_C hL}{\dot{m}C_p}\right)$$

(c) numbers:

Physical properties		
Coolant density	kg/m^3	7.13000E+02
Specific heat	J/(kg K)	5.79400E+03
Viscosity	kg m-1 s-1	9.07000E-05
Conductivity	W/mK	5.41000E-01

Problem data		
pin length	m	3.66000E+00
pin od	m	9.50000E-03
pin square pitch	m	1.26000E-02
mass flow rate per pin	kg/s	3.66000E-01
peak linear rating	W/m	4.13000E+04

Coolant inlet temperature	K	5.66500E+02

Computed geometric quantities

flow area per pin	m^2	8.78779E-05
wetted perimeter	m	2.98451E-02
hydraulic diameter	m	1.17779E-02

Dimensionless numbers

Reynolds number	-	5.40830E+05
Prandtyl No.	-	9.71379E-01
Nu from D-B	-	8.77267E+02
Heat transfer coefficient	W m-2 K-1	4.02961E+04
Convenient intermediate nos.		
q-dot-dash-max/m-dot Cp*(L/pi)		2.26894E+01
Location of T clad max		6.80211E-01
Value of T clad max		6.30349E+02

(d) Unchanged. Heat generation not function of flow rate.