Water Reactor Thermal Hydraulics

Analytical (Matlab) Pin and Channel Analysis

Objectives

This exercise is intended to

-reinforce and increase your understanding of channel analysis

-help familiarize you with typical values of the various thermal-hydraulic quantities

-allow you to investigate the concept and application of "departure from nucleate boiling", and appreciate its limitations.

a_TFINTERACTIVE

a_TFINTERACTIVE is a direct implementation of the equations presented in the notes on channel analysis.

a_ TFINTERACTIVE comes with reactor types AGR, PWR and PW2 'built-in'. Additional types (eg RE1, RE2; they must have 3-character names) can readily be added; just examine the code and follow the same approach.

Run a_TFINTERACTIVE simply by typing a_TFINTERACTIVE at the Matlab prompt. (You will of course need to set your Matlab paths appropriately.

There is no documentation beyond internal comments and the text it writes to the screen; the code is heavily commented, and your lecture notes provide the mathematical / physics background.

The exercise is structured as a series of questions.

1 BASIC MODEL

Run a_TF_INTERACTIVE for the PWR and AGR cases provided. Comment on the thermal conditions predicted in comparison to those predicted for the AGR case provided.

2 IMPROVED AXIAL FLUX VARIATION

Real reactors have axial flux variations significantly different from $\dot{q}'(z) = \hat{\dot{q}}' \cos\left(\frac{\pi z}{L}\right)$.

A better model is

$$\dot{q}'(z) = \hat{\dot{q}}' \cos\left(\frac{\pi z}{L_e}\right); \quad -\frac{L}{2} < z < \frac{L}{2}$$

where L_e is some 'extrapolated length' slightly greater than the channel length.

Modify a_TFINTERACTIVE to model this. This will generate the need for an additional item of data; the extrapolated length. You can either add this using the same interactive approach as the other data, or simply add a hard-coded line, which is less elegant but easier to implement.

Comment on the changed thermal conditions.

3 DEPARTURE FROM NUCLEATE BOILING ('CRITICAL HEAT FLUX')

Evaluate the "departure from nucleate boiling ratio" (DNBR) variation along your channel.

This will require you know what the departure from nucleate boiling is, and how it is predicted using correlations based on measurements. Learning this is one of the main outputs for you from this present exercise. The book by Tong (Tong, L. S. and Y. S. Tang (1997). Boiling Heat Transfer and Two-phase Flow, Taylor and Francis, Washington) gives a good introduction, as does the report by Hewitt & Walker. There are various correlations; 'W3' is a good, general purpose one.

The 'W-3' correlation predicts CHF a function of inlet sub-cooling, pressure and coolant mass flux:

$$\dot{q}_c = K_1(p,x_e)\cdot K_2(x_e,G)\cdot K_3(D_e)\cdot K_4(h_{in})$$

where:

$$K_1(p,x_e)=[1.157-0.869x_e].$$
$$\{(2.022-0.06238p)+(0.1722-0.01427p)\exp[(18.177-0.5987p)x_e]\}$$

$$K_2(x_e,G)=[(0.1484-1.596x_e+0.1729x_e|x_e|)\cdot 2.326G+3271]$$

$$K_3(x_e,D_h)=[0.2664+0.8357\exp(-124.1D_e)]$$

$$K_4(h_{in})=[0.8258+0.0003413(h_{sat}-h_{in})]$$

It is applicable:-

$$5.5<p<16MPa$$
$$1356<G<6800kg/m^2s$$
$$1.5<D_h<1.8cm$$
$$-0.15<x_e<+0.15$$
$$0.254<L<3.7m$$

Notation:

$\dot{q}_c$	kW/m^2	critical heat flux
p	MPa	pressure
x_e		local quality
D_e	m	equivalent hydraulic diameter
G	Kg/m^2.s	mass flux
h_{sat}	kJ/kg	saturated liquid enthalpy
h_{in}	kJ/kg	inlet enthalpy

The correlation above is for uniformly heated channels, but for sub-cooled conditions, as here it can be applied reasonably accurately to non-uniform heating cases. (Why?).

Of just what is 'DNBR' the ratio? (Type it out in detail; it will help you understand this issue.) Consider carefully just what actual meaning it has.