Chemical Reactor Analysis

In this problem, we take the case of a jacketted CSTR and understand its dynamical behaviour. CSTR's are meant to be operated at steady state. However, before the steady state is reached, there are transients in the system which must die out with time. Due to the provision of heating/cooling by a fluid in the jacket, this arrangement is also called diabatic or isothermal reactor. We use the following input and dynamical variables:

C: Concentration of the reactant in the reactor

C_f: Concentration of the reactant in the feed

T: Reactor temperature

T_f: Feed temperature

T_j: Jacket temperature

F: Constant volumetric feed rate of the reactant

F_j: Constant volumetric feed rate of heating/cooling fluid in the jacket

V: Reactor volume

r: rate of reaction

The mass and energy balance over the reactor give the following governing dynamical equations:

$$\frac{dC}{dt} = \frac{F}{V}(C_f - C) - r$$

$$\frac{dT}{dt} = \frac{F}{V}(T_f - T) + \left(\frac{-\Delta H}{\rho c_p}\right) r - \frac{UA}{V\rho c_p}(T - T_j)$$

(a) For the given system, determine the steady state concentration profile.

(b) Determine the steady state reactor temperature(s). Comment upon the number of steady state temperatures in the system. Do you see any bifurcation in the system that you previously came across?

(c) Generate the steady state reactor temperature profile as a function of jacket temperature.

(d) Generate the steady state reactor temperature profile as a function of feed temperature.

(e) Linearise the coupled dynamical equations to get a linear model. Comment upon the stability of the steady state temperatures.