6.0 Include the control element that you need to install in operating the reactor and specify your justification

a. What is the transfer function for the reactor?

In the pyrolysis reaction we have chosen, the fluidized bed reactor consists of an electrical heater which is used to maintain the desired temperature in the reactor.

Thus, the transfer function for the temperature control is as follows:

Unsteady State Energy Balance

For reactors' elements $:mC\frac{dT}{dt} = wC(T_i - T) + h_eA_e(T_e - T)$ ---(1)

For heating elements (heater) $:m_eC_e\frac{dT_e}{dt} = Q + h_eA_e(T_e - T)$ -------------(2)

Steady State Energy Balance

For reactors' elements $:0 = wC(\overline{T_i} - \overline{T}) + h_eA_e(\overline{T_e} - \overline{T})$ ---------(3)

For heating elements (heater) $:0 = \overline{Q} + h_eA_e(\overline{T_e} - \overline{T})$ -----------------------(4)

Now, subtract the steady state equation from the unsteady state Energy balance.

For reactors' elements $:mC\frac{dT}{dt} = wC[(\overline{T_i}\text{-}\overline{T_i})\text{-}(T - \overline{T})] + heAe[(Te - \overline{T_e}) - (T - \overline{T})]$ ----(5)

For heating elements (heater) $: m_e\,C_e\,\frac{dTe}{dt} = (Q - \overline{Q}) - heAe[(Te - \overline{T_e}) - (T - \overline{T})]$ ---(6)

With these 2 equations, we multiply (5) by $\frac{1}{wC}$ and (6) by $\frac{1}{heAe}$ & $\frac{dT}{dt} = \frac{dT\prime}{dt}$ and

$$\frac{dTe}{dt} = \frac{dTe'}{dt}$$

For reactors' elements $:\frac{m}{w}\frac{dT\prime}{dt} = -(T' - T_i') + \frac{heAe}{wC}(T_e' - T)$ ---------------(7)

For heating elements (heater) $: \frac{m_e\,C_e}{heAe}\frac{dTe\prime}{dt} = \frac{Q\prime}{heAe} - (T_e' - T')$ ------------------------(8)

Next, we apply Laplace Transform on equations (7) and (8) :

For reactors' elements $:\left(\frac{m}{w}s + \frac{heAe}{wC}\right)T'(s) = T_i'(s) + \frac{heAe}{wC}T_e'(s)$ ------------(9)

For heating elements (heater) $:\left(\frac{m_e\,C_e}{heAe} + 1\right)T_e'(s) = \frac{Q'(s)}{heAe} + T'(s)$ ---------------------(10)

Now, since we got 2 temperature output (one is reactor temperature's output $[T'(s)]$ and another one is the heater's temperature output $[T_e'(s)]$, therefore we will need to eliminate the $T_e'(s)$. This is because it is the intermediate variable. We obtained:-

$$\left[\frac{m}{w}\frac{m_e\,C_e}{heAe}s^2 + \left(\frac{m_e\,C_e}{heAe} + \frac{m_e\,C_e}{wC} + \frac{m}{w}\right)s + 1\right]T'(s) = \left(\frac{m_e\,C_e}{heAe} + 1\right)T_i'(s) + \frac{1}{wC}Q'(s) \quad \text{---(11)}$$

To obtain the effect of Q' on T', assume that Ti is constant at its normal steady state at its nominal steady state, $\bar{T_\iota}$, this means that $T_i'(s) = 0$

$$\frac{T'(s)}{Q'(s)} = \frac{\frac{1}{wC}}{b_2 s^2 b_1 s + 1} = G_1(s)$$

Similarly, to obtain the effect of $T'i$ on T', assume that $Q = \bar{Q}$, this means that Q'(s) = 0

$$\frac{T'(s)}{Ti'(s)} = \frac{\left(\frac{m_e\,C_e}{heAe}s+1\right)}{b_2 s^2 b_1 s+1} = G_2(s)$$

Where

$$b_1 = \frac{m_e\,C_e}{heAe} + \frac{m_e\,C_e}{wC} + \frac{m}{w} \qquad ; \qquad b_2 = \frac{mm_e\,C_e}{wheAe}$$

By using the superposition principle, the effects of changes in both input temperature, T_i and input heat Energy, Q is as follows:-

$$T'(s) = G_1(s)Q'(s) + G_2(s)\,T_i'(s) \text{ -------- Transfer Function}$$

b. What is the order of the transfer function?

The order of the transfer function is first order.

c. Identify the control variable(s), manipulated variable(s), and possible disturbance variable(s) for the reactor.

Controlled Variables (CV) : Compositions of Bio-Oil, BioChar and Permanent Gas
: Mass Flow Rate of Bio-Oil, BioChar and Permanent Gas (kg/hr)

Manipulated Variables (MV) : Rate of Biomass Feed Flow (kg/hr)

Disturbance Variables (DV) : Process Operating Temperature
: Process Operating Pressure
:The presence of catalysts

d. What type of control algorithm (P, PI, or PID controllers) would you use? Why?

In our pyrolysis technology, we recommend *PID controller* to be use. For PID controller, oscillation is reduced and hence there will not be steady state which is also known as offset. PID controller also reduces response time, which then corrects the error signal once it is detected. Here, the response can be improved by increasing the derivative time. It will reduce the maximum deviation, response time and also the oscillatory.