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180749

GIVEN:

A heated, pressurised, ternary benzene (B) - toluene (T) - ethylbenzene (EB) feed flashes after depressurisation across a pressure reducing valve (PRV). The flash drum pressure is 100 kPa. Vapour and liquid streams exit the flash drum. The nominal feed conditions are a flow rate of 1 kmol/min, the temperature of 200 °C and equimolar composition.

AIM:

1. Develop a MATLAB code for obtaining the steady-state solution of the above flash drum system. Also, obtain the nominal steady-state solution and the vapour fraction variation with the pressurised feed temperature.

2. Develop a dynamic simulation in MATLAB to obtain the transients in liquid/vapour flow rates and compositions and temperature as the feed rate with the following points.
   a. The feed composition and feed temperature are changed about the nominal steady-state.
   b. The feed rate change is a step change.
   c. The feed composition change is implemented for each of the three components, with the other two components remaining in the same proportion.
   d. The feed temperature is changed as a lag of time constant 2 mins.
   e. The liquid rate is under P only level control.

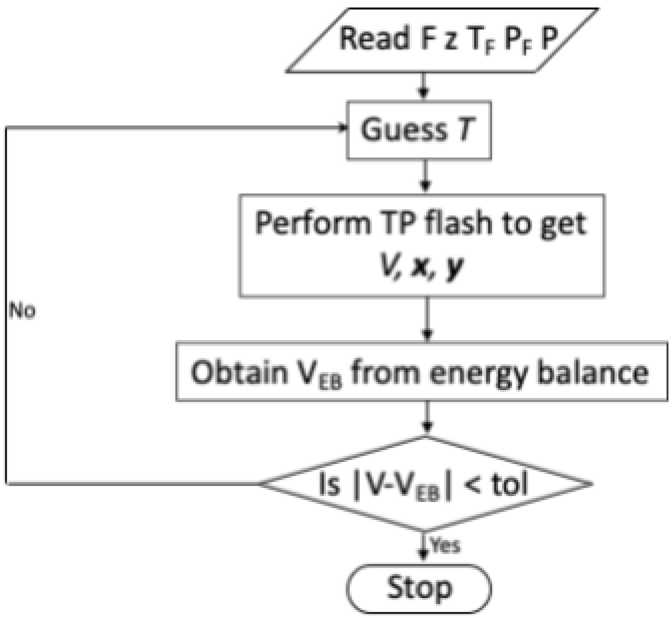
   The relevant physical property data:

Parameter	Benzene	Toluene	EB
A	13.8594	14.0098	14.0045
B	2773.78	3103.01	3279.47
C	220.07	219.79	213.20
C_P *(J/mol°C)*	133	157	186.6
H_{vap} *(kJ/mol)*	33.8	38.0	355.7

Antoine Equation: *$\ln(P^{sat}) = A - B/(T+C)$ P^{sat} in kPa, T in °C*

THEORY & GOVERNING EQUATIONS:

- **Flash Drum Simulation – Steady State:**
  We need first to find the temperature since it is not known to apply the TP flash method for steady-state calculation. We use energy balance and the secant method to guess the temperature.
  - The algorithm to be used:

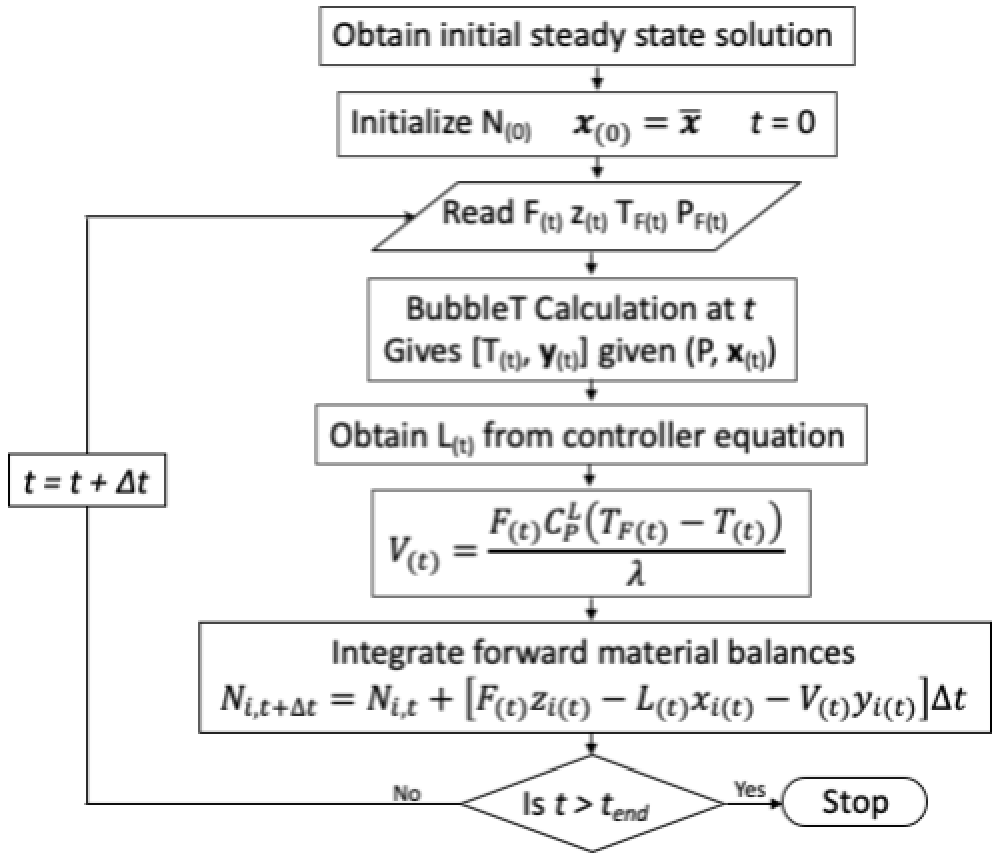


  - Energy Balance:
    $H_v = C^L_{py}*T + l_y$
    $H_l = C^L_{px}*T$
    $H_f = C^L_{pz}*T_f$
    $F* H_f = V*H_v + L*H_l$
    Veb = F*(Clpz*Tf – Clpx*T)/ (Clpy – Clpx) *T + y

  - Secant Method:
    $\Delta T = -f * \alpha / \frac{df}{dT}$ where $0 < \alpha < 1$ and $\frac{df}{dT}$ is calculated by the secant method as
    $\frac{df}{dT} = \frac{dv}{dT} - \frac{dv_{EB}}{dT}$, where, $\frac{dv}{dT} = \frac{v(T+dT) - v(T)}{\Delta T}$ and $\frac{dv_{EB}}{dT} = \frac{v_{EB}(T+dT) - v_{EB}(T)}{\Delta T}$

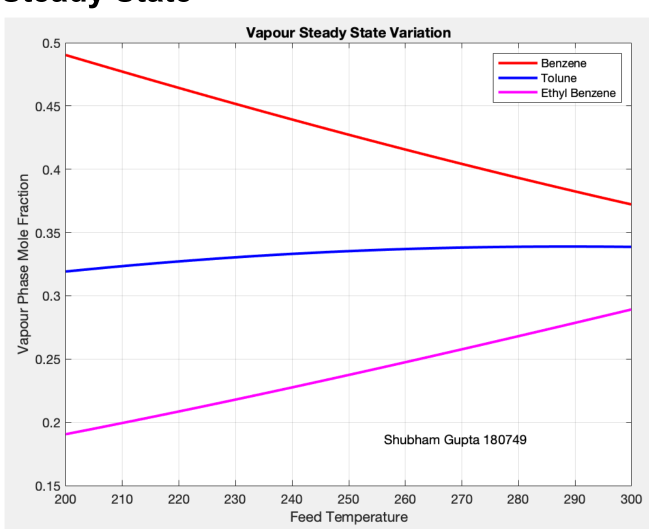
- **Flash Drum Simulation – Dynamic State:**
  - We first calculate the steady-state value of flash-drum which is then used to calculate the values after perturbations.
  - We can express $\frac{dN_{i,t}}{dt}$ as $\frac{N_i(t+\Delta t) - N_i(t)}{\Delta t}$ $\Rightarrow N_i(t + \Delta t) = N_i(t) + \Delta t * \frac{dN_{i,t}}{dt}$ where
    $\frac{dN_{i,t}}{dt} = F * z_{i,t} - V * y_{i,t} - L * x_{i,t}$

- Algorithm to be used:



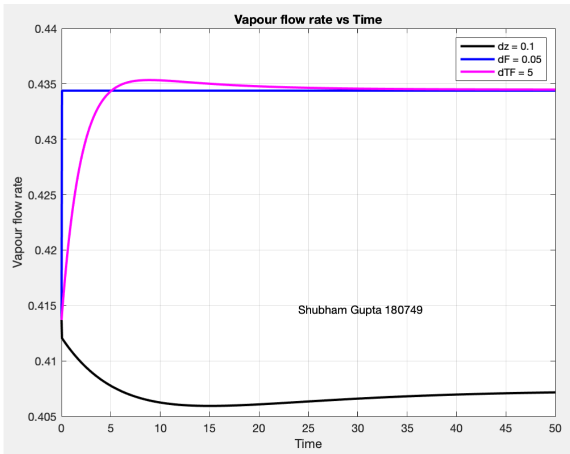
OBSERVATIONS:

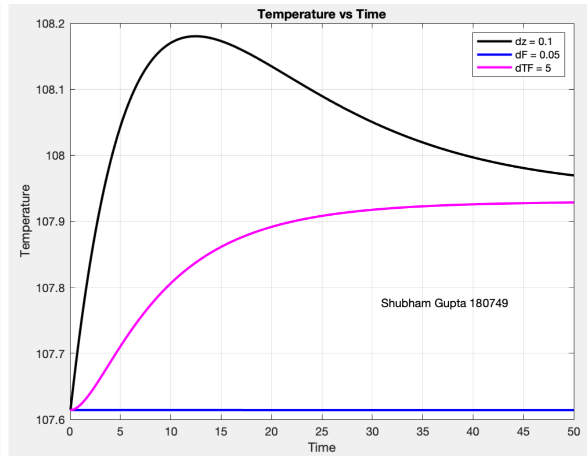
- **Steady State**

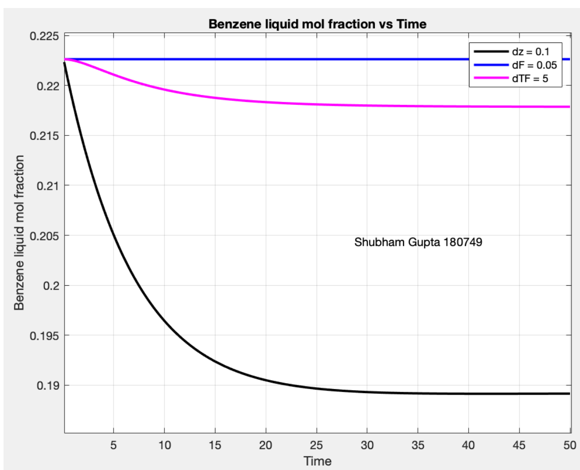


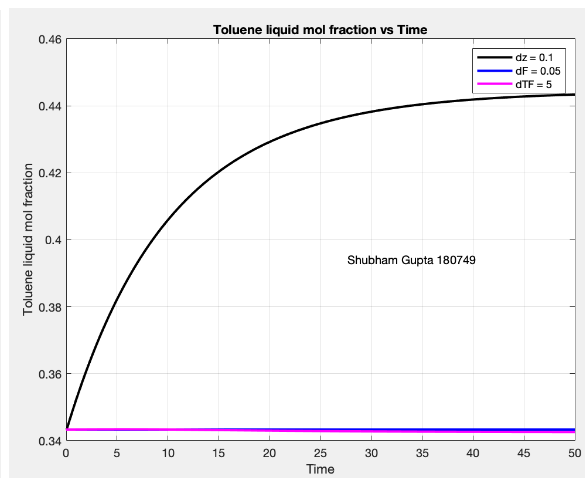
Above is the graph of flash drum simulation for steady state.

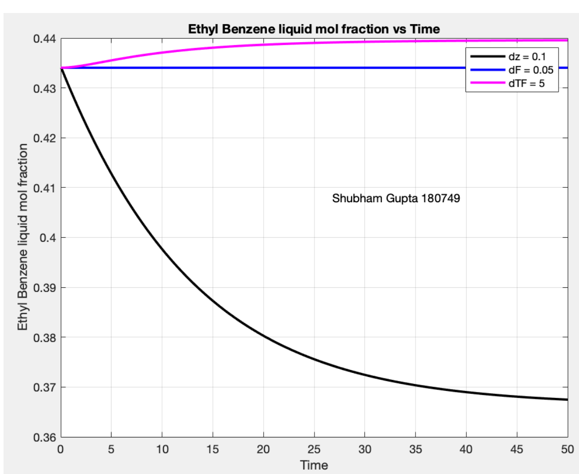
- **Dynamic State**











Above are the graphs of flash drum simulation for dynamic state. They include feed volume flow rate, feed temperature, benzene liquid mole fraction, toluene liquid mole fraction, and ethyl benzene liquid mole fraction vs time at specific parameters mentioned below.
dz = 0.1, dF = 0, dTF = 0 (black)
dz = 0, dF = 0.05, dTF = 0 (blue)
dz = 0, dF = 0, dTF = 5 (magenta)

CONCLUSIONS:

1. On increasing the feed rate we observe that the vapour flow rate increases faster whereas the liquid flow rate increases slowly to reach a steady-state.

2. Since no significant overshooting was observed we don't need to calculate dew point.