CHN-302: Engineering Analysis and Process Modeling

Assignment 2

Weightage: 5%+ Optional Bonus Querstions

Deadline: Feb 6, 2019, Midnight (extended deadline of Feb 13, 2019 ONLY for the bonus questions)

Instructions:

1. *Assignments need to be submitted individually, instances of plagiarism (copying assignment from others or allowing others to copy your assignment will be* ***strongly*** *peanlized.*
2. *Scans/photographs of handwritten assignments should be merged in a single pdf file and emailed to ch401.iitr@gmail.com (**Not** to any other email ID of instructor)*
3. *Hard copies of assignments or typed copies of assignments should not be submitted*

1. **(1% weightage)**
   A double-effect evaporator with reverse feed is used to concentrate 4536 kg/h of a 10 wt. % sugar solution to 50 %. The feed enters the second effect at 37.8 C. Saturated steam at 115.6 C enters the first effect and the vapor from this effect is used to heat the second effect. The absolute pressure in the second effect is 13.65 kPa abs. The overall coefficients are $U_1 = 2270 \frac{W}{m^2 \cdot K}$ and $U_2 = 1705 \frac{W}{m^2 \cdot K}$. The heating areas for both effect are equal. Calculate the heat transfer area and steam consumption. Neglect boiling point elevation.

2. (**1.5% weightage**)
   Sugar solution is concentrated in an n-effect evaporator, where fresh steam is fed in each effect to vaporize the solution. Feed enters the first effect and concentrated liquid from i-th effect ($i = 1,2, \dots, n-1$) is fed to $(i+1)$-th effect; concentrated product is taken out of n-th effect.
   a. Draw a schematic of the system with proper labeling.
   b. Write the material (component and overall) and energy balance equations for each effect.
   c. Using reasonable assumptions that ensures an analytical solution, derive the expression for sugar concentration in the m-th effect ($m \leq n$). Discuss when the assumptions will fail.
   d. Draw the expected profile of sugar concentration with the number of effects.
   e. After how many effects, sugar crystals will start forming.
   f. Numerically solve the equations derived in b) by modifying the code discussed in the class.

3. (**2.5% weightage**)
   a) Show that the Newton-Raphson method for one variable can be derived using the Taylor series approximation of functions.
   b) Derive the Regula-Falsi method for one variable as an approximation of the Newton-Raphson method derived in (a), where the derivative of the function is approximated as the difference in function values at two points divided by the difference in value of the variable at the two points.
   c) Show that the Newton-Raphson method gives the true solution in just one iteration for linear functions, irrespective of the guess value.
   d) Suggest mathematical equations (not similar to the ones discussed in the class or given in the python codes) that gives rise to the following when direct substitution method is applied
      a. Good convergence
      b. Poor convergence
      c. Oscillatory instability
      d. Divergence instability
   e) Using a numerical solution done manually or a computer program, test the performance of partial substitution scheme and Newton-Raphson method in improving the convergence behaviour in solutions of these equations. Discuss your findings. You can modify the python codes posted on Channel-I or use any other programming language but implement the full algorithm. Use of equation solver functions (e.g., in MATLAB) will get no credits. Attach a readable program script (with adequate commenting) and a screenshot of program output. Discuss your results.

(Optional Bonus Question 1: Upto a maximum of 3% CWS – Deadline: Feb 13, Demonstration in Instructor Office)
Extend the code for the Newton-Raphson method applied on the multiple-effect evaporator (in Channel-I) for an N-effect evaporator where N is an integer, for both forward feed and backward feed arrangement. Please derive and discuss the relevant equations and variables. The code should work for any value of N. You can write the code in any programming language but must implement the full algorithm.
(Optional Bonus Question 2: Upto a maximum of 3% CWS – Deadline: Feb 13, Demonstration in Instructor Office)
Write a code (in any programming language) to perform the material balance on any flowsheet. The code should be able to take a text (file) input for the flowsheet, compute the degree of freedom for each unit, solve the flowsheet and return the solution as a text (file) output.