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Approach to Design, Modelling, and Simulation of MED for Desalination Plant

Chirag R. Thakur[1], Girish R. Jangle[2], Akash D. Hiwse[3]
[1, 2, 3]Priyadarshini Institute of Engineering & Technology, Nagpur, Maharashtra, India.

Abstract: Increasing global demands for the fresh water is driving research and development of advance desalination technology. Modelling and simulation is vital for process dynamics analysis and plant initial design. The extensive range of mathematical version for multiple effect distillation column in process industry are mentioned and model of MED is developed that is flexible, simple to use. It's modelled in modular technique wherein every subcomponent modelled individually and then instantiated in order to piece collectively in complete plant version. It allows for studying various MED configurations with minimum code duplication. The solution is to be made via the usage of equation, differential equation which simplify the coding complexity dramatically and reduce the number of required approximation and assumptions. MATLAB is used to modelling and simulation. This allows sensitivity to key variable associated with input, operating and design circumstance.

Keywords: Modelling and simulation, MED, modular method, differential equation, MATLAB.

I. INTRODUCTION

The call for of specialty chemicals, pharmaceuticals, and biochemical is multiplied with each passing year [2]. Consequently to acquire that selectivity we need to enhance productivity in terms of quality and quantity. The products are simply in solid, liquid, or gaseous form. Thus industry investing massive amount to get characteristic extent of desired products.

Distillation is a process of separation of volatile components based on their boiling point. The bottom product is almost in liquid state i.e. Residue, even as the distillate can be a liquid or vapour or both [1]. It may be produced in batch or no. of stages referred as multiple effects. The separation is obligatory to form different stages in counter current path to be greater efficient. The relative volatility, boiling point, and reflux have a vital function.

In absorption or desorption, new phase is shaped by means of introducing third substance however in distillation new phase is created via vaporization or condensation [3]. Distillation becomes an energy intensive separation approach in which relative volatility is as little as feasible (1.50) [1]. These days modelling and simulation performs a crucial function for scrutiny of system behaviour in any industry [2].

Simulation is a computer program based on numerical technique to a set of differential equations targeting specific system evolves in time (KulaKowsk et al., 2007). It offers relationship together with mass balance, power balance, phase equilibrium, and chemical equilibrium. Distillation model must include material balance and flow, energy balance and flow, liquid or from vapour flow within a stage, pressure, temperature, hydraulic dynamic system, constraints, and chemical reactions while steady state analysis is used for process flow sheet design to determine mass & energy balance, approximate equipment sizes or perhaps steam properties, and the ability of dynamic models[1].

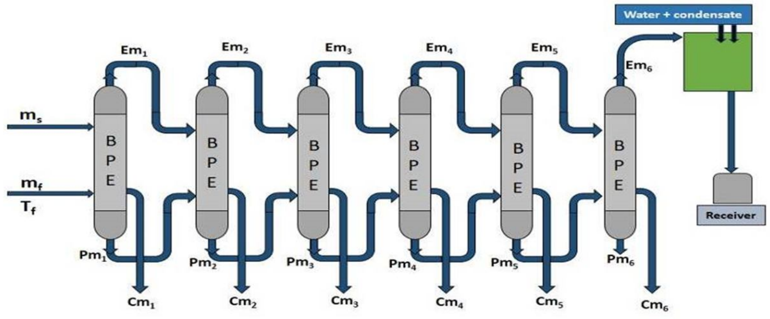


Fig 1. MED plant (6 effect)

Nomenclature

M_f = Mass flow rate of feed, kg/sec
M_d = Mass flow rate of distillate, kg/sec
M_s = Mass flow rate of steam, kg/sec
L_s = Latent heat of steam, kJ/Kg^{o}C
L_v = Latent heat of vapor, kJ/Kg^{o}C
Lv_1, Lv_2, Lv_3, Lv_4, Lv_5, Lv_6 = Latent heat of vapor from 1st to 6th effect, kJ/Kg^{o}C
B_n = Brine flow rate for nth effect, Kg/sec
B_1, B_2, B_3, B_4, B_5, B_6 = Brine flow rate from 1st to 6th effect, kJ/Kg^{o}C
D_i = Distillate from ith effect, kg/sec
D_1, D_2, D_3, D_4, D_5, D_6 = Distillate from 1st to 6th effect, kg/sec
D_n = Distillate from nth effect, kg/sec
D_{i-1} = Distillate from i-1 effect, kg/sec
X_f = Mole fraction of feed
X_n = Mole fraction of nth effect
X_i = Mole fraction of ith effect
X_{i-1} = Mole fraction of i-1 effect
Q_1, Q_2, Q_3, Q_4, Q_5, Q_6 = Amount of heat required for 1st to 6th effect respectively, kJ/kg
Q^n = Amount of heat required for nth effect, kJ/kg
Q_{n-1} = Amount of heat required for n-1 effect, kJ/kg
Q_c = Heat associated for cooling, kJ/kg
A_i = Area for ith effect, m^2
A_1, A_2, A_3, A_4, A_5, A_6 = Area for 1st to 6th effect respectively, m^2
A_c = Area of cooling, m^2
A_m = Mean area of column, m^2
U_i = Overall heat transfer coefficient for ith effect, kW/m^2 ^{o}C
U_1, U_2, U_3, U_4, U_5, U_6 = Overall heat transfer coefficient for 1st to 6th effect, kW/m^2 ^{o}C
T_i = Temperature of ith effect, ^{o}C
ΔT_{loss} = Temperature loss of column, ^{o}C
ΔT_i = Temperature drop for ith effect, ^{o}C
ΔT_1, ΔT_2, ΔT_3, ΔT_4, ΔT_5, ΔT_6 = Temperature drop from 1st to 6th effect respectively, ^{o}C
T_{cw} = Temperature of cooling water, ^{o}C
T_f = Temperature of feed, ^{o}C
Cp = Specific heat at constant pressure, kJ/^{o}C
sM_{cw} = Specific cooling water flow rate, kg/sec
sA = Specific area of column, m^2
PR = Performance ratio
$(LMTD)_c$ = Log mean temperature difference of cooling section, ^{o}C

II. DESCRIPTION OF MATHEMATIC MODEL FOR MULTIPLE EFFECT DISTILLATION

The sea water can be assumed in mathematical modelled as a binary mixture of fresh water and salt. In addition, behaviour of system of such kind can best be expressed by means of equations concerning variables for the heat transfer, its derivatives (there is n equation for the heat transfer rate in every impact, which relates the effect thermal load to the area, usual heat transfer coefficient) and temperature driving force. Easy material balance for putting in equations and system parameters might be useful for system analysis.

The variables and required specification of the following system parameters are determined:

A. Temperature of the motive steam (Ts)
B. Vapour temperature in effect n (Tn)
C. Salt concentration in the brine stream leaving effect n (Xn)
D. Salt concentration in the feed stream (Xf)
E. Total distillate flow rate (Mn)

III. CALCULATION THEORY

A. Overall Balance

The overall material and salt balance equations are written to determine the brine flow rate leaving effect n, B_n, and the feed flow rate, M_f , M_d the mass flow rate of distillate, . The equation can be written as:

$$M_f = M_d + B_n \qquad ..(1)$$
$$X_f * M_f = X_n * B_n \qquad ..(2)$$

Substituting M_f in 2, one can obtained the expression:

$$B_n = \frac{X_f}{(X_n - X_f)} * M_d \qquad ..(3)$$

the above equation contains principally three terms, one is feed flow rate second, related flow rate in term of mole fraction and third term is an expression for brine flow rate leaving effect. Therefore, Calculations of B_n and M_f are only made once are not included in the following iteration sequence.

B. Temperature Profile

The thermal load in all effects is thought steady, thus

$$Q_l - Q_2 = \ldots = Q_{n-i} = Q_n \qquad ..(4)$$

With

$$Q_1 = M_s * L_s, \quad for\ the\ first\ effect..(5)$$
$$Q_i = D_i * L_{vn} \ ,for\ effects\ 2\ to\ n \quad ..(6)$$

Where,

Q is the thermal load, Ms is the mass flow rate of motive steam, D_n is the distillate flow rate in effect i, X_i is the steam latent heat at T_s, and L_{vi} is the latent heat of formed vapors at (T_i - ΔT_{loss}), and the subscript i, s, and v defines effect i, the steam, and the formed vapor. The thermal load in every effect can also be described in phrases of the heat transfer area in the effect A, the temperature driving force ΔT, and the overall heat transfer coefficient U. This is

$$Q_i = A_i * U_i * \Delta T_i \qquad ..(7)$$

Since the heat transfer area and thermal load are equal in all effects,

$$\frac{Q_1}{A_1} = \frac{Q_2}{A_2} = \ldots = \frac{Q_{n-i}}{A_{n-i}} = \frac{Q_n}{A_n} \qquad ..(8)$$

From 7 and 8, the following identity additionally applies

$$U_1 * \Delta T_1 = U_2 * \Delta T_2 = \ldots = (U_{n-i}) * (\Delta T_{n-i}) = U_n * \Delta T_n \qquad ..(9)$$

The total temperature drop throughout the effects is described as

$$\Delta T = T_s - T_n \qquad ..(10)$$

Where, T_s and T_n are the temperatures of the motive steam and the vapour formed within the last effect n respectively. This drop is also equal to the sum of temperature drop per effect, or

$$\Delta T = \Delta T_1 + \Delta T_2 + \ldots. + \Delta T_{n-i} + \Delta T_n \ ..(11)$$

Equations 9 and 11 can be used to define ΔT_n in terms of the overall heat transfer coefficient and the total temperature drop in all effects. From 9, ΔT_2 can be expressed in terms of ΔT_n through

$$\Delta T_2 = \Delta T_1 * \left(\frac{U_1}{U_2}\right) \qquad ..(12)$$

Also ΔT_3 can be expressed in terms of ΔT_2 by

$$\Delta T_3 = \Delta T_2 * \left(\frac{U_2}{U_3}\right) \qquad ..(13)$$

Substituting equation 12 in 13

Trendy relation for other effects expressed as

$$\Delta T_i = \Delta T_1 * \left(\frac{U_1}{U_i}\right) \qquad ..(14)$$

Substituting the result given in Eq. 14 in Eq. 11 gives

$$\Delta T = \Delta T_1 * U_1 \left(\frac{1}{U_1} + \frac{I}{U_2} + \ldots + \frac{l}{U_{n-i}} + \frac{1}{U_n} \right) \qquad ..(15)$$

If estimates for Ui are made, then, temperature drop in all effects may be acquired from equation 15 and 14. The actual temperature profile is then calculated from the following relations. In the first effect

$$T_1 = T_s - \Delta T_i \qquad ..(16)$$

and in effects 2 to n

$$T_i = T_i - 1 - \Delta T_1 * \left(\frac{U_1}{U_i}\right) \qquad ..(17)$$

Calculation of the temperature profile from Equation 16 and 17 requires specification of the overall heat transfer coefficients, U_i.

C. *Profiles of Salt Concentration and flow Rates of Brine and Distillate*

The distillate flow rates are obtained from the following balance and the thermal loads, Eq. 6

$$M_d = D_1 + D_2 + \cdots + D_{i-1} + D_n \qquad ..(18)$$

$$D_i * L_{vi} = D_{i-1} * L_{vi-1}, \quad for\ effects\ 2\ to\ n \qquad ..(19)$$

Eq. 19 is used to determine the values of Di (for i = 2 to n) and we get trendy recursive formula as following equation:

$$D_i = D_i * \frac{L_{v1}}{L_{vi}}$$

$$with\ i = 2\ to\ n \qquad ..(20)$$

From Equation 20 and 18, we get

$$M_d = D_1 + D_1 * \frac{L_{v1}}{L_{v2}} + \ldots. + D_1 * \frac{L_{v1}}{L_{vn-1}} + D_1 * \frac{L_{v1}}{L_{vn}} \qquad ..(21)$$

Eq. 20 is then rearranged to obtain an expression for D_1

$$D_1 = \frac{M_d}{L_{v1 *}(1/L_{v1} + 1/L_{v2} + \ldots\ldots + 1/L_{vn-1} + 1/L_{vn})} \qquad \ldots(22)$$

The recursive formula obtained for distillate flow rates for values of (N = 2 to n) are

$$D_n = D_1 * \frac{L_{v1}}{L_{vn}}$$

However, the expression for brine flow rate in the first effect

$$B_1 = M_f - D_1 \qquad ..(23)$$

Effects from 2 to n is given by

$$B_i = B_{i-1} - D_i \qquad ..(24)$$

Similarly, salt balances (X) for initial effect and effect from 2 to n are obtained:

$$X_i = X_f * \frac{M_f}{B_1} \qquad ..(25)$$

$$X_i = X_{i-1} * \frac{B_{i-1}}{B_i} \qquad ..(26)$$

D. *Heat transfer Area*

The heat transfer areas in effects 1 to n need to be calculated to test the primary assumption of the model, i.e., equal heat transfer areas. The heat transfer area for first effect is given by

$$A_1 = \frac{D_{1*} L_{v1}}{U_{1*(T_S - T_1)}} \qquad ..(27)$$

and for effects 2 to n it is defined as

$$A_i = \frac{D_{1*} L_i}{U_{i*(T_i - \Delta T_{loss})}} \qquad ..(28)$$

The ΔT_{loss} in the above equation corresponds to the thermodynamic losses in every effect and its value might also ranges from 0.5-3 ^oC.

E. Performance Parameters

The performance ratio (PR), is defined as the flow rate ratio of distillate (M_d) and motive steam (M_s). This is

$$PR = \frac{M_d}{M_s} \qquad ..(29)$$

The value of the steam flow rate, M_s, is obtained from the assumption of equal thermal loads, where,

$$M_s = D_{1*} \frac{L_{v1}}{L_S} \qquad ..(30)$$

The specific heat transfer area (sA) is

$$S_A = \frac{\sum_{I=1}^{n} A_i + A_c}{M_d} \qquad ..(31)$$

Where A_i is the heat transfer area in effect i and A_c is the down condenser heat transfer area, which is obtained from

$$A_c = \frac{Q_c}{U_2 * ((LMTD)c)} \qquad ..(32)$$

$$(LMTD)c = \frac{(T_f - T_{cw})}{\ln[(T_n - T_{cw})/(T_n - T_f)]} \qquad ..(33)$$

Where T_{cw} is the intake seawater temperature, T_f, is the outlet seawater temperature, and T_n is the condensation temperature of the vapor formed in the last effect. The thermal load of the condenser is calculated from

$$Q_c = D_n * L_{vn} \qquad ..(34)$$

The specific cooling water flow rate is defined as

$$sM_{cw} = M_d / M_{cw} \qquad ..(35)$$

Where, M_{cw} is the cooling water flow rate and is received from the condenser energy balance

$$n * L_{vn} = (M_f + M_{cw}) C_p (T_f - T_{cw}) \qquad ..(36)$$

IV. PROBLEM UTTERANCE

The problem behalf to designing of six effects multiple effect evaporators has been shown in table 1.

Table 1. Different parameters and it values

Sr no	Parameters	Values
1	Number of effect, n	6
2	Motive steam temperature, T_s	100°C
3	Total product flow rate, M_d	1 kg/sec
4	Salt concentration in feed seawater, X_f	42000 ppm
5	Salt concentration in rejected brine, X_6	70000 ppm
6	Vapor temperature in last effect, T_6	40°C
7	Thermodynamic losses in all effects, ΔT_{loss}	2°C
8.	Seawater temperature leaving the condenser, T_f	35°C
9.	Intake seawater temperature, T_{cw}	25°C

V. ANALYTICAL DESIGN CONCEPT

Earlier than beginning the iterations, the latent heat of the motive steam and the vapor formed in the last effect are obtained from the steam tables or the correlation.

This gives, Standard values

$$L_s = 2499.5698 - 2.204864\ T_s - 2.304\times10^{-3}\ T_s^2$$

$$= 2499.5698 - 2.204864\ (100) - 2.304\times10^{-3}\ (100)^2$$

$$= 2256.043 \text{ kJ/kg}$$

The flow rates of the brine leaving effect number 6 and the feed seawater are obtained from Equation 1 and 2.

A. *The Brine Flow rate Calculation*

The brine flow rate can be estimated for effect number 6 by using equation 3

$$B_n = \frac{X_f}{(X_n - X_f)} * M_d$$

$$= (42000/\ (70000-42000))\ (1)$$

$$= 1.5 \text{ kg/s}$$

Then the feed flow rate M_f is equal to the sum of M_d and B_6

The total temperature drop across the effects, $T_s - T_6$, is equal to 100 - 40 = 60 ^{o}C. The overall heat transfer coefficients in effects 1 to 6 are particular and are assumed to remain steady in the course of the iterations.

B. *Overall Heat Transfer Coefficient Calculation*

U_1, is set equal to 2.4 kW/m^2*C*.

$$\mathbf{U_{i+1} = 0.95\ U_i}$$

Values of the overall heat transfer coefficient in all effects are summarized in the following table 2.

Table 2. Overall heat transfer for each effect

No. of effects	1	2	3	4	5	6
overall heat transfer coefficient (U)	2.4	2.28	2.16	2.0577	1.9548	1.8571

The summation of the inverse for the overall heat transfer coefficient calculated for temperature drop consistent with effect is

= 2.8529 m^2 ^{o}C/kW

The temperature drop in the first effect is then calculated

$$\Delta T1 = \frac{\Delta Tt}{U1 * \sum_{i=1}^{n} \frac{1}{Ui}} = \frac{60}{2.4 * 2.8529} = 8.7629\ oC$$

$$\frac{1}{\sum_{i=1}^{6} Ui} = \frac{1}{U1} + \frac{1}{U2} + \frac{1}{U3} + \frac{1}{U4} + \frac{1}{U5} + \frac{1}{U6}$$

For effect 2,

$$\Delta T_2 = \Delta T_i\ (U_1/U_2) = (8.7628)\ (2.4)/(2.28) = 9.224\ ^{o}C$$

The same can be calculated for the effect 3 to 6

$$\Delta Tj = \Delta Ti\ (Ui\ /\ Uj)$$

Where, i and j are effect numbers

$i = 2,3,4,5$

$j = 3,4,5,6$

C. *The Value of ΔT_i Calculation*

Table 3. Values of ΔT_i for effect 1 to 6

No. of effects	1	2	3	4	5	6
Temperature drop (ΔT_i)	8.7628	9.224	9.7095	10.2205	10.7584	11.3247

It must be stated that the temperature drop in step with effect will increase because the effect temperature is decreased, i.e., $\Delta T_1 > \Delta T_2 > \Delta T_3 > \Delta T_4 > \Delta T_5 > \Delta T_6$.

D. *The Temperature Profile Calculation*

Equations 17 and 18 can be useful to determine the temperature profile from effect 1 to 6.

$\because T_s = 100$

$$T_1 = T_s - \Delta T_1 = 100 - 8.762 = 91.2372\ ^{o}C$$

$$T_i = T_i - 1 - \Delta T_1 * \left(\frac{U_1}{U_i}\right) \qquad \text{(Equation for calculation of 2 to 6 effects)}$$

This value assessment is with the initial specification of 40°C. Table 4 suggests the value of temperature from effect 1 to 6.

Table 4. Values of temperature from effect 1 to 6

No. of effects	1	2	3	4	5	6
Temperature (Tv_i)	91.2372	82.0132	72.3037	62.0831	51.3247	40

E. *The Latent Heat Values in all Effects Calculation*

We have mentioned the correlation between temperature and latent heat of vaporisation,

$$Lv_1 = 2499.5698 - 2.204864\ Tv_1 - 2.304x10^{-3}\ Tv_1^{2} = 2284.47\ kJ/kg$$

Similarly, for effects from 2 to 6 can be calculated by

$$Lv_2 = 2499.5698 - 2.204864\ Tv_i - 2.304x10^{-3}\ Tv_i^{2} = 2308.4\ kJ/kg$$

Thus on summarisation of value of latent heat from effect 1 to 6, we can tabulate the data in table 5.

Table 5. Latent heat from each effect

No. of effects	1	2	3	4	5	6
Latent heat (Lv_i)	2284.47	2308.4	2333.17	2358.78	2385.21	2412.46

The flow rate profiles of the distillate and brine as well as the brine concentrations calculation is drawn from equation 20, 23, & 25. Consequently D_1 is rearrangement of equation 20. Eventually the (D), (B), (X) in effects 1 to n are calculated. Therefore, the brine flow rates are obtained from Equation 23 and 24. The salt concentration profile is calculated from Equation 25 and 26.

On summarisation of brine and distillate amassed in each effect we can tabulate the data in the shape of table as shown below.

Table 6. Brine, concentration, and distillate collection in each effect

No. of effects Effect	1	2	3	4	5	6
Distillate (D_i)(kg/s)	0.1712	0.1694	0.1676	0.1658	0.1639	0.1621
Brine (B_i)(kg/s)	2.3288	2.1584	1.9918	1.826	1.6621	1.5
Concentration (X_i) (ppm)	45087.6	48625	52716.8	57502.8	63174.3	70000

F. *The heat Transfer Areas are Calculated*

The heat transfer region defines the amount of heat accrued and it became essential to find it for each effect. Therefore from equation 27 and 28, values for results 1 to 6 are

$$A_1 = \frac{D_{1*} L_{v1}}{U_{1*(T_s - T_1)}}$$

$$= (0.1712)(2284.47)/(2.4(100 - 91.24))$$

$$=18.59 \text{ m}^2$$

The most distinction in effect areas is equal to 0.35 m^2. Assuming an errors criterion of less than 0.0001 m^2 is required; consequently, a new iteration collection must be initiated. The second new release starts with calculations of the new heat transfer area.

$$Am = \frac{\sum_{i=1}^{n} Ai}{n}$$

$$= \frac{18.56+23.74+23.42+23.12+22.84+22.58}{6}$$

$$= 22.38 \text{ m}^2$$

A new profile for the temperature drop across the effects is then calculated

$$\Delta T_1 = \Delta T_1 (A_1/A_m)$$

$$= (8.7628)(18.59)/(22.38)$$

$$= 7.28\ ^oC$$

Summary of flow rates, concentrations, temperatures, and heat transfer areas in the final iteration are given in the table 7.

Table 7. Temperature and area of each effect

Effect	1	2	3	4	5	6
T (^{o}C)	92.67	84.96	76.84	68.29	59.29	40
A (m^2)	22.1446	22.1445	22.1445	22.1446	22.1446	22.1446

G. The System Performance Parameters Calculation

The vital overall performance ratio is determined and received from equation 29 to 33 in following table 8.

Therefore the specific cooling water flow rate has been determined as equal value, on account that the total product flow rate is equal to 1 kg/s.

Table 8. System performance parameter

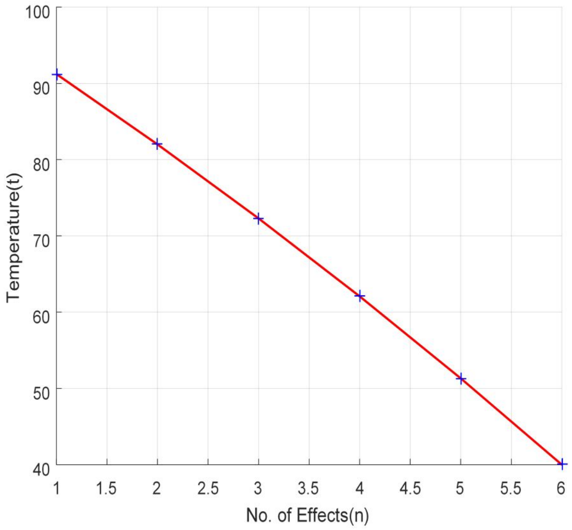
System performance parameters	values
M_s (Steam flow rate)	0.1726 kg/s
PR (Performance Ratio)	5.79
Q_c (Thermal load)	389.44 kJ/s
$(LMTD)_c$ (Logarithmic Mean Temperature Difference)	6.819 °C
A_c (Heat Transfer Area)	32.628 m^2
sA	165.49 m^2
M_{cw} (Cooling water flow rate)	13.73 kg/s.

VI. RESULTS

A. Temperature Profile vs no. of Effects

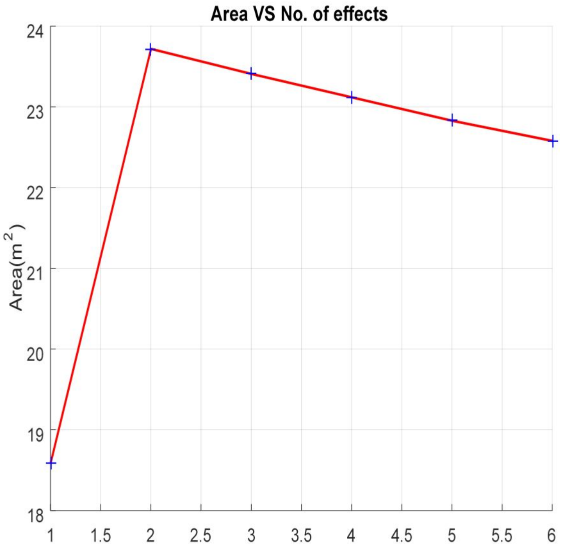
Graph (a) depicts the temperature profile of MEE at diverse numbers of effects. It was observed that the temperature profile of MEE onto the effects is strongly depending on the initial temperatures. For distinct effects there has been spark off down take profile. at some stage in the 1st effect the temperature intimately reached to a plateau level. However, the temperature displaying excessive attain of plateau decreases with growth in the wide variety of effects. Mainly for initial effect one, the temperature seen at high peak were 91 and 90.5 respectively.

Consequently, the sharp downfall was discovered as in line with the growth in effects. This end result shows that the no. of results will increase with lower in temperature.



Graph (a). Temperature profile

B. *Area vs no. of Effects*

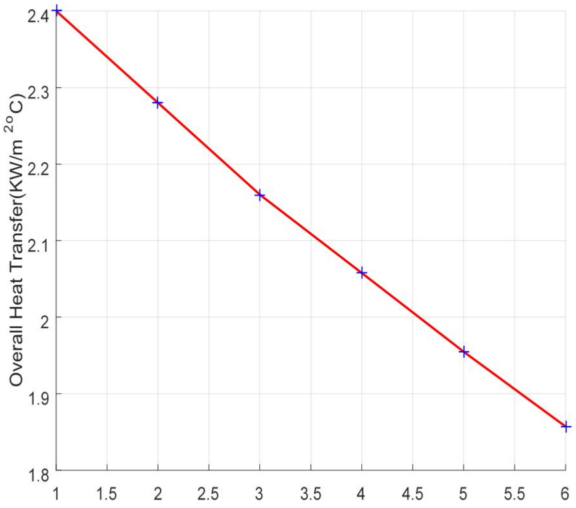


Graph (b). Area of each effect

Graph (b) suggests the variation in area with no. of effects. The experiment was theoretical. As expected the area (heat transfer area) tends to be very low for the initial effect in MEE. However, the area has a tendency to increase sharply for the secondary effect which was 23.9 m^2. Consequently from that point of effect remark becomes drawn that the area tends to decrease from higher to a lower degree for the rest of effects. As the effects go by, that the predictions of rate seem to come at the equilibrium stage. The average error decrease from 23.9 m^2 to 22.9 m^2 (as no. of effect was raised). The heat transfer area changes with effects up to equilibrium condition. Thus the composition profile can further be improved if higher prediction of these two variables is acquired.

C. *Overall Heat Transfer vs. no. of Effects*

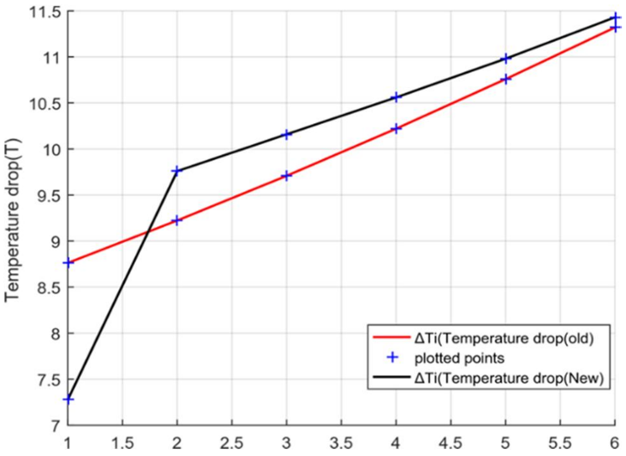
Graph (c) suggests the composition profile for overall heat transfer for each effect. The overall heat transfer in each stage of results has a tendency to decrease because the number of effects is decreased. Initially, all the effects have heat transfer however as time move by means, the amount of heat transfers showing the decrease in behaviour. In all six effects, the slope of equilibrium may be seen in terms of downfall. This may imply that the heat transfer rate obtained with this rate has a better variation rate.



Graph (c). Overall heat transfer

D. Temperature Drop vs no. of Effects

Graph (d) depicts that temperature drop (old) indicates the consistent distinction in each effect whereas new temperature drop does not comply with the identical pathway. The heat losses emerge as stagnant for the old ones but it could be reduced if mild modelling modifications achieved with high efficiency.



Graph (d). Temperature drop

VII. CONCLUSION AND DISCUSSION

We studied the modelling and simulation of multiple-effect Distillation where we determined the Distillate flow rate (kg/s), Brine flow rate (kg/s), the concentration of TDS at initial and final stage (ppm), old and new temperature (^oC), overall heat transfer area (m^2) and Temperature drop (^oC) in concurrent flow.

The graph suggests the diverse parameters relation and unlocks the opportunity for counter-current that is in recent times a topic of research and development (R&D) for the sugar industry. The maximum difference in effective area is determined to be 0.35 m^2 and the error generated was 0.01%. Therefore, we are able to conclude that effective mean area can affect temperature drop in large proportion.

For that reason, error, temperature drop, and overall heat transfer rate ought to remain low while the area of heat transfer need to be high for higher performance of multiple effect distillation.

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