ABSTRACT FOR TRAY DRYER

Description:

This code is for cross-circulation drying, taking in account 2 cases as follows:
1) The temperature and humidity of drying gas remains constant
2) The temperature and humidity of drying gas vary along the tray

CASE – I:

The flux of water entering dry air is given by: $N_c = k_y(Y_s - Y_i) = (h_c + h_b)(T_{Gi} - T_s)/\lambda_w$
where, k_y is the mass transfer coefficient in gas phase
Y denotes humidity and s in subscript denotes saturation
h_c is heat transfer coefficient at tray bottom
h_b is combined heat transfer coefficient to drying surface from tray bottom
T denotes temperature and s in subscript denotes saturated
λ_w denotes latent heat of vaporization
$1/h_b = 1/h_c + l/k_s$
where l is the thickness of tray and k_s is conduction coefficient of tray
The quantity of unbound moisture removed in constant rate period is given by:

$$M_c = al_s(\rho_s)(X_i - X_c) = W_s(X_i - X_c);$$

For constant rate drying period, the time taken to dry is:

$$t_c = \frac{W_s(X_i - X_c)}{a N_c}$$

Where, X denotes moisture and c denotes critical condition
a is the area available for drying
W_s is the amount of dry solid present in feed
For falling rate period, the time for drying is given by:

$$t_f = \frac{W_s}{a} \frac{\lambda_w (X_c - X^*)}{(h_b + h_c)(T_{Gi} - T_s)} \ln \frac{X_c - X^*}{X_f - X^*}$$

(For Derivation, refer to Binay K Dutta's book "Principles of Mass Transfer and Separation Processes" Pg 559)
where, X_f denotes final moisture content
the total time required for drying, therefore, is $t_c + t_f$

CASE II:

Only the governing equations, used in Python code are given below. For more detailed proof, one may refer Binay K Dutta's book "Principles of Mass Transfer and Separation Processes" Pg 575.

The rate of drying in constant rate period is given by:

$$N_c = \frac{Q}{a\lambda_w} = \frac{G_s(bw)c_H(T_{Gi} - T_{Go})}{a\lambda_w}$$

The quantity of unbound moisture removed in constant rate period is given by:

$$M_c = al_s(\rho_s)(X_i - X_c) = W_s(X_i - X_c);$$

where, l_s is the volume of solid
ρ_s is the density of solid
The constant rate drying period is given by:

$$t_c = \frac{M_c}{aN_c} = \frac{a(l_s)(\rho_s)(X_i - X_c)(\lambda_w)}{G_s' bwc_H(T_{Go} - T_{Gi})}$$

where, G'_s is the gas flow rate; b is breadth of tray; w is width of tray; c_H is specific heat capacity of dry gas and

$$T_{Gi} - T_{Go} = (T_{Gi} - T_s)(1 - \exp[-L/(H_{tG})_h])$$

$$\frac{G_s' w c_H}{h_c} = (H_{tG})_h$$

the time taken for falling rate period is given by:

$$t_f = \frac{W_s}{a}\frac{X_c - X^*}{N_c} \ln \frac{X_c - X^*}{X_f - X^*}$$

$$= \frac{W_s(X_c - X^*)\lambda_w}{bwG_s' c_H(T_{Gi} - T_s)(1 - \exp[-L/(H_{tG})_h])} \ln \frac{X_c - X^*}{X_f - X^*}$$

The total time required for drying is $t_c + t_f$

Reference: Binay K Dutta, "Principles of Mass Transfer and Separation Processes" (2009)

Examples:

1) The amount of water in 0.7 Kg dry solid carbon is to be reduced from 0.3 kg to 0.014 Kg. The critical moisture content is 0.06 and equilibrium moisture content is 0.002. The dimension of tray is: 5m x 0.6m x 1m. Operating temperature is 313K. Convection coefficient is 43.3 J/m^2K and conduction coefficient is 12 J/mK. The drying area is 0.6 m^2. Density of solid is 2500 Kg/m^3. Find the product stream concentration and time taken to dry assuming (i) constant temperature and humidity of air (ii) Variable temperature and humidity. Initial Humidity = 0.02. The air flow rate is 1 Kg/s.

Ans) The results are as given below obtained from analytical mass balance and simulated mass balance:

Component	Composition in vapor stream (in Kg)	
	Simulation	Analytical
Air	0.98	0.98
Water	0.31	0.31
Carbon	0	0

Component	Composition in solid stream (in Kg)	
	SImulation	Analytical
Air	0	0
Water	0.014	0.014
Carbon	0.7	0.7

(i) The time taken for the solid to completely dry is 0.1 hours in case of constant humidity and constant temperature.

(ii) The time taken for the solid to completely dry in case of varying humidity and temperature is 673.88 hours.

The discrepancy in both the results is due to wrong assumption of constant humidity and temperature for such low flowrate of air.