SEPARATION PROCESS

DRYING
Part 3

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Calculation Methods For Falling-Rate Drying Period

- The rate of drying is not constant in the falling rate period
- For any shape of falling rate drying curve, drying time can be determined by numerically or graphically finding the area under the curve for plot 1/r vs X

$$R = -\frac{L_S}{A}\frac{dX}{dt}\text{; rearrange} \qquad t = \int_{t_1}^{t_2} dt = \frac{L_S}{A}\int_{X_2}^{X_1}\frac{dX}{R}$$

Special Case: R = aX+b (linear) and both X1 and X2 are less than Xc

$$t = \frac{L_S\left(X_1 - X_2\right)}{A\left(R_1 - R_2\right)}\ln\frac{R_1}{R_2}$$

Special Case: R = aX (linear function through origin)

$$t = \frac{L_S X_C}{AR_C}\ln\frac{R_C}{R_2}$$ or $$t = \frac{L_S X_C}{AR_C}\ln\frac{X_C}{X_2}$$ and $$R = R_C\frac{X}{X_C}$$

Drying In Falling Rate Period By Diffusion or Capillary Flow

- In the falling rate period, the surface of the solid being dried is no longer completely wetted, and the rate of drying steadily falls with time.
- Previously, empirical method were used to predict the time of drying
- Also, the actual rate-of-drying curve was numerically or graphically integrated to determine the time of drying
- In another method, an approximately straight line between critical free moisture content to the origin at zero free moisture was assumed (R=aX)
- Rate of moisture movement in falling rate period-governed by the rate of internal movement of the liquid by liquid diffusion or capillary movement

$$R = -\frac{L_S}{A}\frac{dX}{dt} = aX$$

$$\frac{dX}{dt} = -\frac{aA}{L_S}X$$

Drying In Falling Rate Period By Diffusion

- Diffusion in the solid control the drying process
- Relatively slow drying in non-granular material (e.g. soap, gelatin, glue) and later stages of drying of bound water (e.g. in wood, textiles, leather, paper, foods, starches)
- Difficulty in analyzing drying data – initial moisture distribution is not uniform throughout the solid
- During drying period – resistance to mass transfer of water vapor from the surface is usually small

$$R = -\frac{l_S}{A}\frac{dX}{dt} = \frac{\pi^2 L_S D_L}{4x_1^2 A} X$$

$$t = \frac{4x_1^2}{\pi^2 D_L} \ln \frac{8X_1}{\pi^2 X}$$

Drying In Falling Rate Period Capillary Flow

- Water can flow from regions of high concentration to low concentration region as a result of capillary action rather than by diffusion if the pore sizes of the granular materials are suitable.
- Capillary Theory
  - Assumes that a packed bed of non-porous spheres contains a void space between the sphere called pores
  - As water is evaporated, capillary forces are set-up by the interfacial tension between water and solid
  - These forces provide driving force for moving the water through the pores to the drying surface
  - Since the mechanism of evaporation during this period is the same as during the constant period, the effects of variables gas velocity, temperature of gas, humidity of gas and so on will be the same as for the constant rate drying period

$$t = \frac{x_1 r_S l_W X_C}{h(T - T_W)} \ln \frac{X_C}{X}$$

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Azilah Ajit
Hayder Bari, Prof
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