HEAT TRANSFER IN AGITATED VESSELS

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GROUP MEMBERS

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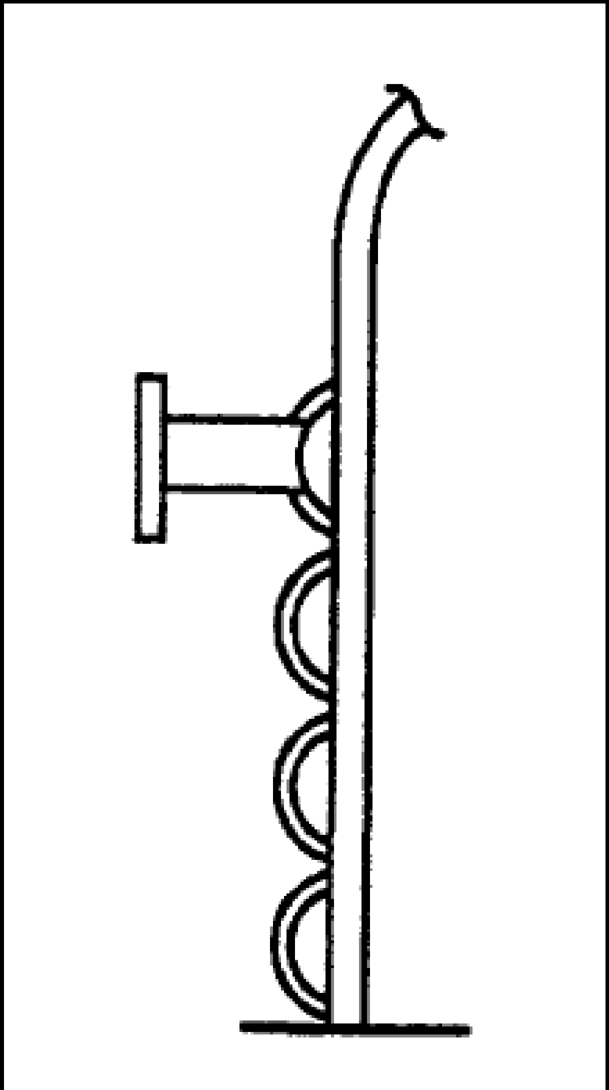
Problem Statement

A batch polymerization reactor, 1500mm in diameter and 1800 mm high, has a limpet coil of 18 turns. The inner diameter of the half-pipe is 52.5 mm and the pitch of the coil is 79.5 mm. In Each batch, 2200 kg of the monomer at 25 ^{o}C is charged to the reactor that has to be heated to 80 ^{o}C before the initiator is added to start the polymerization.



Problem Statement

Heating is done by a hot fluid available at 120^0C. The average viscosity of the hot fluid may be taken as 4 cP, and that of the monomer as 0.7 cP. The vessel is provided with a flat blade turbine agitator (six blade. 0.5 m diameter) which rotates at 150 rpm.

Problem Statement

The volume of the charge is such that, the liquid surface remains nearly at the level of the top of the limpetted region . The height of the limpeted section = 1464 mm. A fouling factor of 0.0002 h m^2 ^oC/kcal may be taken for both the vessel and the coil side. Calculate the time required to heat the charge.

DATA: Reactor & Coil

Reactor diameter	1500mm
Reactor height	1800mm
No of turns in coil	18
Pitch of coil	79.5mm
Inner diameter of half pipe	52.5mm

DATA

Weight of monomer per batch	2200kg
Temperature of hot fluid	120 ^oC
Final temperature of monomer	80 ^oC
Density	900 kg/m^3
Viscosity of hot fluid	4cP
Thermal conductivity	0.28 kcal/h m ^oC
Heat capacity	0.50 kcal/kg ^oC

DATA: agitator

FLAT BLADE TURBINE AGITATOR

No. of blades	6
Diameter	0.5m
Rpm	150 rpm

SOLUTION

STRATEGY

1- Calculate Internal Heat Transfer Area of the Vessel

2- Calculate the vessel-side heat transfer coefficient

3-Calculate Coil side Heat transfer coefficient

SOLUTION

STRATEGY

4- Calculate Overall Heat Transfer coefficient

5- Calculate Time Required for Batch Heating

Inside heat transfer area of the vessel

The inside heat transfer area of the vessel

$$A_i = \pi D_t H$$

$H = 1464mm$

$D_t = 1500mm$

$$A = 6.9\ m^2$$

VESSEL SIDE H.T COEFFICIENT

- Agitator diameter = **0.5 m**
- **Rpm. = 150**

Equation for h_i is

$$h_i = \frac{0.74 \times k \times (Re)^{0.67} (Pr)^{0.33}}{D_t}$$

VESSEL SIDE
H.T COEFFICIENT

- **Pr. (Prandtl no.)** `= $\dfrac{(0.45)(0.7 \times 10^{-3})(3600)}{0.15}$

  $= 7.56$

Re.**(Reynold no.)** $= \dfrac{d^2 N \rho}{\mu} = \dfrac{(0.5)^2(150/60)(850)}{(0.7 \times 10^{-3})}$

$= 7.59 \times 10^5$

VESSEL SIDE
H.T COEFFICIENT

- Putting the values of variables in the equation of h_i

$$h_i = \frac{0.74 \times 0.15 \times (7.59 \times 10^5)^{0.67} (7.56)^{0.33}}{1.5}$$

$$= \mathbf{1256\ kcal / h\ m^2\ {}^oC}$$

COIL SIDE H.T COEFFICIENT

Take the linear velocity of the heat transfer fluid = 1.5 m/s

Flow area of the coil $= (\pi/4)(0.0525)^2 = 2.165 \times 10^{-3}\ m^2$

Flow area of the fluid $= (1.5)(2.165 \times 10^{-3})(3600)$

$= 11.69\ m^3/h$

Mass flow rate of the fluid = $W_c = (11.69)(850) = 9936$ kg/h

COIL SIDE HT COEFFICIENT

Hydraulic diameter of the limpet coil, d_H

$$d_H = \frac{(4)(\pi/8)(d_i)^2}{d_i + (\pi/2)d_i} = \frac{\pi \quad (0.0525)}{2 + \pi} = 0.0321 \text{ m}$$

Coil Reynolds Number

$$Re = \frac{V d_H \rho}{\mu} = \frac{(1.5)(0.0321)(900)}{4 \text{ x } 10^{-3}} = 10{,}820$$

COIL SIDE H.T COEFFICIENT

Prandtl Number of the coil fluid

$$Pr = \frac{C_p \mu}{k} = \frac{(0.5)(4 \times 10^{-3})(3600)}{0.28} = 25.7$$

Coil side heat transfer coefficient

$$\frac{d_e\ h_o}{k} = 0.027 \times (Re)^{0.8} (Pr)^{0.33} [1 + 3.5(de/dc)]$$

$$h_0 = 1080 \text{ kcal/h m}^2\ {}^0C$$

Overall Heat Transfer Coefficient

- $U = 467$ kcal /h m^{2} ^{0}C

TIME REQUIRED

- Given data is
- $W_c = 9936$ kg/h
- $c_{pc} = 0.5$ kcal/kg ^{O}C
- $W_v = 2200$ kg
- $c_{pv} = 0.45$ kcal/kg ^{o}C
- inlet temperature of the coil fluid, T_{ci} = 120 ^{o}C
- initial temperature of the vessel liquid, T_{vi} = 25 ^{o}C.
- final temperature, T_{vf} = 80^{o}C

TIME REQUIRED

Putting the values of the various quantities in, we get

$$\ln(T - t_1/T - t_2) = (W_cC_{pc}/W_vC_{pv})((K - 1)/ K)$$

$$K = \exp(U_iA_i/W_cc_{pc})$$
$$= \exp((467)(6.9)/(9936)(0.5)) = 1.913$$

$$\ln(120\text{-}25/120\text{-}80) = (9936)(0.5)/(2200)(0.45)(1.913\text{-}1/1.913)\ t$$

$t = 22\text{mins}$

THANKS