

Calculation part 10.05.2007:

Please, each answer on the individual sheet of paper.

Question 1

The dimensions of softwood chips are as follows: length 25 mm, width 15 mm and thickness 10 mm. The moisture content of the chips is 40 w-%. The Basic Density of the pine wood is 400 kg/m³. The chips are steamed by means of saturated steam at pressure 0.14 MPa(abs). The permeability of air in wet softwood chips is assumed to be $2,25 \cdot 10^{-17}$ m²/s

- Calculate mass of water and air in chip per kg OD chip.
- How long time does it take to reach the air removal efficiency 95 %.

Some useful equations for diffusivity

$$\alpha_D = \frac{\rho_a K_a RT}{\mu_a M_a}$$

- where
- ρ_a = density of air
 - K_a = permeability of air
 - μ_a = viscosity of air
 - M_a = molecular weight of air
 - R = ideal gas constant
 - T = temperature, () K

Question 2

Pulp suspension from a tank open to atmosphere is pumped at flow rate 100 l/sec. The consistency of sulphate mass is 5 % and temperature 65 C. The inlet pipe diameter is 250 mm, length 4 m and there are two bends of 45 degree. The level of the tank is at smallest 1 m measured from the center of pump impeller. The NPSH_{req} value of pump is 6 m. You can assume the density of pulp suspension as density of water.

- Calculate the linear velocity of the flow.
- What is the NPSH_{av} value when the level is at lowest and at temperature 65 °C ?
- What is the temperature of pulp suspension where the cavitation starts?

Question 3

The extraction liquor of a continuous digester is taken to the flashing cyclone by using the flow rate of 110 kg/s. Before flashing the temperature of the liquor is 165 °C and dry solids concentration 17 w-%. Into which temperature the liquor has to be flashed if the obtained flow of the flashing steam is 9 kg/s? What pressure does this temperature correspond? What is the dry solids concentration of the liquor after the flashing? It can be assumed that the specific heat of the liquor keeps constant during the flashing process and is 3,9 kJ/(kg K). In addition, it can be assumed that the boiling point rise of the liquor can be neglected.

Question 4

The height of the displacement washing zone in a continuous digester is 10 m. Pulp of kappa number 28 is washed in the washing zone. The average compression pressure in the washing zone is 15 kPa. The pressure drop in the washing liquid over the washing zone is measured to be 125 kPa.

- What is the superficial velocity of the washing liquid in the washing zone?
- If the superficial velocity is doubled what would be the pressure drop? Assume other properties unchanged.

You can use the following equations in the calculations:

The porosity of the chip bed:
$$\varepsilon = 0,644 + \left(\frac{P_c}{10000} \right)^{0,59} (-0,831 + 0,139 \ln \kappa)$$

Where

P_c = compression pressure, () Pa

κ = kappa number

The pressure drop:

$$\frac{\Delta p}{L} = R_1 \frac{(1-\varepsilon)^2}{\varepsilon^3} v_o + R_2 \frac{(1-\varepsilon)}{\varepsilon^3} v_o^2$$

Where

$\frac{\Delta p}{L}$ = pressure drop per unit length of chip

bed, () Pa/m

ε = porosity of chip bed

v_o = superficial velocity of the liquid in the chip bed, ()m/s

R_1 = constant = $0,52 \cdot 10^5$

R_2 = constant = $15 \cdot 10^5$