Birla Institute of Technology and Science, Pilani

Semester II Session: 2021-2022

CHE F412 PROCESS EQUIPMENT DESIGN

Comprehensive Examination

Date: 20/05/2022 **Full Marks: 80**

Duration: 3 hours (120 minutes)

Instructions

- **Be to the point, don't write essays**
- **Please be careful with the units. Wrong units will fetch no credit**
- **Answer all parts of a question at one place only**
- **Write assumptions wherever required with proper justifications**
- **Symbols should have proper nomenclature**

---

1. A tall vertical column 4 m in outside diameter is to be installed as an absorption tower. The available specifications are:

Operating temperature= 160 °C	Operating pressure= 5 kg/m^2
Skirt height = 3.0 m	Insulation thickness = 100 mm
Tray spacing = 0.5 m	Permissible material stress of shell = 1000 kg/m^2
Top space disengagement = 1.2 m	Welded joint efficiency = 85%
Weir height = 50 mm	Density of shell material = 7000 kg/m^3
Bottom space separation = 1.8 m	Density of insulation = 500 kg/m^3
Tray loading without liquid = 100 kg/m^2	Density of water= 1000 kg/m^3
Tray support ring = 45 mm×45mm×11 mm angles	Overhead vapour pressure line = 280 mm
Corrosion allowance = 2 mm	Weight of ladder = 60 kg/m
Wind force acting over vent = 200 kg/m^2	Weight of 280 mm outer diameter pipe = 50 kg/m

Assume (i) elliptical head with major to minor axis ratio = 2:1; (ii) Thickness of insulation being greater than shell, insulation diameter to be equal to mean diameter of the shell; (iii) Weir height as the height of water in the tray; (iv) Height of one tray can be taken to be as 1 m and (v) cross section of a tray can be assumed to be as circle. Calculate all the stresses and check if 50 m is acceptable height for the tower. Consider internal pressure and upwind side. **[20]**

2. A self-supported conical roof is to be designed for a cylindrical storage tank of diameter 5 m. The slope of the conical roof is limited to 1:5. The roof plates are lap welded with continuous filled weld on the tope side only. Roof is subjected to a superimposed load of 150 kgf/m^2. Density of plate material is 7000 kg/m^3. Poisson's ratio = 0.33; Modulus of elasticity = 2×10^6 kg/cm^2. Using a factor of safety 2, 6 and 8, estimate whether a plate thickness of 10 mm is sufficient for fabrication. Assume that the superimposed load along with the weight of roof per unit area to be the total pressure on roof. (1 kg/m^2 = 1 kgf/m^2) [**20]**

3. Consider a rectangular bar, having dimensions "*l*", "*b*" and "*h*" as length, breadth, and height under non-stressed condition. When this bar is stressed, the change in dimensions is designated as "Δl", "Δb" and "Δh", respectively. Under stressed conditions, increment in length is accompanied by a decrease in breadth and height of the bar, under consideration. Assume Poisson's ratio as "μ" (the ratio of longitudinal strain to lateral strain) and volumetric strain as "e_v" (Ratio of change in volume to original volume). With the help of a neat diagram, derive a relation between volumetric strain (e_v) and Poisson's ratio (μ). (Hint: The final relation should contain additional terms related to applied pressure (P), area of rectangular bar (A) and elastic modulus (E)) **[20]**

4. A rod 12.5 mm. in diameter is stretched 3.2 mm under a steady load of 10 kN. What stress would be produced in the bar by a weight of 700 N, falling through 75 mm before commencing to stretch, the rod being initially unstressed? Elastic modulus is 2.1×10^5 N/mm^2. **[10]**

5. Write briefly about the following: (**2.5×4=10**)

(a) Rupture Disc

(b) Tube arrangement patterns in a heat exchanger (Diagrammatic representation necessary)

(c) Type of reaction forces in the design of flange joint

(d) Horizontal and vertical stiffeners

~All the Best; Happy Summer Holidays~

Supplementary Information

Table for standard thickness

APPENDIX B — STANDARD VALUES

Table B-1 Steel Plates

Thickness : (mm)	5, 5.5, 6, 7, 8, 9, 10, 11, 12, 14, 16, 18, 20, 22, 25, 28, 32, 36, 40, 45, 50, 56, 63, 71, 80.
Width : (mm)	160, 180, 200, 220, 250, 280, 320, 355, 400, 450, 500, 560, 630, 710, 800, 900, 1 000, 1 100, 1 250, 1 500, 1 600, 1 800, 2 000, 2 200, 2 500.
Length :	6 m — 10 m easily available.

Table B-2 Strip Steels

Thickness : (mm)	0.8, 0.9 1.0, 1.1, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.5 2.8, 3.2, 3.5, 4.0, 4.5.
Width : (mm) :	100, 110, 125, 140, 160, 180, 200, 220, 250, 280, 320, 355, 400, 450, 500, 560, 630, 710, 800, 900, 1 000.

List of important formulas:

$\sigma = \frac{P}{A}(1 + \sqrt{1 + \frac{2AEh}{P \times L}})$	$E = \frac{Stress}{Strain} = \frac{\frac{Steady\ Load}{Area}}{\frac{Change\ in\ length}{Original\ length}}$
$\epsilon_x = \frac{\Delta L}{L}$	$\epsilon_y = \frac{\Delta b}{b}$
$\mu = -\frac{\epsilon_y}{\epsilon_x}$	$Critical\ Stress = \frac{PD}{2tsin\theta}$
$f_c(critical) = \frac{E}{\sqrt{3(1-\mu^2)}}(\frac{t}{r})$	$r = \frac{D/2}{sin\theta}$
$t = \frac{PD_0}{2fJ + P}$	$t_h = \frac{PD_0V}{2fJ}$
$V = \frac{1}{6}(2 + K^2)$	$f_a = \frac{PD}{4(t-c)}$
Volume of ellipsoid $= \frac{\pi}{6}(D_0^3 - D_i^3) \times \rho_{shell}$	$f_{dx} = \frac{weight\ of\ shell}{cross-section\ \ of\ \ shell}$
$f_{d(ins)} = \frac{\pi D_{ins} t_{ins} \rho_{ins}}{\pi D_m (t_s - c)}$	$f_{d(liq)} = \frac{\sum \text{liquid weight per unit height}(X)}{\pi D_m (t_s - c)}$
$f_{d(att)} = \frac{\Sigma \text{weight of the attachment per unit height (X)}}{\pi D_m (t_s - c)}$	$f_{dx} = f_{ds} + f_{d(ins)} + f_{d(liq)} + f_{d(att)}$

Weight of pipe insulation=area of the pipe×Density×height of column=$\frac{\pi}{6}(D_{0\,ins}^2 - D_{i\,ins}^2) \times \rho_{shell}$	
$f_{wx} = \dfrac{1.4 p_w X^2}{\pi D_0 (t_s - c)}$	(a) Internal pressure and upwind side $f_{t\,max} = (f_{wx}\ or\ f_{sx}) + f_{ap} - f_{dx}$
(c) Internal pressure and downwind side $f_{c\,max} = (f_{wx}\ or\ f_{sx}) - f_{ap} + f_{dx}$	Where, $f_{t\,\max}$ and $f_{c\,\max}$ maximum tensile and compressive stresses f_{wx} = stress due to wind load f_{sx} = stress due to seismic load f_{ap} = axial stress from internal or external pressure (uniform over the entire height) f_{dx} = stress due to dead loads
Number of trays=[(height-1)/tray spacing]+1	