

Dr. Radha Shyam

6/12/2022  
135  
M

National Institute of Technology Hamirpur  
Department of Chemical Engineering

B.Tech. 3<sup>rd</sup> Year (Semester V)  
End-Semester Examination  
Process Equipment Design [CH-313]

Max Marks : 50

Time : 3 Hours

Date: 05/12/22

- Make appropriate assumptions if needed

**Question 1(a)** Briefly discuss about materials used for low temperature operations. (5)

**Question 1(b)** Starting with expression for stress concentration around a circular hole,

$$\sigma_t = \frac{\sigma}{2} \left( 1 + \frac{r^2}{a^2} \right) - \frac{\sigma}{2} \left( 1 + \frac{3r^4}{a^4} \right) \cos(2\theta)$$

Show that reinforcement boundary for cylindrical and spherical openings is  $2d$ . (5)

**Question 2** A vessel having 1.6m outside diameter is to operate at a pressure of  $5\text{kg/cm}^2$ . The permissible stress of the material used for fabrication is  $1020\text{Kg/cm}^2$ . Weld joint efficiency is 85%. Calculate the thickness required for a cylindrical vessel and a spherical vessel? (4+4)

**Question 3** A tall vertical vessel 2.2m in outer diameter and 34m in height has a shell thickness 14mm. Corrosion allowance is not necessary. The vessel is insulated with 80mm thick magnesia insulation. The vessel has no attachment. Wind force acting over the vessel is  $128\text{Kg/m}^2$ . Weight of vessel is 91000kg. Calculate the bending moment induced in the vessel and calculate resulting bending stress. (7)

**Question 4(a)** A distillation column is 5m in length from tangent line to tangent line of closure. Outer diameter of the shell is 3m. The new vessel is to operate under perfect vacuum at  $400^\circ\text{C}$ . The material of construction of vessel is IS: 2002-1962 Gr 1. Stiffeners are to be used at 1m spacing of the vessel to increase its rigidity. Calculate the thickness of the pressure vessel for above design. Modulus of elasticity of carbon steel at  $400^\circ\text{C}$  is  $1.67 \times 10^5 \text{ MN/m}^2$ . (6)

**Question 4(b)** A thin walled pressure vessel is subjected to an internal pressure. If the radius of shell is increased by 2% and the thickness is reduced by 2%, after keeping internal pressure constant, what is percentage change in hoop's(circumferential) stress. (4)

**Question 5(a)** Starting from Hooke's Law for stress in one direction, derive the expression for generalized Hooke's law for strain in case of bidirectional stresses. (5)

**Question 5(b)** Explain(i) Beltrami's Theory(ii) Von Misses Yield Criteria (2+3)

**Question 6.** A 1m outer diameter process vessel is operated at a pressure of  $3.5\text{kg/cm}^2$  (g). Permissible stress for material of construction of head and shell is  $1200\text{kg/cm}^2$ . Weld joint efficiency is 1 and corrosion allowance is 3mm. Calculate the thickness of ellipsoidal head. (5)

-----End of Paper-----

## APPENDICES

## APPENDIX A — MECHANICAL PROPERTIES OF METALS

Table A-1 Mechanical Properties of Carbon and Low Alloy Steels

<u>Material specification</u>	<u>Grade</u>	U.T.S. 10 <sup>8</sup> N/m <sup>2</sup>	Yield stress 10 <sup>8</sup> N/m <sup>2</sup>	% Elonga- tion	Allowable stress values in 10 <sup>8</sup> N/m <sup>2</sup> or temperature upto °C								
					250	300	350	400	450	475	500	525	550
PLATES													
IS : 2002-1962	1	3.63	1.98	26	0.93	0.85	0.76	0.70	0.42	0.35	...	...	...
	2 A	4.12	2.06	25	0.96	0.88	0.79	0.72	0.42	0.35	...	...	...
	2 B	5.10	2.55	20	1.18	1.08	0.98	0.81	0.42	0.35	...	...	...
IS : 2041-1962	20 Mo 55	4.71	2.75	20	1.40	1.29	1.20	1.12	1.05	0.75	0.54	0.36	...
	20 Mn 2	5.10	2.95	20	1.37	1.25	1.13	0.81	0.42	0.35	...	...	...
IS : 1570-1961	15 Cr 90 Mo 55	4.91	2.95	20	1.56	1.49	1.41	1.31	1.23	1.14	0.84	0.56	0.34
	C 15 Mn 75	4.12	2.26	25	1.04	0.96	0.87	0.79	0.42	0.35	...	...	...
FORGINGS													
IS : 2004-1962	Class 1	3.63	1.82	...	0.84	0.77	0.69	0.63	0.42	0.35	...	...	...
	Class 2	4.32	2.16	15	1.00	0.91	0.83	0.75	0.42	0.35	...	...	...
	Class 3	4.91	2.46	21	1.14	1.04	0.94	0.81	0.42	0.35	...	...	...
	Class 4	6.18	3.09	15	1.44	1.31	1.19	0.81	0.42	0.35	...	...	...
IS : 1570-1961	20 Mo 55	4.71	2.75	20	1.40	1.29	1.20	1.12	1.05	0.75	0.54	0.36	...
	10 Cr 2 Mo 1	4.91	3.14	20	1.75	1.69	1.60	1.54	1.43	1.24	0.94	0.68	0.48
IS : 2611-1964	15 Cr 90 Mo 55	4.91	2.95	20	1.56	1.49	1.41	1.31	1.23	1.14	0.84	0.56	0.34

Table A-1 Continued

261

Table A-1 Continued

<u>Material specification</u>	<u>Grade</u>	U.T.S. 10 <sup>8</sup> N/m <sup>2</sup>	Yield stress 10 <sup>8</sup> N/m <sup>2</sup>	% Elonga- tion	Allowable stress values in 10 <sup>8</sup> N/m <sup>2</sup> for temperature upto °C								
					250	300	350	400	450	475	500	525	550
TUBES, PIPES													
IS : 3609-1966	1% Cr ½% Mo	4.32	2.34	22	1.25	1.18	1.12	1.04	0.98	0.95	0.84	0.56	0.34
	2½% Cr 1% Mo	4.81	2.46	19	1.37	1.32	1.25	1.20	1.13	1.10	0.94	0.68	0.48
IS : 1570-1961	20 Mo 55	4.51	2.46	21	1.25	1.15	1.07	1.01	0.94	0.75	0.54	0.36	...
IS : 1914-1961	U.T.S.	3.14	1.57	30	0.72	0.66	0.60	0.54	0.42	0.35	...	...	...
	U.T.S.	4.22	2.11	22	0.98	0.90	0.81	0.74	0.42	0.35	...	...	...
IS : 2416-1963	U.T.S.	3.14	1.57	30	0.72	0.66	0.60	0.54	0.42	0.35	...	...	...
IS : 1978-1961	St 18	3.10	1.73	...	0.80	0.73	0.65	0.60	0.42	0.35	...	...	...
	St 20	3.31	1.94	...	0.90	0.82	0.74	0.67	0.42	0.35	...	...	...
	St 21	3.31	2.07	...	0.96	0.88	0.79	0.72	0.42	0.35	...	...	...
	St 25	4.14	2.42	...	1.12	1.02	0.93	0.81	0.42	0.35	...	...	...
IS : 1979-1961	St 30	4.14	2.90	...	1.35	1.23	1.12	0.81	0.42	0.35	...	...	...
	St 32	4.35	3.17	...	1.47	1.35	1.22	0.81	0.42	0.35	...	...	...
	St 37	4.33	3.59	...	1.67	1.52	1.38	0.81	0.42	0.35	...	...	...

SECTIONS, PLATES, BARS										
IS : 226-1962	St 42-S	4.12	2.36	23	0.96	0.88	0.80	..	..	..
IS : 961-1962	St 55 HTW	4.92	2.84	20	1.12	1.05	0.94	..	..	..
IS : 2062-1962	St 42-W	4.12	2.26	23	0.96	0.88	0.80	..	..	..
IS : 3039-1965	Grade A	..	..	..	0.96	0.88	0.80	..	..	..
	Grade D	..	..	..	1.12	1.05	0.94	..	..	..
IS : 3503-1966	Grade 1	3.63	2.00	26	0.84	0.77	0.70	0.64	0.42	0.35
	Grade 2	4.12	2.27	25	0.96	0.88	0.80	0.72	0.42	0.35
	Grade 3	4.32	2.38	23	1.00	0.91	0.83	0.75	0.42	0.35
	Grade 4	4.61	2.54	22	1.12	1.05	0.94	0.81	0.42	0.35
	Grade 5	4.92	2.71	21	1.19	1.09	0.98	0.81	0.42	0.35
IS : 3945-1966	Grade A-N	4.32	2.36	23	0.96	0.88	0.80	..	..	..
	Grade B-N	4.92	2.80	20	1.12	1.05	0.94	..	..	..

Table A-8 Values of Specific Weight and Poisson's Ratio of Some Metals

Material	Specific weight N/m <sup>3</sup>	Poisson's ratio
Aluminium	2.65 × 10 <sup>4</sup>	0.34
Brass	8.35 × 10 <sup>4</sup>	0.35
Copper	8.79 × 10 <sup>4</sup>	0.35
Iron	7.74 × 10 <sup>4</sup>	0.28
Nickel	8.74 × 10 <sup>4</sup>	0.36
Steel	7.70 × 10 <sup>4</sup>	0.30

## REFERENCES:

1. IS : 2825 — 1969 Code for Unfired Pressure Vessels.
2. IS : 4503 — 1969 Specification for Shell and Tube Type Heat Exchangers.

## APPENDIX B — STANDARD VALUES

Table B-1 Steel Plates

Thickness : 5, 5.5, 6, 7, 8, 9, 10, 11, 12,  
(mm) 14, 16, 18, 20, 22, 25, 28,  
32, 36, 40, 45, 50, 56, 63,  
71, 80.

Width : 160, 180, 200, 220, 250,  
(mm) 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 : 0.8, 0.9 1.0, 1.1, 1.2, 1.4,  
(mm) 1.6, 1.8, 2.0, 2.2, 2.5 2.8,  
3.2, 3.5, 4.0, 4.5.

Width : 100, 110, 125, 140, 160,  
(mm) 180, 200, 220, 250, 280,  
320, 355, 400, 450, 500,  
560, 630, 710, 800, 900,  
1 000.