A WAY OF ASSESSING THE ADMISSIBLE STRESSES IN AREAS WITH CHAMFERED BRACING RIBS OF THE AIR – PRESSURE CYLINDRICAL FRAMES (II)

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Abstract. The first part of the article [1] brought in a theoretical study on the way of assessing the state of the admissible stress in a cylindrical structure with radial equidistant chamfered bracing ribs. The inner pressure and the temperature are looked upon as external loads, whereas the connecting ones are considered internal loads (the shearing stress and unitary bending moments). The present article carries out the exemplification of the theoretical results, taking into account an assembly with connecting flanges with chamfered bracing ribs.

Key words: air – pressure tanks; chamfered bracing ribs

1. EXEMPLIFICATION

Table 1

Values of shearing stresses and connecting unitary bending moments, respectively of the bending moments generated by axial stresses which are generated at the middle of the width of short structural elements.

Nodal plane	Q_{0i}	M_{0i}	$M_{\overline{P}1}$
	N / mm	**Nmm / mm**	**Nmm / mm**
0 – 1	+ 72,3	62449	19316
1 – 2	- 135,6	42848	18270
2 – 3	+ 124,9	33584	16209
3 – 4	- 104,4	27087	14118
4 – 5	+ 83,4	21702	12026
5 – 6	- 63,9	17063	9904
6 – 7	+ 46,4	13064	7751
7 – 8	- 31,0	9658	5598
8 – 9	+ 17,9	6810	3414
9 – 10	- 7,4	4487	1200
10 – 11	- 0,6	2631	1077
11 - 12	+ 9,1	1127	-

Note: Element “0” represents the flange ring, and “12” smooth cylindrical tank

We consider as practical application the case of an air-pressure tank provided with an assembly with connecting flanges with chamfered bracing ribs, having the following geometrical and functioning characteristics[1]: $r_{im} = 500$ mm; $\delta_c = 16$ mm; $p_c = 2,5$ MPa; $E_c = E_n = 2,1 \cdot 10^5$ MPa; $\nu_c = \nu_n = 0,3$; $\ell_n = 120$ mm; $h_n = 96,5$ mm; $\ell_1 = 15$ mm.

It is accepted that the chamfered distance of the bracing ribs, i.e. 120 – 15 = 105 mm be divided in 10 short structural units whose height is $t =$ 105 : 10 = 10,5 mm. Following the methodology from [1], as a result of solving the linear, algebraic system of the continuity equation of the deformation of the short structural elements, respectively of the flange ring and of the even cylindrical tank, the values/results shown in the table are obtained for the shearing stress and the connecting unitary bending moments.

Table 2

Axial and circumferential stresses (stress x 10^{-5}, N/m ^{2})

Element	Load p_c	Load $\overline{P}_1$	Load Q_{0i}	Load M_{0i}	Total stress	Intensification coefficient
	Axial stresses ($\sigma_{xc}^{(tot)}$)					α_{xc}
1	+ 132	+ 184	+ 25	- 108	+ 233	0,587
2	+ 129	+ 188	- 7	- 65	+ 245	0,617
3	+ 123	+ 196	- 12	- 61	+ 256	0,645
4	+ 116	+ 205	- 12	- 41	+ 268	0,675
5	+ 109	+ 215	- 11	- 32	+ 281	0,708
6	+ 101	+ 226	- 10	- 26	+ 291	0,733
7	+ 92	+ 239	- 8	- 20	+ 303	0,763
8	+ 82	+ 254	- 7	- 16	+ 313	0,788
9	+ 71	+ 270	- 5	- 14	+ 322	0,811
10	+ 59	+ 290	- 3	- 13	+ 333	0,839
11	+ 45	+ 312	- 2	- 10	+ 345	0,869
	Circumferential stresses ($\sigma_{\theta c}^{(tot)}$)					$\alpha_{\theta c}$
1	+ 843	-	+ 162	- 690	+ 315	0,397
2	+ 840	-	- 47	- 424	+ 369	0,465
3	+ 834	-	- 79	- 349	+ 406	0,511
4	+ 830	-	- 83	- 292	+ 455	0,573
5	+ 824	-	- 82	- 245	+ 497	0,626
6	+ 819	-	- 79	- 207	+ 533	0,671
7	+ 813	-	- 74	- 175	+ 564	0,710
8	+ 808	-	- 69	- 159	+ 580	0,730
9	+ 802	-	- 57	- 160	+ 585	0,737
10	+ 797	-	- 41	- 175	+ 581	0,732
11	+ 791	-	- 34	- 177	+ 580	0,730

Considering the above mentioned values there can be calculated further on, on the basis of the previously explained connections, the values of the stress appeared at the superior levels of the short structural elements which have been considered by dividing the chamfered bracing ribs area. It has to be remarked that the connecting unitary bending moments and those formed by the $\overline{P}_1$ axial stress have opposite values (the plus/positive sign for M_{0i} was considered the one of the trigonometric sense, and respectively the opposite one of the later for $^{(i)}M_{\overline{P}1}$).

Table 3

Equivalent stresses (stress x 10^{-5}, N/m ^{2})

Elem.	1	2	3	4	5	6	7	8	9	10	11
$\sigma_c^{(ech)}$	277	327	358	398	433	463	489	503	508	505	506

$\alpha_c^{(ech)}$	0,403	0,475	0,520	0,578	0,629	0,673	0,711	0,731	0,738	0,734	0,735

Table 4

Axial and circumferential stresses (stress x 10^{-5}, N/m ^{2})

Element	Load						Total stress	
	p_c	$\overline{P}_1$	Q_{0i}		M_{0i}			
	Axial stresses ($\sigma_{xc}^{(tot)}$)							
1	+ 132	+ 184	- 64	- 24	- 267	- 196	- 5	+ 96
2	+ 129	+ 188	- 131	- 74	- 154	- 112	+ 32	+ 131
3	+ 123	+ 196	- 135	- 72	- 124	- 87	+ 60	+ 160
4	+ 116	+ 205	- 123	- 60	- 113	- 72	+ 85	+ 189
5	+ 109	+ 215	- 108	- 47	- 110	- 61	+ 106	+ 216
6	+ 101	+ 226	- 92	- 34	- 111	- 51	+ 124	+ 242
7	+ 92	+ 239	- 71	- 21	- 116	- 39	+ 144	+ 271
8	+ 82	+ 254	- 48	- 11	- 127	- 26	+ 161	+ 299
9	+ 71	+ 270	- 22	- 4	- 135	- 7	+ 184	+ 330
10	+ 59	+ 290	- 5	- 2	- 128	+ 14	+ 216	+ 361
11	+ 45	+ 312	+ 2	- 4	- 135	+ 53	+ 209	+ 406
r	**-**	**-**	**r_{im}**	**r_{em}**	**r_{im}**	**r_{em}**	**r_{im}**	**r_{em}**
	Circumferential stresses ($\sigma_{\theta c}^{(tot)}$)							
1	+ 843	-	+ 73	+ 109	- 738	- 716	+ 178	+ 236
2	+ 840	-	- 171	- 118	- 451	- 439	+ 218	+ 283
3	+ 834	-	- 202	- 145	- 371	- 360	+ 261	+ 329
4	+ 830	-	- 194	- 136	- 313	- 301	+ 323	+ 393
5	+ 824	-	- 178	- 122	- 268	- 254	+ 378	+ 448
6	+ 819	-	- 158	- 106	- 232	- 214	+ 429	+ 499
7	+ 813	-	- 133	- 87	- 204	- 181	+ 476	+ 545
8	+ 808	-	- 105	- 71	- 192	- 162	+ 511	+ 575
9	+ 802	-	- 71	- 54	- 196	- 157	+ 535	+ 591
10	+ 797	-	- 43	- 40	- 209	- 167	+ 545	+ 590
11	+ 791	-	- 32	- 31	- 219	- 158	+ 540	+ 602
r	**-**	**-**	**r_{im}**	**r_{em}**	**r_{im}**	**r_{em}**	**r_{im}**	**r_{em}**

The stresses developed by the external and internal loads in the cylindrical tank on which the chamfered bracing ribs are provided for can be seen in the tables 2 (the axial and circumferential stresses) and 3 (the equivalent stresses) – without taking the curvature into account – respectively tables 4 and 5 – considering the curvature as well.

Analyzing the values shown in the tables 2 and 3 it comes out a strong intensification of the axial stresses, as compared to the circumferential ones, especially in the area close to the flange ring. An interesting remark is also that of the increasing of the equivalent stresses values towards ″the end of the bracing rib″ - the smallest breadth of the bracing ribs. This phenomenon has as an explanation the ″spur effect when the cylindrical tank comes into contact with the bracing rib. Under the impact of the inner pressure, the cylindrical tank has a real tendency of enhancing the radius of the median surface, while the bracing ribs, by their turning round (in the opposite trigonometric direction) are opposed to this.

Table 5

Equivalent stresses (stress x 10^{-5}, N/m^2)

Elem.	1	2	3	4	5	6	7	8	9	10	11
$\sigma_c^{(ech)}$ (r_{im})	181	204	237	290	338	382	423	453	471	475	472
$\sigma_c^{(ech)}$ (r_{em})	206	245	285	340	388	432	472	498	513	515	532

In the case when the curvature is taken into accout it results the same effect of increase of the stresses from the cylindrical tank towards the end of the bracing rib. This time it can by noticed distinct stresses both on the internal and external surface of the cylindrical tank.

The equivalent stresses, calculated according to the IV Th resistance theory [2, 3], taking or not into consideration are below the value of the curvature allowable stress specific to the building material used for the tank and the bracing ribs. As for the bracing ribs the situation of the axial and circumferential stresses, respectively the equivalent stresses are the way they are presented in the tables 6, 7 (without taking the curvature into account) and 8, 9 (considering the curvature as well).

Table 6

Axial and circumferential stresses (stress x 10^{-5}, N/m^2) – no taking into the consideration the curvature

Element	Load				Total stress
	p_c	$\overline{P}_1$	Q_{0i}	M_{0i}	
	Axial stresses ($\sigma_{xn}^{(tot)}$)				
1	- 121	+ 184	- 23	+ 99	+ 139
2	- 123	+ 188	+ 7	+ 62	+ 134
3	- 128	+ 196	+ 12	+ 53	+ 133
4	- 133	+ 205	+ 13	+ 47	+ 132
5	- 138	+ 215	+ 14	+ 41	+ 132
6	- 145	+ 226	+ 14	+ 37	+ 132
7	- 152	+ 239	+ 14	+ 33	+ 134
8	- 160	+ 254	+ 14	+ 32	+ 140
9	- 169	+ 270	+ 12	+ 34	+ 147
10	- 180	+ 290	+ 9	+ 39	+ 158
11	- 193	+ 312	+ 8	+ 43	+ 170
	Circumferential stresses ($\sigma_{\theta n}^{(tot)}$)				
1	+ 797	- 45	+ 154	- 652	+ 254
2	+ 795	- 46	- 44	- 401	+ 304
3	+ 791	- 48	- 74	- 331	+ 338
4	+ 787	- 50	- 79	- 277	+ 381
5	+ 784	- 53	- 78	- 233	+ 420
6	+ 781	- 55	- 75	- 197	+ 454
7	+ 777	- 58	- 71	- 167	+ 481
8	+ 774	- 62	- 66	- 153	+ 497
9	+ 771	- 70	- 39	- 153	+ 491
10	+ 769	- 70	- 39	- 169	+ 491
11	+ 766	- 76	- 33	- 171	+ 486

Table 7

Equivalent stresses (stress x 10^{-5}, N/m ^{2})

Elem.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
$\sigma_n^{(ech)}$	220	264	295	335	372	404	430	444	436	434	432

Table 8

Axial and circumferential stresses (stress x 10^{-5}, N/m ^{2}) – taking into the consideration the curvature

Element	**Load**						**Total stress**	
	p_c	$\overline{P}_1$	Q_{0i}		M_{0i}			
	Axial stresses ($\sigma_{xn}^{(tot)}$)							
1	- 121	+ 184	- 68	+ 150	+ 18	+ 407	+ 13	+ 620
2	- 123	+ 188	- 54	+ 250	+ 19	+ 235	+ 30	+ 550
3	- 128	+ 196	- 43	+ 258	+ 21	+ 198	+ 46	+ 524
4	- 133	+ 205	- 31	+ 241	+ 18	+ 194	+ 59	+ 507
5	- 138	+ 215	- 19	+ 217	+ 14	+ 202	+ 72	+ 496
6	- 145	+ 226	- 8	+ 188	+ 15	+ 218	+ 87	+ 487
7	- 152	+ 239	+ 2	+ 150	+ 15	+ 241	+ 104	+ 478
8	- 160	+ 254	+ 10	+ 103	+ 23	+ 273	+ 127	+ 470
9	- 169	+ 270	+ 13	+ 49	+ 40	+ 297	+ 154	+ 447
10	- 180	+ 290	+ 10	+ 14	+ 64	+285	+184	+409
11	- 193	+ 312	+ 7	+ 3	+ 100	+ 320	+ 226	+ 442
r	-	-	**r_{em}**	**r_{en}**	**r_{em}**	**r_{en}**	**r_{em}**	**r_{en}**
	Circumferential stresses ($\sigma_{\theta n}^{(t0t)}$)							
1	+ 797	- 45	+ 151	+ 163	- 656	- 635	+ 247	+ 280
2	+ 795	- 46	- 47	- 31	- 416	- 351	+ 286	+ 367
3	+ 791	- 48	- 77	- 61	- 342	- 289	+ 324	+ 393
4	+ 787	- 50	- 82	- 67	- 278	- 269	+ 377	+ 401
5	+ 784	- 53	- 80	- 67	- 234	- 224	+ 417	+ 440
6	+ 781	- 55	- 76	- 65	- 199	- 187	+ 451	+ 474
7	+ 777	- 58	- 72	- 63	- 168	- 155	+ 479	+ 501
8	+ 774	- 62	- 66	- 61	- 153	- 139	+ 493	+ 512
9	+ 771	- 70	- 55	- 52	- 153	- 138	+ 497	+ 515
10	+ 769	- 70	- 39	- 39	- 167	- 154	+ 493	+ 506
11	+ 766	- 76	- 34	- 33	- 168	- 155	+ 488	+ 502
r	-	-	**r_{em}**	**r_{en}**	**r_{em}**	**r_{en}**	**r_{em}**	**r_{en}**

Table 9

Equivalent stresses (stress x 10^{-5}, N/m ^{2})

Elem.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
$\sigma_n^{(ech)}$ (**r_{em}**)	241	272	304	351	386	414	436	443	441	431	423
$\sigma_n^{(ech)}$(**r_{en}**)	538	485	472	463	471	481	490	492	485	465	475

The tables 3 and 5 show an increasing of the values of the equivalent stresses from the element to the vicinity of the end of the bracing rib. In the case of the bracing ribs it can be notice an increasing of the equivalent stresses to the element 8 – when the curvature is not taken into consideration, respectively at the external surface of the cylindrical tank, defined by the radius r_{em}. Outside the chamfered bracing ribs, it can be noticed a decreasing of the stress values to the element 5, an increasing to the element 8 and next a slight diminishing (table 9). At the same time, according to table 9 one can see a substantial difference between the values of the axial stresses at the outer surface of the cylindrical tank and those at the external circumference of the bracing ribs conditioned by the compression of the latter from the tank towards the flange ring. Also in the case of the bracing ribs, the maximum of the equivalent stresses are below the level of the allowable stress of their material. Thus, it can be said that the geometry of the ribbed area is technically suited for the intended functional conditions.

Notations:

f_{1x}, f_2, f_{3x} - material function[1]; c_{ux} - filing axial coefficient, characteristic at each lamellar element "*i*" [1]; h_n - width of each lamellar element; E_c, E_n - longitudinal elasticity modules of the tank and ribs materials (in the case of he same material $E_c = E_n$); ν_c, ν_n - transverse shrinkage coefficients of the tank and ribs materials (in the case of he same material $\nu_c = \nu_n$); p_c - calculus internal pressure; $\overline{P}_1$ - axial stress because of internal pressure action; $M_{\overline{P}1}$ - unitary bending moment developed of $\overline{P}_1$ axial stress at the median surfaces level of short structural elements; M_0, Q_0 - unitary bending moment and connecting shearing stress, characteristic to each short structural element; r_{im}, r_{em}, r_{mc} - radius of the internal surface, external surface and median surface of the smooth cylindrical tank; r_{0n}, r_{en} - radii of the neutral circumferences of the short structural elements, respectively external radii of the corresponding circumference; x - current distance measured from the separation plane of the ribbed surface of the flange ring, in the case of this exemplification; u, w - axial displacement, respectively radial; α - stresses intensification and concentration coefficients; β_i, γ_i - diminishing factors; σ_x, σ_θ - circumferential and meridional stresses.

References

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