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New formula for predicting plastic buckling pressure of steel torispherical heads under internal pressure

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S1 Comparison of predictions and experimental results of buckling pressure for torispherical heads

Tables S1–S4 shows the comparison of predictions of different formulas and experimental results for torispherical heads. The experimental results of ZJU-X1–ZJU-X4, ZJU-CAP1–ZJU-CAP2 and ZJU-STD1–ZJU-STD2 are from Li et al. (2019). The rest of the experimental results are obtained from the literature reported by Miller (1999).

Table S1 Comparison of predictions of Eq. (14) and experimental results for torispherical heads formed by spinning and pressing

Head No.	D_i (mm)	D_i/t	R_i/D_i	r/D_i	Material	Yield strength, S_y (MPa)	Experimental buckling pressure, P_{exp} (MPa)	Eq. (14), P_b (MPa)	Relative error (%)
ZJU-X1	1800.0	450	0.940	0.140	Stainless steel	392	2.51	1.91	−24
ZJU-X4	1200.0	400	1.000	0.120	Stainless steel	327	1.45	1.66	14
ZJU-X2	1800.0	450	1.010	0.120	Stainless steel	392	1.77	1.62	−8
ZJU-X3	1200.0	400	1.000	0.120	Stainless steel	340	1.47	1.73	18
KR1	1526.5	238	0.982	0.062	Carbon steel	425	4.14	3.86	−7
T16	500.4	370	1.000	0.100	Carbon steel	262	1.21	1.39	15
T15	500.4	373	1.000	0.100	Carbon steel	262	1.30	1.37	5
T10	500.1	355	1.000	0.040	Carbon steel	270	0.79	1.00	27
T9	505.0	368	1.000	0.040	Carbon steel	239	0.83	0.83	0
T4	502.9	370	1.093	0.060	Carbon steel	280	1.19	1.04	−13
T3	502.9	381	1.093	0.060	Carbon steel	290	1.13	1.03	−9
SC6	1371.6	412	0.778	0.074	Stainless steel	294	1.92	1.58	−18
SC5	1371.6	412	0.833	0.074	Stainless steel	294	1.92	1.44	−25
SC3	1371.6	412	1.000	0.111	Stainless steel	294	1.71	1.37	−20
SC4	1371.6	412	1.000	0.074	Stainless steel	294	1.37	1.13	−18
T5	500.1	535	1.000	0.040	Carbon steel	263	0.39	0.49	26
T6	501.9	543	1.000	0.040	Carbon steel	279	0.37	0.51	38
T13	500.4	543	1.000	0.100	Carbon steel	253	0.61	0.71	16
T2	502.9	541	1.093	0.060	Carbon steel	259	0.44	0.51	16
T1	502.9	550	1.093	0.060	Carbon steel	230	0.43	0.44	2

Head No.	D_i (mm)	D_i/t	R_i/D_i	r/D_i	Material	Yield strength, S_y (MPa)	Experimental buckling pressure, P_{exp} (MPa)	Eq. (14), P_b (MPa)	Relative error (%)
T11	502.9	1068	1.000	0.100	Carbon steel	253	0.26	0.23	−12
SC17	2057.4	618	0.833	0.074	Stainless steel	294	0.74	0.73	−1
SC11	2743.2	824	0.722	0.074	Stainless steel	294	0.59	0.55	−7
SC16	2057.4	618	1.000	0.074	Stainless steel	294	0.66	0.58	−12
KN2b	1676.4	629	1.000	0.076	Stainless steel	207	0.34	0.40	18
SC10	2743.2	824	0.833	0.074	Stainless steel	294	0.54	0.45	−17
SC12	2743.2	824	1.000	0.056	Stainless steel	294	0.46	0.31	−33
SC9	2743.2	824	1.000	0.074	Stainless steel	294	0.43	0.36	−16
SC8	2743.2	824	1.000	0.111	Stainless steel	294	0.48	0.43	−10
K5	4249.4	1044	1.000	0.083	Stainless steel	294	0.23	0.25	9

Table S2 Comparison of predictions of the formulas and experimental results for torispherical heads assembled from formed segments

Head No.	D_i (mm)	D_i/t	R_i/D_i	r/D_i	Yield strength, S_y (MPa)	Experimental buckling pressure, P_{exp} (MPa)	Eq. (14)		Eq. (15)	
							Calculation results (MPa)	Relative error (%)	Calculation results (MPa)	Relative error (%)
ZJU-CAP1	4797.0	872	0.780	0.210	509	1.15	1.27	10	1.02	−11
ZJU-CAP2	4797.0	872	0.780	0.210	588	1.15	1.47	28	1.18	3
ZJU-STD1	5000.0	909	0.890	0.170	612	0.70	1.08	54	0.86	23
ZJU-STD2	5000.0	909	0.890	0.170	558	0.70	0.99	41	0.79	13
SC1	1371.6	412	1.000	0.167	294	1.93	1.66	−14	1.33	−31
SC2	1371.6	412	1.000	0.167	294	1.92	1.66	−14	1.33	−31
Meesters	2743.2	457	1.000	0.085	290	0.98	1.00	2	0.80	−18
CBI2	4876.8	711	0.900	0.170	353	0.73	0.93	27	0.74	1
CBI1	4876.8	980	0.900	0.170	361	0.40	0.56	40	0.45	13
Fino	18288	2304	0.905	0.173	262	0.09	0.10	11	0.08	−11
SC14	2057.4	618	1.000	0.167	294	0.83	0.84	1	0.67	−19
SC15	2057.4	618	1.000	0.167	294	0.74	0.84	14	0.67	−9
K4	4249.4	730	0.890	0.162	294	0.48	0.73	52	0.58	21
K1	4249.4	825	0.910	0.159	294	0.37	0.58	57	0.46	24
SC7	2743.2	824	1.000	0.167	294	0.41	0.52	27	0.42	2
SC13	2743.2	824	1.000	0.167	294	0.57	0.52	−9	0.42	−26
K2	4249.4	880	1.000	0.163	294	0.32	0.46	44	0.37	16
K3	4249.4	915	1.000	0.166	294	0.29	0.44	52	0.35	21
Stennett	1936.8	953	1.000	0.105	293	0.28	0.33	18	0.26	−7

Table S3 Comparison between experimental results and Aylward & Galletly's formula

Head No.	D_i (mm)	D_i/t	R_i/D_i	r/D_i	S_y (MPa)	Buckling pressure (MPa)		$\frac{P_b}{P_{exp}}$
						Experiment, P_{exp}	Formula, P_b	
T13	500.4	543	1.000	0.100	253	0.61	3.97	6.5
T2	502.9	541	1.093	0.060	259	0.44	3.03	6.9
T1	502.9	550	1.093	0.060	230	0.43	2.91	6.8
T11	502.9	1068	1.000	0.100	253	0.26	0.76	2.9
SC17	2057.4	618	0.833	0.074	294	0.74	3.23	4.4
SC16	2057.4	618	1.000	0.074	294	0.66	2.51	3.8
KN2b	1676.4	629	1.000	0.076	207	0.34	2.42	7.1
SC10	2743.2	824	0.833	0.074	294	0.54	1.63	3
SC9	2743.2	824	1.000	0.074	294	0.43	1.24	2.9
SC8	2743.2	824	1.000	0.111	294	0.48	1.48	3.1
K5	4249.4	1044	1.000	0.083	294	0.23	0.72	3.1
Stennett	1936.8	953	1.000	0.105	293	0.28	1.00	3.6

Table S4 Comparison of different formulas for predicting the buckling pressure of torispherical heads

Head No.	Experimental buckling pressure, P_{exp} (MPa)	Galletly's Eq. (4)		Galletly & Błachut's Eq. (5)		Galletly & Błachut's Eq. (6)		Miller's Eqs. (8)–(13)	
		P_b (MPa)	Relative error (%)	P_b (MPa)	Relative error (%)	P_b (MPa)	Relative error (%)	P_b (MPa)	Relative error (%)
ZJU-X1	2.51	1.61	−36	1.38	−45	1.25	−50	1.50	−40
ZJU-X4	1.45	1.32	−9	1.12	−23	0.99	−32	1.45	0
ZJU-X2	1.77	1.31	−26	1.12	−37	1.00	−44	1.25	−29
ZJU-X3	1.47	1.38	−6	1.16	−21	1.03	−30	1.50	2
KR1	4.14	N/A	N/A	N/A	N/A	N/A	N/A	1.88	−55
T16	1.21	1.02	−16	0.87	−28	0.76	−37	1.06	−12
T15	1.30	1.01	−22	0.86	−34	0.75	−42	1.05	−19
T10	0.79	N/A	N/A	N/A	N/A	N/A	N/A	0.46	−42
T9	0.83	N/A	N/A	N/A	N/A	N/A	N/A	0.40	−52
T4	1.19	0.65	−45	0.55	−54	0.51	−57	0.73	−39
T3	1.13	0.64	−43	0.55	−51	0.50	−56	0.73	−35
SC6	1.92	N/A	N/A	N/A	N/A	N/A	N/A	0.85	−56
SC5	1.92	0.93	−52	0.81	−58	0.72	−63	0.83	−57
SC3	1.71	1.07	−37	0.90	−47	0.80	−53	1.15	−33
SC4	1.37	0.76	−45	0.65	−53	0.58	−58	0.79	−42
T5	0.39	N/A	N/A	N/A	N/A	N/A	N/A	0.30	−23
T6	0.37	N/A	N/A	N/A	N/A	N/A	N/A	0.31	−16
T13	0.61	0.55	−10	0.48	−21	0.43	−30	0.61	0
T2	0.44	0.33	−25	0.29	−34	0.27	−39	0.42	−5
T1	0.43	0.29	−33	0.25	−42	0.24	−44	0.36	−16
T11	0.26	0.20	−23	0.18	−31	0.16	−38	0.18	−31
SC17	0.74	0.50	−32	0.45	−39	0.40	−46	0.50	−32
SC11	0.59	N/A	N/A	N/A	N/A	N/A	N/A	0.34	−42
SC16	0.66	0.41	−38	0.36	−45	0.33	−50	0.46	−30
KN2b	0.34	0.29	−15	0.25	−26	0.23	−32	0.32	−6
SC10	0.54	0.32	−41	0.29	−46	0.27	−50	0.30	−44
SC12	0.46	0.21	−54	0.19	−59	0.18	−61	0.22	−52
SC9	0.43	0.26	−40	0.24	−44	0.22	−49	0.27	−37
SC8	0.48	0.37	−23	0.33	−31	0.30	−38	0.33	−31
K5	0.23	0.20	−13	0.18	−22	0.17	−26	0.19	−17
ZJU-CAP1	1.15	N/A	N/A	N/A	N/A	N/A	N/A	1.13	−2
ZJU-CAP2	1.15	N/A	N/A	N/A	N/A	N/A	N/A	1.23	7
ZJU-STD1	0.70	1.07	53	0.96	37	0.94	34	0.61	−13
ZJU-STD2	0.70	0.98	40	0.88	26	0.85	21	0.57	−19
SC1	1.93	1.50	−22	1.26	−35	1.19	−38	1.72	−11
SC2	1.92	1.50	−22	1.26	−34	1.19	−38	1.72	−10
Meesters	0.98	0.72	−27	0.62	−37	0.55	−44	0.76	−22
CBI2	0.73	0.89	22	0.78	7	0.76	4	0.71	−3
CBI1	0.40	0.56	40	0.50	25	0.49	23	0.40	0
Fino	0.09	N/A	N/A	N/A	N/A	N/A	N/A	0.08	−11
SC14	0.83	0.81	−2	0.70	−16	0.67	−19	0.74	−11
SC15	0.74	0.81	9	0.70	−5	0.67	−9	0.74	0
K4	0.48	0.69	44	0.61	27	0.58	21	0.59	23
K1	0.37	0.55	49	0.49	32	0.47	27	0.44	19
SC7	0.41	0.52	27	0.46	12	0.44	7	0.42	0
SC13	0.57	0.52	−9	0.46	−19	0.44	−23	0.42	−26
K2	0.32	0.46	44	0.41	28	0.39	22	0.36	13
K3	0.29	0.44	52	0.39	34	0.38	31	0.34	17
Stennett	0.28	0.28	0	0.25	−11	0.23	−18	0.22	−21

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