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Study on Carrying Capacity of Square shell and Parameter analysis

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Abstract: Square shell is one structural type which is quite common to be seen in engineering. This paper focuses on the carrying capacity of square shell, and studies the influence of round radius and shell thickness on the ratio of mass to external volume and load factor under linear buckleing of shell. Numerical results show that, With the increase of round radius, the ratio will first decrease, then increase and approach that of circular shell, while the load factor will also increase. With the increase of shell thickness, the ration of shell will increase and the load factor will rapidly increase. This will help to better design of pressure hull of submarines.

Keywords: Square shell; carrying capacity; load factor.

1. Introduction

Due to the advantages of simple construction and large inner space, square shell has wide application in engineering, such as pressure hull for submarine, oil pipes and so on.

Many researchers have conducted research work on characteristics of square shell. Liu et.al [1] studied the state deformation behavior of non-circular bellows, and the formula to calculate the deformation of bellow with rectangular cross section. Xiong et.al [2] analyzed the influence of non-circular section due to machining error on structural vibration and sound radiation property。 Gao et.al. [3] investigated the natural vibration of beam with non-circular section on the basis of space curved beam theory. Cao et.al. [4] put forward a new manufacture plan for part with non-circular section, which will increase the machining precision and use less time. Liu and Wei [5] established the mechanical model for pressure vessel with double cavity, and the design project is also well tested. Ji et.al. [6] conducted wind tunnel experiment to study the aro-dynamic characteristics of patrol missile with non-circular section.

It should also be noted that the variety of curvature will make the stress and carrying capacity of square shell much more complex. Therefore, the carrying capacity of square shell is studied in this work, and the influence of round radius and shell thickness is also investigated.

2. Model set

2.1. Model Introduction

The square shell is of length 8m, cross section of shell is shown in Fig.1, section is of width 2.6m, and four rounds are distributed at every corner with round radius R. Parameter R is variable in later analysis, but the external surface of shell remains the same.

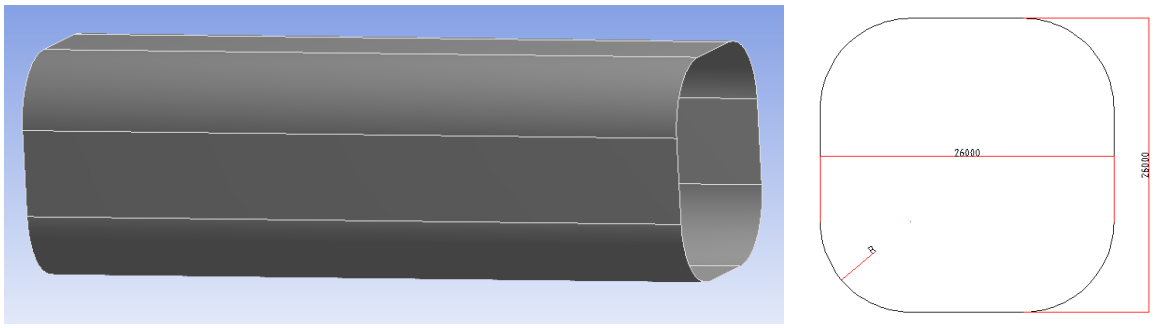


Fig.1 square shell and cross section

2.2. Boundary conditions

In this work, fixed boundary is selected by setting the deformation of rotation degree of elements at both ends of shell to zero. Boundary condition of shell is shown in Fig.2.

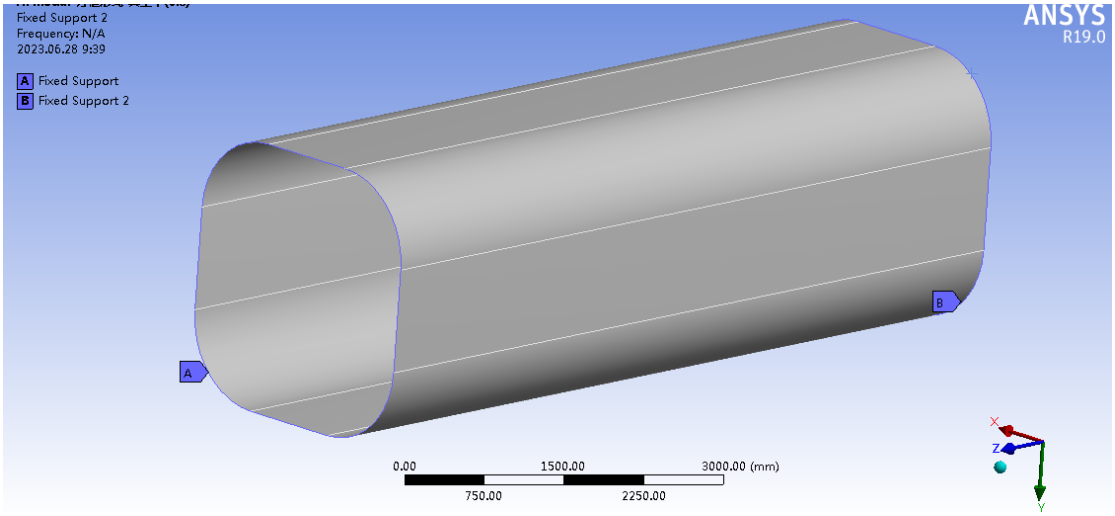


Fig.2 Boundary condition of shell

2.3. Analysis procedure

The ratio of mass to external volume is a typical parameter to describe the carrying capacity of shell, and it's defined as

$$\eta = \frac{m}{V} \times 100\%$$

Where, m is mass of shell, the unit is t. V is external volume of shell, the unit is m3.

To obtain the ratio of mass to external volume, the mass and external volume of square shell will first be calculated.

The FEM software ANSYS workbench is applied to conduct numerical simulation work to get the load factor of linear buckling.

3. Ratio of mass to external volume

3.1. Influence of round radius

To study the effect of round radius on the ratio of mass to external volume, the ratio in case of different round radius are given in Table 1.

It's noted that, with the increase of round radius, the ratio will first decrease and then increase, and it will finally approach that from the circular shell（which is the special case of R=1.3m for square shell）.

This conclusion indicates that it's possible to obtain a better design for underwater structure with less mass by adjust proper round radius.

Table 1 Ratio of mass to external volume in case of different round radius

Round radius （m）	External volume （m^3）	Mass （t）	Ratio
0.3	53.462	6207.8	11.61%
0.5	52.363	5992.1	11.44%
0.8	49.685	5668.7	11.41%
1	47.213	5453	11.55%
1.2	44.191	5237.4	11.85%
1.3 (circular shell)	42.474	5214.5	12.28%

3.2. Influence of shell thickness

To get clear the influence of shell thickness on the ratio of mass to external volume, The ratios in cases of different thickness are given in Table 2.

It's noted that, with the increase of shell thickness, the external volume will remain the same, and the mass of shell will increase, so the ratio of mass to external volume will also increase.

Table 2 Ratio of mass to external volume in case of different shell thickness

thickness (mm)	Volume （m^3）	Mass （t）	Ratio
10	49.685	5668.7	11.41%
9	49.685	5101.8	10.27%
8	49.685	4534.9	9.13%
7	49.685	3968.1	7.99%
6	49.685	3401.2	6.85%
5	49.685	2834.3	5.70%
4	49.685	2267.5	4.56%
3	49.685	1700.6	3.42%
2	49.685	1133.7	2.28%

4. Carrying capacity

4.1. Influence of round radius

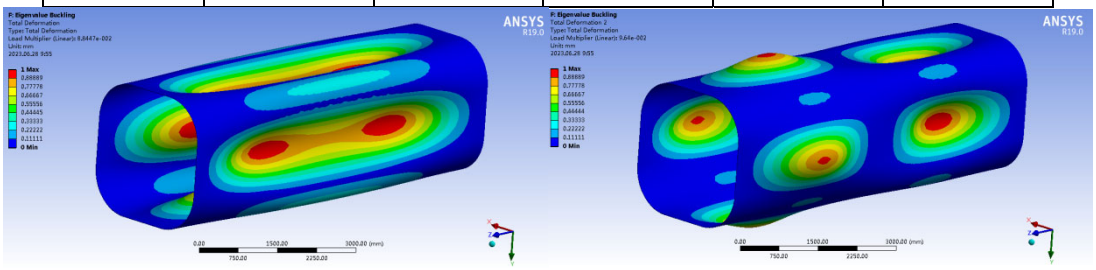
To reveal the influence of round radius on carrying capacity of square shell, load factors in cases of different round radius are given in Table 3. And linear buckling modes of shell for the first four mode are also plotted to give a better understanding of the carrying capacity of square shell. Round radius in numerical calculation is 0.8m.

It's noted that, with the increase of round radius, load factor with the same order will become bigger and bigger.

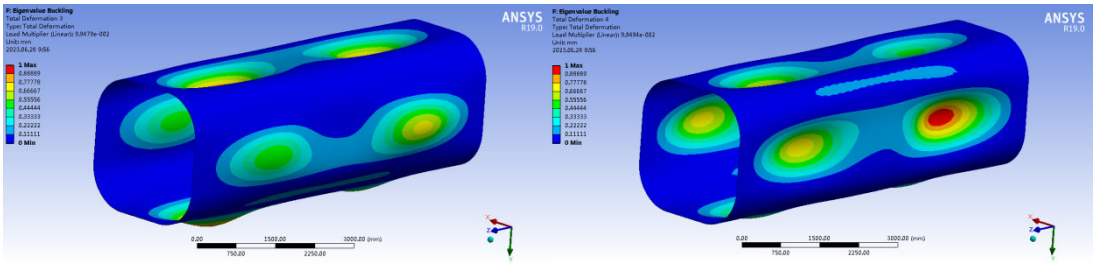
The first four mode of square shell in case of linear buckling is shown in Fig.3.

Table 3 Load factor of the first order in case of different shell thickness (Unit:MPa)

Order	Round radius (m)				
	0.3	0.5	0.8	1	1.2
1	6.74E-02	5.50E-02	8.84E-02	1.35E-01	2.16E-01
2	6.87E-02	5.55E-02	9.64E-02	1.62E-01	2.25E-01
3	6.89E-02	5.89E-02	9.95E-02	1.62E-01	2.25E-01
4	8.33E-02	5.89E-02	9.95E-02	2.00E-01	2.68E-01
5	8.34E-02	5.95E-02	9.99E-02	2.03E-01	2.90E-01
6	8.55E-02	5.95E-02	9.99E-02	2.04E-01	2.98E-01
7	8.80E-02	6.35E-02	1.03E-01	2.04E-01	3.48E-01
8	9.17E-02	6.42E-02	1.03E-01	2.19E-01	3.87E-01
9	1.04E-01	9.73E-02	1.12E-01	2.20E-01	3.90E-01
10	1.05E-01	9.85E-02	1.14E-01	2.24E-01	3.90E-01



(a) first mode; (b) second mode



(c) third mode; (d) fourth mode

Fig.3 the first four mode of square shell in case of linear buckling

4.2. Influence of shell thickness

Then, the influence of shell thickness on carrying capacity of square shell is conducted, and load factors of linear buckling in cases of different shell thickness is given in table 4. R=0.8m.

It's noted that, with the decrease of shell thickness, the first order load factor of square shell will rapidly decrease. When the shell thickness decrease from 10mm to be 5mm, the reduction of load factor for the first order has already reduce more than 90%. This indicates that shell thickness has great effect on carrying capacity of square shell.

Table 4 Load factor of the first order in case of different shell thickness

Order	Thickness (mm)	Load factor (MPa)
1	10	0.0884
2	9	0.0626
3	8	0.0420
4	7	0.0271
5	6	0.0139
6	5	0.0065
7	4	0.0027
8	3	0.0009
9	2	0.0002

5. Conclusion

This paper applies the FEM to study carrying capacity of square shell, and the influence of round radius and shell thickness on the ratio of mass to external volume and load factor under linear buckling of shell is also conducted. Numerical results show that, With the increase of round radius, the ratio will first decrease, then increase and approach that of circular shell, while the load factor will also increase. With the increase of shell thickness, the ration of shell will increase and the load factor will rapidly increase. This will help to better design of pressure hull of submarines.

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References

[1] Liu Xin. The deformation behavior of flexible non-circle section bellows at deflection states[J]. PRESSURE VESSEL TECHNOLOGY, 1994, 11(5):62-69

[2] Xiong Lu，Li Tianyun, Zhu Xiang. FE Analysis of the Acoustic Radiation Effects of Cylindrical Shell Contains Manufacturing Geometric Errors[J]. SHIP ＆ OCEAN ENGINEERING, 2011, 40(6):73-76

[3] Gao Shanshan, Huang Xin, Hao Ying. Free Vibration Analysis of Straight Beam with Non-circular Cross Section[J]. Henan Science and Technology, 2019: 110-111

[4] Cao Hui, Liang Ning, Zhang Na. Research on the Technology of Concentric Different Diametric Noncircular NC Turning[J]. Modular Machine Tool ＆ Automatic Manufacturing Technique, 2012,(8):59-61

[5] Liu Min, Wei Hong. Design and Application of Wall Thickness of Isobaric Pressure Vessel with Double Cavity[J].Mechanical Research & Application, 2019, 32(5):30-31

[6] Ji Xiuling, Zhang Taiheng, He Guanglin. Experiment on aerodynamic characteristics of loitering munitions with non-circular cross section [J]. Journal of Nanjing University of Science and Technology (Natural Science), 2010, 34(1): 71-74