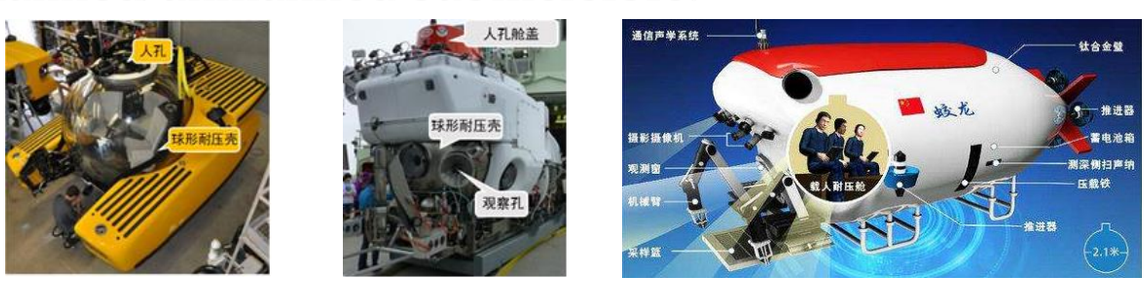
2017 International Bionic Innovation Competition

Bionic study of deep egg-shaped pressure hulls

Abstract

Most in-service deep pressure hulls are spherical shells, which have the disadvantages of high imperfection sensitivity, irrational hydrodynamics and inefficient space utilization, and these problems are unsolved. Some inspirations could be gained from the eggshell structure with those advantages such as an excellent load-carrying capacity, weight-to-strength ratio, span-to-thickness ratio, and aesthetic appeal.Therefore, our work puts forward a new geometry, an egg-shaped pressure hull, to take place of the spherical pressure hull. Mechanical characteristics comprising ultimate strength and buckling of the egg-shaped pressure hulls proposed based on the geometric function of goose eggshell are explored theoretically, numerically and experimentally. Our study can provides a solid foundation for further applications in deep-sea manned/unmanned submersible.



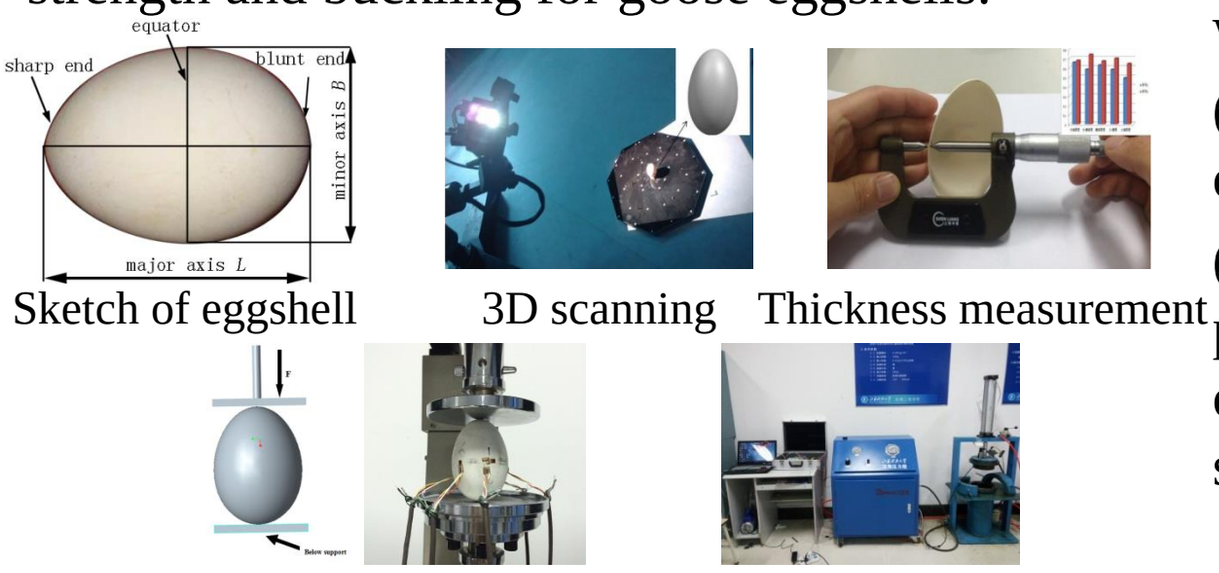
TRITON 3000/3 ALVIN Jiaolong

Fig.1 Spherical pressure hulls in existing deep-sea submersible.

Methods

1 Biological test of goose eggshells

We measured the geometry including major axis，minor axis，shape, volume，surface area, thickness and shape index, and investigate the mechanical performance including ultimate strength and buckling for goose eggshells.



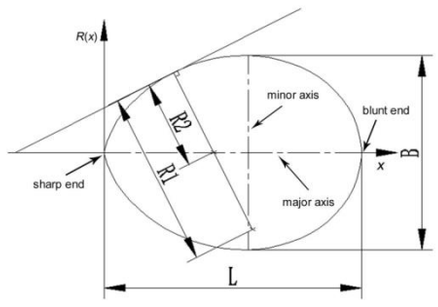
Sketch of eggshell 3D scanning Thickness measurement

Compressive test Hydrostatic pressure test

Fig.2 Sketch of goose eggshell and its testing equipment.

2 Investigation on egg-shaped pressure hulls

We established a bionic design method for the egg-shaped pressure hulls. And we conducted a deep study into the buckling of the proposed egg-shaped pressure hulls by comparison of numerical, theoretical and experimental data. Additionally, we also examined the effect of sharp index (*SI*) and thickness (*t*) on buckling of these hulls.



Geometry of the egg-shaped pressure hull Resin model Metal model

Fig. 3 Sketch of the egg-shaped pressure hull and its manufacturing models.

Results

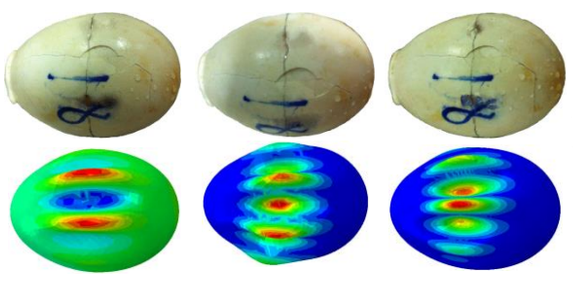


Fig.4 Buckling shapes of eggshells.

Fig.5 Collapse shapes of metal models.

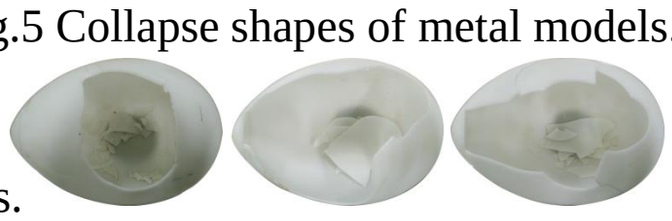


Fig.6 Collapse shapes of resin models.

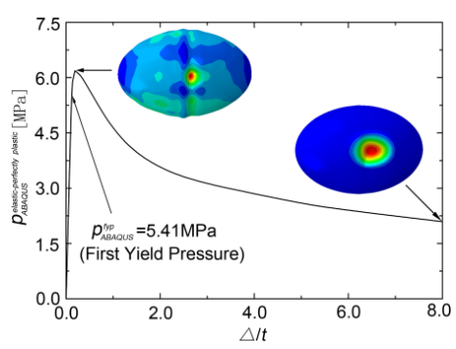


Fig.7 Equilibrium path for a model along with its buckling modes.

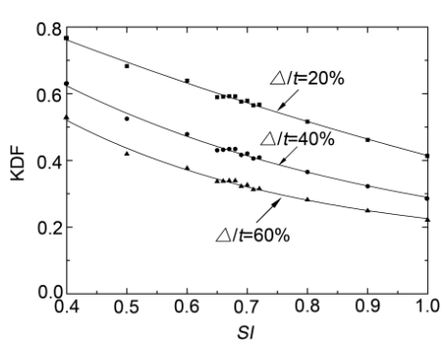


Fig.8 Knock down factors of egg-shaped pressure hulls with different Shape index SIs.

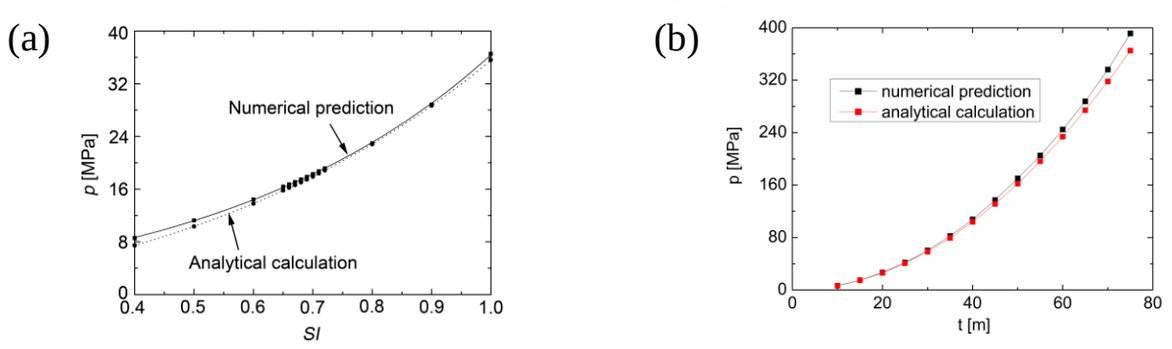


Fig.9 Linear buckling loads of egg-shaped shells versus shape index *SI* (a) or thickness t (b) obtained from numerical predictions and analytical calculations.

(1) Eggshells show a high pressure resistant performance, which is strongly affected by their shape and thickness.

(2) Our study can obtain a good agreement by comparison of numerical, theoretical and experimental data.

(3) Egg-shaped pressure hulls have an overall superior performance to spherical ones and are convenient for opening holes at the both ends, which can provide a new style of pressure hulls for deep-sea submersibles.

Publications/patens or rewards

[1] Investigation on egg-shaped pressure hulls. Marine Structures 2017, 52, 50-66

[2] Buckling of egg-shaped shell subjected to external pressure. Thin-walled Structures 2017, 113, 122-128

[3] Elastic buckling of egg-shaped shells subjected to external pressure: A comparison of experimental and theoretical data. Ships and Offshore Structures 2017 (Accepted)

[4] Stability analysis of eggshells subjected to external pressure. Advances in Natural Science 2016, 9, 23-31