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Compression performance of column-cell sandwich composite

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A R T I C L E I N F O

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A B S T R A C T

A new sandwich structure which core is made of thin-walled semi-ellipsoidal shell is designed, column-cell sandwich composite was prepared by pre-panel preparation process. A series of quasi-static axial compression experiments were carried out on 2 × 2 thin-walled semi-ellipsoidal shell, the compression deformation and yield behavior of thin wall semi-ellipsoidal shells with different materials, diameters and wall thicknesses were studied by means of ANSYS/LS-DYNA finite element simulation and experiment. Then, the effect of filling mode of epoxy resin on the mechanical properties of Column-cell sandwich composites was studied. The results show that the deformation process of the thin spherical shell can be divided into local flattening, axisymmetric depression, non-axisymmetric depression and compaction stage. As the wall thickness increases, the deformation mode changes from the polygon to the ring and the deformation process become three stages; small diameter requires larger force under the conditions of the same compression displacement, as the diameter increases, the critical displacement of flipping and asymmetric buckling increases; Epoxy filled in the spherical shell of the sample specific compression performance is better than filled in the outer shell and better than unfilled with epoxy resin.

1. Introduction

As a common configuration in metal thin-walled structure, spherical shell element has the advantages of good design, light weight, high span and strong bearing capacity [1]. At present, the research on it is mainly focused on its impact resistance [2,3], the energy absorption performance under blast loading [4,5]. With the development of lightweight and high-strength materials, study on the mechanical properties of thin-walled metal spherical shell are also increasing.

Updike [6,7] studied the yield behavior of thin-walled semi-spherical shells under rigid plate compression and proposed an analytical model for the relationship between axial load-displacement; Gupta [8–10]studied the bending deformation of thin-walled spherical shells during axial quasi-static compression, and analyzed the dynamic response of thin-walled spherical shells under dynamic impact by drop-weight experiment, the influence of the radius and thickness of the spherical shell on its deformation mode and mechanical properties is mainly considered. Gupta and Venkatesh [11] studied the axial impact resistance behavior and deformation modes of metal spherical shells at different strain rates.M.Shariati [12]studied the mechanical properties of three kinds of thin-walled (102,77,53 mm) thin-walled semi-spherical shells under different axial loads, such as rigid plane, rectangular parallelepiped, cylindrical and so on, and discussed the variation law of average axial load. The domestic Yu Wei [13,14] studied the effect of different head contact area on the mechanical properties of the semi spherical shell under quasi-static compression, result shows that the smaller the area of pressure head is, the worse the mechanical properties of semi-spherical shell is. Hao Weiwei [15] studied the static compression performance of thin walled stainless steel spherical shell by means of the combination of theoretical calculation and experiment, and found that the compression turning mode of the spherical shell is mainly determined by the diameter of the spherical shell. Zhang Wei [16] studied various forms of thin-walled spherical shell structure and their the dynamic behavior under impact loading by finite element simulation, and discussed the deformation law and dynamic response characteristics of thin-walled metal hollow sphere. Hu Jianxing [17] studied the axial compression load-displacement curves of stainless steel hemispherical shells under various boundary conditions,

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found that the faster the internal force of the film increases in the hemispherical shell, the more number of sides of a polygons will be generated when non-axisymmetric depression occurs.

Nowadays, most researches on thin-walled spherical shells are based on thin-walled spherical shells, and the research is more common in numerical simulation. The buckling analysis of ellipsoid shells and its compression properties are rarely reported. The deformation law of the spherical shell and the flat pressure performance of the sandwich structure composed of the spherical shell are studied. The influences of the material and geometric parameters of the thin-walled metal spherical shell on the compression of the spherical shell are discussed. Then, in view of the hollow structure of the spherical shell, the influence of the filling mode on the compression properties of the thin-walled ellipsoidal shell is compared by filling the epoxy resin, which can be used for the study of the design of the composite material and the bearing capacity of the composite.

2. Experimental procedure

2.1. Raw materials

Some different diameter, thickness of copper, stainless steel spherical shell (Chongqing-Vatican company); Aluminum alloy plate: Size 80 mm length × 80 mm width × 3 mm thickness (Chongqing-Vatican company); bisphenol A-type epoxy resin (Chongqing Dengke Building Materials company); polyamide (Chongqing Dengke Building Materials company).

2.2. Preparation of materials

2.2.1. Thin-walled ellipsoidal shell processing

Thin-walled ellipsoid shells are made by stamping of sheet metal, keep the mold running slow enough in molding process to avoid obvious changes in wall thickness at different locations of the sample (Wall thickness variation is controlled within 0.05 mm). The temperature of sample can not be changed too much in molding process to avoid damage the molecular structure arrangement of thin - walled ellipsoidal shell matrix materials so that the mechanical properties of the substrate material changes (see Figs. 1 and 2).

The thin wall semi-ellipsoid shell used in this experiment has two kinds of material 0Cr18Ni9 stainless steel (with austenite structure, not by means of heat treatment to be strengthened, can

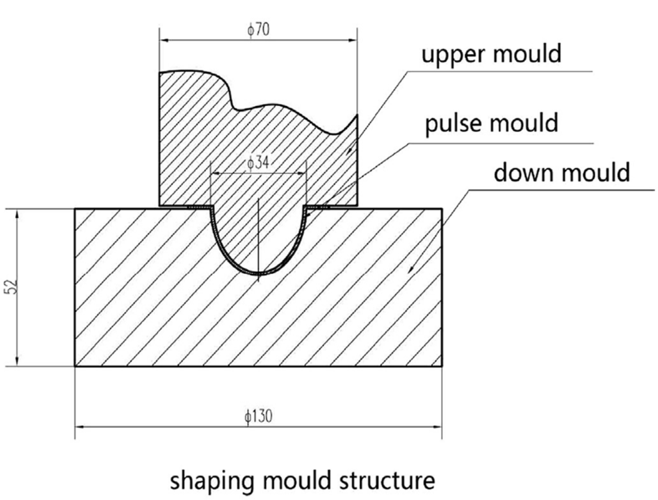

Fig. 1. Stamping forming of thin wall spherical shell.

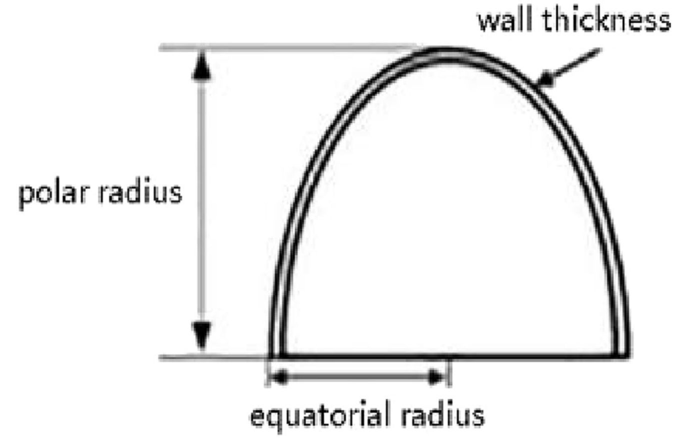

Fig. 2. Schematic diagram of thin wall spherical shell.

only improve strength by cold deformation) and H62 brass (average copper content of 62%), dimensions are available in two sizes, 34 mm and 28 mm in diameter, then the wall thickness of thin-walled spherical shell has four kinds of 0.3 mm, 0.5 mm, 0.7 mm, 0.9 mm, the samples are numbered in the order of material, radius and wall thickness (see Table 1).

2.2.2. Preparation of cylindrical sandwich composites filled with epoxy resin

Epoxy resin and curing agent in accordance with the standard formula 2: 1 preparation, curing at room temperature for 12 h, 60 °C for 6 h and 80 °C for 6 h. When preparing the sample filled with epoxy resin, perfusion on the pressurization device of self design and processing, so that the top of the cylinder in close contact with the panel to form a whole. In order to avoid slippage of the thin-walled ellipsoidal shell bottom edge in the compression process,a groove with the same radius as the thin-walled shell is machined on the base plate (aluminum alloy plate), the thin-walled ellipsoidal shell is clamped into the groove and firmly bonded with the structural adhesive (see Fig. 3).

2.3. Test method

According to the test standard for flat compression properties of sandwich constructions or cores GB/T 1453-2005 [18],quasi-static axial compression test using WAW-100KN computer control testing machine, the maximum load 100 KN, quasi-static compression rate of 2 mm/min, sample size is 80 mm × 80 mm × 3 mm.A set of load displacement curves are obtained for each quasi-static test, the static load compression test of Fig. 4 (a), the physical map is shown in Fig. 4 (b). In order to ensure the accuracy and repeatability of the test results, three times of repeated tests were carried out for same test conditions and the average was used for each data.

3. Finite element analysis

In this paper, a nonlinear explicit finite element software ANSYS/LS-DYNA is used to simulate the mechanical properties of Bxg-34-0.5 and Cu-34-0.5 thin shells.

3.1. Definition of geometric model and material parameters

The geometric model is shown in Fig. 5, top and bottom panel