CYLINDER TYPE PYRAMID LATTICE SANDWICH COMPOSITE STRUCTURE ANALYSIS OF THE AXIAL COMPRESSION PERFORMANCE

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ABSTRACT

The present work provided the access to study the uniaxial compression behaviour of cylinder type pyramid lattice sandwich composite material structure. In the uniaxial compression tests, the main failure modes are the failure of Euler buckling of cylindrical shells, overall buckling, local buckling between corrugated panel and shell wall collapsing. In addition to experimental testing, finite element models for compression simulations have been developed using ABAQUS software. It must be pointed out that, in the course of the experiment, the greater the thickness of the specimen, the shorter the course of its local buckling, the more obvious the collapse of the panel. As a result, the pyramid lattice cylindrical shell panel is the main load bearing component, and the thickness of the panel is the main factor of carrying capacity. Therefore, the load bearing capacity improvement of lattice cylindrical shell can be realized by changing the thickness of the panel and the core design should proceed with the advancement of production process.

1 INTRODUCTION

In the aerospace field, a multi-functional, high loading efficiency, high reliability and low cost structure has always been researched by designers. Sandwich structure is generally determined by the strength and stiffness of large thin panel and middle thick but light core composition [1-5]. According to the different types of materials, using different means to make the connection as a whole, so as to realize the load transfer between the panel and core [6]. The exploration of lightweight sandwich structure can be traced back to the earliest wood as material design of the wing [7]. After the concept of the sandwich structure is put forward, scholars have developed various sandwich structure, early for entity foam sandwich structure, in order to enhance the bearing capacity of the structure, after the Z-pin enhance foam sandwich structure. The research and development of the sandwich structure to a new chapter with the emergence of lattice sandwich structure.

Sandwich cylindrical shell structure mainly has three configurations: inner and outer panel and core, outside board and core, and only core with no panel [8-10]. Carbon fiber composite cylinder is mainly used as rocket fairings, the service condition is very complex [11,12]. In the process of rocket launch, on account of the instability of the airflow is apt to cause the vibration of the key body, so it is necessary to have the ability to resist the strong vibration. At the same time, in the launch process, the structure is mainly subjected to axial compressive load, so the structure must have a strong axial energy absorption capacity, in order to meet the requirements of the service. Having the characteristics of periodic arrangement of carbon fiber reinforced resin matrix composite lattice sandwich structure material is becoming the object of our study because of its low density, excellent mechanical properties and heat conduction reserve space.

To date, a great deal of research work has been proved that lattice sandwich structure has good energy absorption function [13-17]. However, previous studies on the preparation technology has

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always been more complex, and that less research in sandwich shell with the shell structure is commonly used in engineering practice [18,19]. Therefore, this paper adopts integrative molding process for the preparation of lattice core, the specimen of cylinder lattice sandwich structure is prepared for the axial compression test and mechanical performance simulation to analysis the axial compression performance and failure mechanism.

2 EXPERIMENTS

2.1 MATERIALS

Pyramid lattice sandwich cylindrical related parameters：In this paper, the research of carbon fiber composite materials pyramid lattice sandwich cylindrical, raw material is carbon fiber (T300-3 k) reinforced resin matrix composites in plain weave cloth material. Preparation of hot pressing die mold is designed independently by our laboratory, is shown in Fig.1. The core and the inside and outside board are plain weave cloth, hot pressing laminated plates after single layer thickness of 0.2 mm, specimen diameter is 140 mm, inner diameter is 115 mm, specimens of the total height is 172 mm.

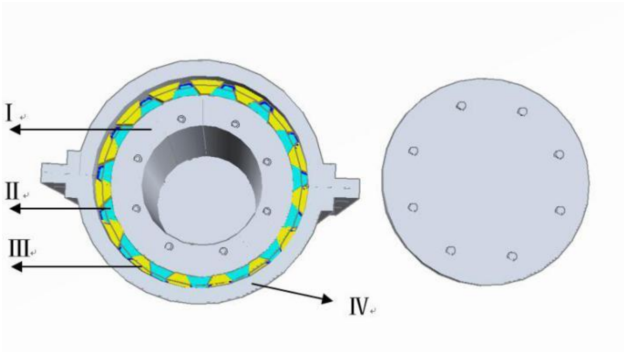

Fig.1: Hot pressing mould
I-Core column, II-The inner core, III-The outer core, IV-The outside clamping mold

Preparation process includes the following four steps:

(a) Pretreatment of the mold：Using acetone to the mold for cleaning. After waiting for mold to dry, the inner core column spliced together，and release agent on the surface mold.

(b) Preparation of cylinder core: According to the size of the cylindrical specimen, presoak material cutting into the required size. Then, cutting out the required number of trapezoidal hole on prepared presoak material, and wrapped it in the column on the inner core. After clamping fixed, pressurized heating and cooling of cylinder core demolding. The preparation process is shown in Fig.2.

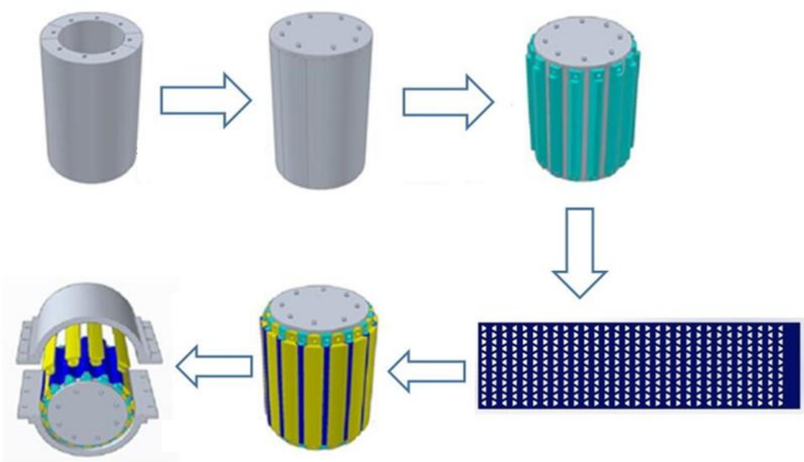

Fig.2: The preparation process

(c) Preparation of panel：The general process is similar to the preparation of the core with panel mold.

(d) Assembly and processing: The film is used to cement core and panel. In addition, the joint between the panels should be enhanced. The preparation of the panel and core is shown in Fig.3.

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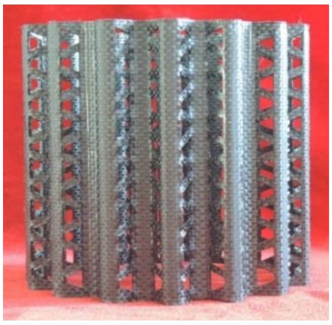

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Fig.3: The preparation of the panel and core. (a) Panel front view; (b) Panel profile; (c) The inner and outer panel; (d) Core front view; (e) Core vertical view

2.2 AXIAL COMPRESSION TESTS

The maximum compression load of 100 tonnage WAW-1000 universal testing machine is used for the axial compression test. With the method of displacement control is to load, loading speed is 0.5 mm/min. The stainless steel plate fixture to fixed at both ends up and down of the specimens, so as to guarantee the universal testing machine in the process of loading, the specimen of strength was conducted along the axial direction.

In order to better understand the deformation of specimens under axial compression loading situation, take the way on the specimen strain gages to observe the change of specimen in the process of experimental strain. According to a report in the literature, the specimen area is mainly damage panel part. Therefore, outer panel decorate seven strain gauge which are basic covers the main deformation area, and decorate a strain gauge on inner panel middle position, to determine the deformation of the panel under the axial compression load. Strain gauge position as shown in Fig.4.

Experiment was carried out on three groups of different thickness of the specimen axial compression experiment, the thickness is 0.4 mm, 0.6 mm and 0.6 mm respectively.

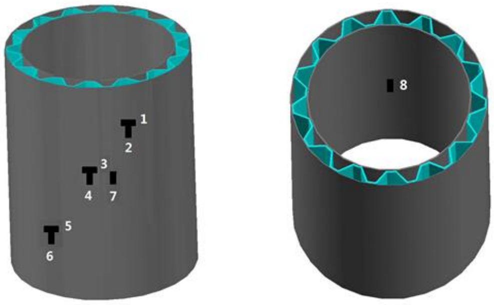


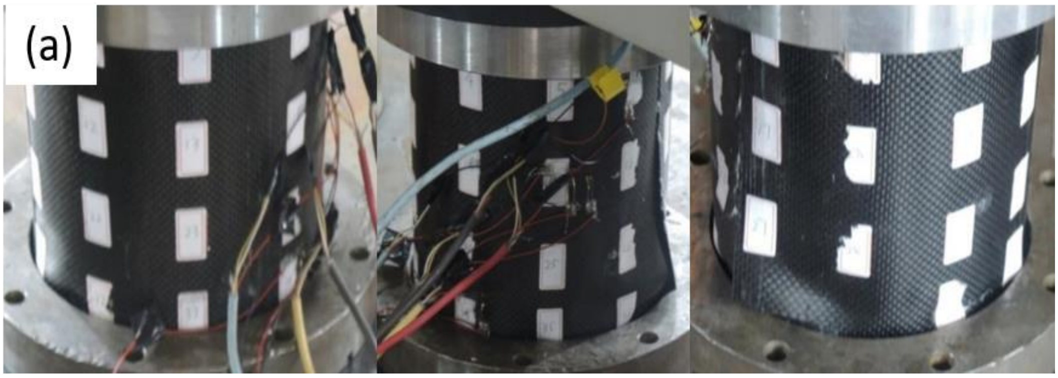
Fig.4: Sketch map strain gauge

Each type of specimen we made three experiments, the data will be averaged to get table1.

thickness (mm)	weight (g)	theoretical value (KN)	simulation value (KN)	experimental value (KN)
0.8	343	119.1	113.4	103.5
0.6	266	96.4	90.9	79.8
0.4	190	50.3	45.7	38.3

Table1:Axial compression bearing capacity of the theoretical value, the simulation value compared with the experimental value

In the process of the axial compression test, observation found that the greater the thickness of the specimen the local buckling of the shorter the journey, panel crushing, the main failure mode to the main panel crushing, the more obvious. Thickness of 0.4 mm, 0.6 mm and 0.8 mm specimen limit load can reach 38.3 KN, 79.08 KN and 103.05 KN respectively. According to the experimental results and theory and the comparison of simulation results, found that for the thicker the panel of the specimen, due to it is in the axial bearing capacity of strong, not easy to occur big deformation, so the linear local buckling is not obvious, the experimental results on the low side. Theory and simulation of experimental results is slightly lower than the reason mainly has two points: the first is the performance of the barrel is lower than the performance of the laminated plates, so with the basic mechanical parameters of the plate with the theory and simulation value slightly higher; The second reason is that in the process of preparation has many damage and defects which make the experimental value low. Progressive failure mode is shown in Fig.5.



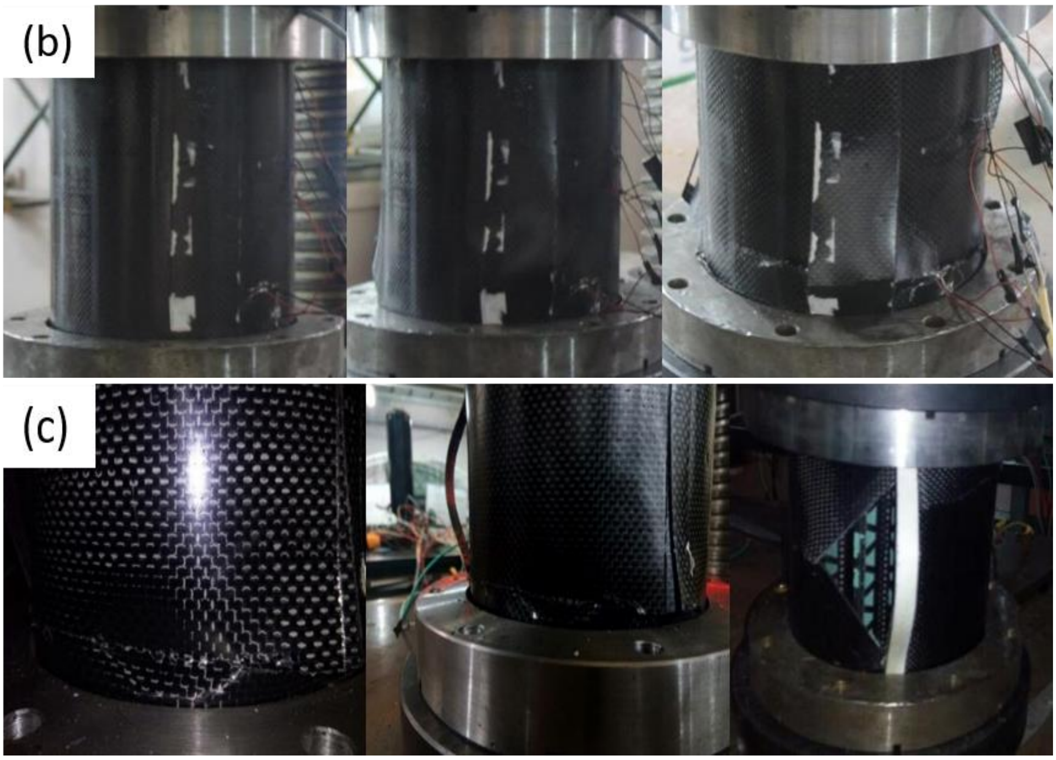


Fig.5.The outer wall gradual failure mode. (a) 0.4mm, (b) 0.6mm, (c) 0.8mm

3 SIMULATION

First use of drawing software SOILDWORKS to map the different thickness of the core and the panel, then the geometry imported into the ABAQUS software. Considering the model is to establish the rules of the cylindrical shell, so that RTZ has been choose in modeling cylindrical coordinate system. The bottom of the circular arc in the model built in the plane R-T and Z direction corresponds to is the height of the direction of specimen. Besides, for the real environment of the simulation test, the pressure plate is introduced into the model.

According to the already listed structure size, the thickness of the specimen size is far less than the overall structure, and can be ignored thickness direction stress, thus selected unit types to S4R. In the grid, in order to ensure the accuracy of classification grid number can be estimated at the same time, the partition mode selection and slightly, meshing the result is shown in Fig.6.

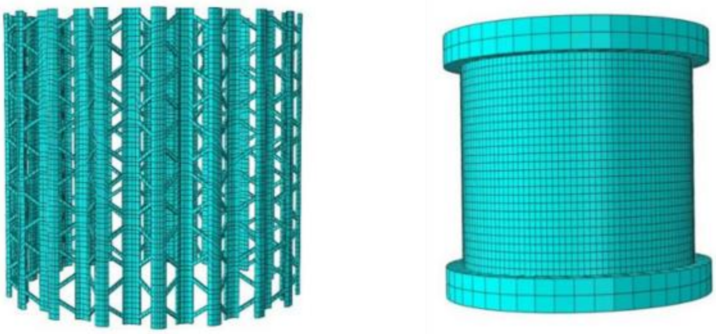


Fig.6. Specimen meshing

Due to the cylinder in service will be along the axial load, so at the specimen during the simulation and the bottom of the pressure plate clamped constraints, and exerted load direction do not restrain the Z direction. In the center of the pressure plate, define a reference point, will be the reference point and the pressure plate surface coupled together, and then from the reference point displacement load of 0.5 mm/min.

This paper adopted by the simulation analysis for the buckling eigenvalue buckling analysis, and is often used to estimate the rigid structure of bifurcate load. Eigenvalue buckling analysis is also known as linear buckling for linear perturbation process, with small displacement and strain based on linear elastic theory. At every stage of the external forces applied, is based on the structure of the initial configuration balance equation. When the load reaches the critical value, the structure of the configuration will suddenly transformed into another state of equilibrium, this process is called buckling. In general, the eigenvalue buckling was used to analysis the rigid structure of bifurcate load. Rigid structure is mainly designed to withstand the axial load, rather than bending behavior, its before buckling deformation usually is very small. Before did not meet bifurcate load reflects is very hard, after reaching bifurcate load, specimen showed a very low stiffness characteristics. Specific analysis process is as follows:

In problem of eigenvalue buckling load made the model of stiffness matrix singularity, therefore has a nontrivial solution of the following equation:

$$([K]+[S])\{X\}=\{F\} \tag{1}$$

If the analysis is linear, can be multiplied by a constant load and stress state, at this time:

$$([K]+\lambda_i[S])\{X\}=\lambda_i\{F\} \tag{2}$$

In a buckling model, displacement may be greater than the load does not increase, so the type is correct.

$$([K]+\lambda_i[S])\{X+\varphi\}=\lambda_i\{F\} \tag{3}$$

By solving the type on, get it:

$$([K]+\lambda_i[S])\{\varphi_i\}=0 \tag{4}$$

For solving the equation of eigenvalue buckling. Here [K] and [S] as the constant value, therefore the general directly places value on the structure of 1N of the load, the output of ABAQUS eigenvalue buckling load values for the structure.

The simulation process need convergence analysis was carried out on the grid, results tend to be stable when the grid size is 2.3.After the buckling stress nephogram of as shown in Fig.7.

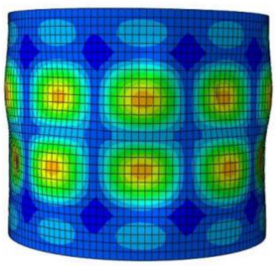


Fig.7. Specimen stress nephogram

4 CONCLUSIONS

In this paper, based on the core of cylinder pyramid lattice structure axial compression performance tests on composite material, won the ultimate load and failure mode of composite materials. Regardless of the thickness of the panel after the local buckling failure modes are first crushing process. And the thinner the specimens, the local buckling, the longer, the more obvious buckling process. Thickness of 0.4 mm, 0.6 mm, 0.8 mm specimen limit load can reach 38.3kN, 79.08kN and 103.05kN respectively, and forecast the corresponding theory is better, more accurate for the prediction of specimen. Inside and outside of the plate is thick, it can withstand the limit load of value will be greater. But inside and outside board using split preparation with enhancement of reinforcement ways can not show the full carrying capacity of the structure. Enhanced after failure the obvious stress concentration in split place. If considering the panel is interrupted preparation, combined with a winding way also can further enhance the limit load, give full play to the potential of bearing structure.

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