Simulation analysis of mechanical properties of composite materials

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Abstract. Based on the technical study of a composite vertical tail, the mechanical properties of honeycomb sandwich structure at the leading edge of the composite were studied fundamental computational analysis. The stress calculation and modal analysis of sandwich beam/plate structure are carried out by using engineering algorithm and two finite element modeling methods. The comparative analysis of the results shows that the two modeling methods can effectively simulate the mechanical properties of composite sandwich structure. In the actual analysis of complex structures, a simple 2D shell element modeling method can be used for preliminary simulation analysis.

1. Introduction
Honeycomb sandwich structure composite is a kind of lightweight, high strength and anisotropic composite. It has high specific strength and specific stiffness, good impact resistance, low density, low thermal conductivity, vibration reduction and wave penetration, and can be designed and manufactured anisotropic according to special requirements [1-2]. Because of the importance of the vehicle rearview mirror, the vehicle manufacturers and suppliers have established various rearview mirror performance and testing standards. The inner rearview mirror assembly is fixed on the vibration tooling according to the real vehicle state, and the electric vibration system is used to sweep the frequency in the range of 20Hz~250Hz with the acceleration of 0.5g [3]. The mirror of the inner rearview mirror is irradiated with the laser. The light spot length reflected on the white board before and after vibration is measured with a ruler, and the torsion Angle is calculated. As a new type of structural material, composite materials have the characteristics of high specific stiffness, high specific strength and good design performance, etc., which have attracted much attention in shipbuilding industry. The use of composite materials on Navy surface ships began in the 1940s, initially for the manufacture of patrol gunboat deckhouses. After 1990s, it began to be used for ship mast, chimney, and overall superstructure and so on. With the further development and utilization of Marine resources, whether military, civilian, boats and rescue, law enforcement, for its mobility, flexibility and economy puts forward new requirements, especially in the armed attack, must reduce the weight of the boat, so that under the condition of same power higher payload, and save fuel, reduce the cost. In 1930s, R.D. Mindlin further considered the transverse shear deformation caused by structural deformation on the basis of Kirchhoff's classical theory, and put forward the theory of medium thick plate. These two theories constitute the two pillars of the traditional plate structure theory system, and have been used up to now, and extended to the shell structure. Traditional structural modeling theories are proposed for single-layer homogeneous material structures.
and cannot be directly applied to the modeling calculation of multi-layer composite structures. Compared with single material structures such as metals, the multiplicity of composite materials and the complexity of laminating modes pose new challenges to the theoretical modeling of multilayer composite structures. After a long period of research, scholars around the world have developed a variety of theories with different modeling accuracy and computational efficiency.

2. Finite element model

2.1. Finite element modeling method

Through finite element analysis, the overall behavior of sandwich structure can be calculated and predicted. Two modeling methods can be used for comparative calculation and analysis according to the properties of materials composing sandwich structures or the accuracy requirements of analysis. In the shell element modeling method, the sandwich structure is idealized into composite laminated plate and shell elements, and the honeycomb core is considered as a laminated layer, and the first-order (transverse) shear deformation is considered. This method ignores the geometric transition of the thickness direction, which can be corrected by the offset of the center line of the shell, as shown in Figure 1. The shell element modeling method is limited to sandwich structures with thin honeycomb cores and ignores the effect of local three-dimensional stress.

Fig 1. Shell element modeling method.

Mixed shell/body modeling method divides sandwich structure into shell-body-shell structure for modeling, laminated plate shell element is used for panel, and solid element is used for sandwich layer. This method can accurately describe the transverse shear characteristics of the sandwich core. Due to the low stiffness and strength in the direction of core thickness, 3D detailed modeling analysis method should be considered in the introduction of local load or in the corner and connection parts. In the modeling process, the aspect ratio of the unit should be properly controlled.

2.2. Bending calculation and analysis of sandwich beam structure

Two kinds of finite element modeling methods are used to model the sandwich beam structure, in which net is considered in the shell model the effect of lattice density (sandwich is divided into 2/4/6 layer cells). The laminate layer is [+45°,0°/90°], and the sandwich beam model is 200mm×100mm, one end of which is fixed and restrained, and the other end is applied with 20N/mm transverse load. See Figure 2 for details.
Fig. 2. Finite element model of sandwich beam.

Fig. 3 shows the overall Von Mises stress nephogram of each model and the ZX shear stress nephogram of the sandwich layer. The maximum displacement of the shell element model is 6.21mm, and that of the mixed shell/body model is 6.49mm. Using the engineering theoretical algorithm in Section 2, the maximum deflection of the beam end is 6.19mm. In the solid finite element model, the mesh density varies along the horizontal layup direction, and the Patran/Nastran simulation environment is used to calculate the planar mesh density without changing. The middle position element of the beam (the position in Fig. 2A) was selected to extract the element stress and node displacement results from .F06 file for comparative analysis. Fig. 4 shows the comparison diagram of the transverse shear stress and displacement of the four models, and the comparison results are normalized into shell element models. According to the analysis and comparison of the results, the shear characteristics of the sandwich can be accurately simulated when the thickness of the solid model is larger than 2 layers.

Fig. 3. ZX shear stress nephogram of sandwich layer.
2.3. Buckling analysis of sandwich plate under unidirectional axial compression

The shell element model and the mixed shell/body model were used for buckling analysis under unidirectional axial compression. A 500×500mm plate structure was selected for the model. The displacement boundary conditions were as follows: one end was constrained by 123 DOF, the loading end was constrained by 23 DOF, and the other ends were constrained by simply supported by 2 directions. An in-plane compression load of 10N/mm was applied at the loading end. In general, linear buckling analysis is concerned with low-order eigenvalue results. The first-order eigenvalue of shell element model is 5.98, and the first-order eigenvalue of mixed shell/body model is 6.29. The results of the first order eigenvalues of the two models are similar, which indicates that the shell element model can effectively replace the solid structure model in the low order modal analysis of axial compression buckling.

3. Conclusions

In this paper, engineering algorithm and two finite element modeling methods are used to analyze the bending stress and axial buckling of sandwich structure composites. The engineering theory and the finite element calculation results show that both the shell element model and the mixed shell/body model can effectively simulate the bending characteristics of sandwich cantilever beam structure, and the mixed shell/body model can analyze the mechanical characteristics of sandwich layer in detail. It has a certain reference significance for the modeling calculation of sandwich structure composite materials.

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