The Optimization and Design of Complicated-Surface Panel Based on Automate Fiber Placement

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Due to the developments of high-performance composite materials, multi-constraint optimization designing methodologies and automate fiber placement (AFP) technologies, various advantages of applying AFP to fabricate composite panels are obtained. However, in terms of the composite panels subjected to the out-of-plane pressures, there are still many problems to be solved. For the purpose of minimizing the panel' weight and optimizing the best manufacturing technology, this paper investigates the optimal designing of the composite panel considering the panel layout, stiffeners' details and the routine of AFP.

According to the requirements of structure' s stiffness, strength, stability, durability, damage tolerance, maintenance capability, the structure is not allowed to buckle under the limit load, while local buckling can occur before the ultimate load. Besides, when the overpressure is applied, some local damages of the materials are permitted in such a structure which is designed based on constraints of the loads, temperature, sealant condition, corrosion resistance and so on. To gain the lightest structure, four options including the thick-skin panel, the sandwich panel without stiffeners, the panel with hoop stiffeners and the rigid stiffened panel are optimized and compared.

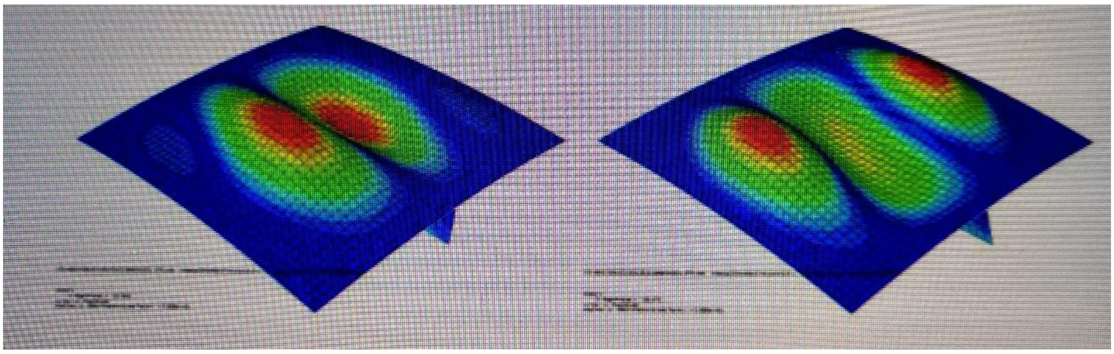

Fig 1. The First-order and Second-order Buckling Mode of a Double-curvature Stiffened panel

For the special characters, such as the irregularly double curvature and largely negative curvature, the panel under the complicated loading conditions, the analysis method and failure criteria are proposed. The iso-parametric shell element (Fig.2) is utilized to simulate the skin and stiffeners, and the interface between the above two components is simplified as a specially defined element. Accordingly, the process of buckling, post-buckling and the damaging can be analyzed, which means the interlaminar damage of both skin and stiffeners is detailed through the corrected Hashin criteria. Furthermore, the interlaminar damages at the normal and tangential directions are controlled by the tension and shear criteria respectively. With the combination of all the validation experiments at every level of the pyramid procedures, the availability and veracity are validated and corrected. By doing so are all the designing allowables of the composite panel confirmed. Finally, the analysis methodologies of the stiffness, strength and load-carrying capability of the rigid stiffened panel with negative curvature are established.

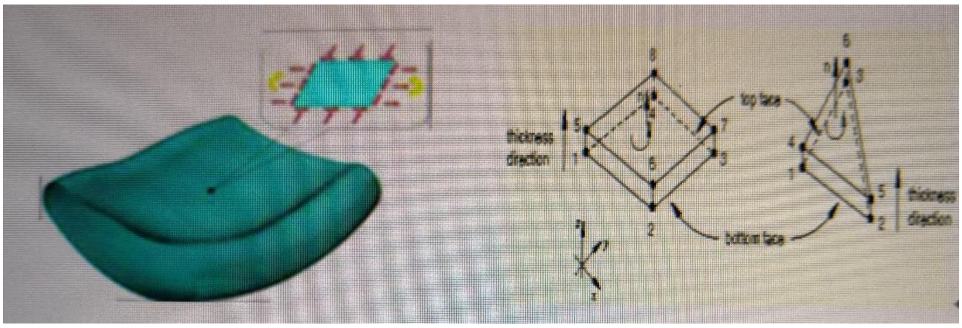

Fig 2. The Iso-parameter Shell Element

It is known that the sophisticated surface of the composite panel generates quite different curvatures at different positions. The fibers tracks of AFP on the regular surface cannot cause obvious errors, while it is inversed for the irregular surface whose fibers tracks could offset the expected seriously. This could cause some fibers overlapped or separated. Consequently, it is very of difficulty to ensure the practical fibers' angles in line with finite element models. This phenomenon, especially the serious areas, can rise the problem of fibers' torsion and warping deformation, resulting in the reduce of panel's stiffness, strength and load-carrying capability. In order to minimize this effect, all the requirements about the structural strength, manufacture-process realize and quality control are taken into account, when the composite panel is designed. The effects of direction's offset, overlaps, and gaps of the fibers on the structural strength, surface smoothness and structural weight are investigated and validated. The designing criteria as well as the manufacturing standards are defined. In addition, the fiber tracks are optimized through numerous iterations, which generates the accurate definition of designing parameters of the complex composite panel.