Study on The Postbuckling Behavior And Carrying Load Ability of Stiffener Composite Panels

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Introduction: Now composite materials are used in the structural design. To reduce weight, the postbuckling of composite material loading ability has been considered. It is still a difficult problem on mechanical field that the postbuckling carrying load ability at and after the panel falls into instability [1-3]; whether the panel can recover after unloaded and the damage load of single layer or multi-layers of composite panels. Whether the composite panel instability is allowed in ultimate load condition has not have an agreement in aircrafts design field.

In this paper, the panels carrying load ability after its installation is analyzed by the calculation. Experimental research, methods and analysis on composite panel boxes postbuckling carrying load ability have been proposed.

The analysis theory on composite material box: The NASTRAN program has been used on the primary analysis on the box test piece. The panels, beams and stringers on box test piece have been simplified into Quat4 panels, beams and rods. Based on the maximum strain of the pressed middle area obtained by FEM analysis, engineering method has been used to calculate the stability of the panel to decide the critical load of the composite panel.

The panel will be instable at 59% ultimate loading under compress–shear coupling condition [4]. Axial compress and shear buckling load is shown in figure 1.

Here: $R_x = N_x / N^0_{xcr}$， $R_{xy} = N_{xy} / N^0_{xycr}$，$N^0_{xcr}$、$N^0_{xycr}$: buckling load.

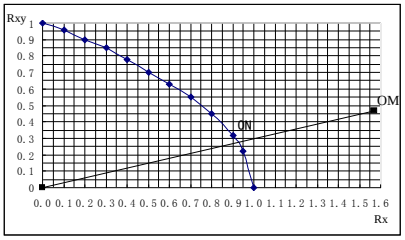

Figure1. Stiffened composite panels buckling analysis

The postbuckling on the shell panel structure is a classic nonlinearity problem. The total loading ability usually comes from the postbuckling behavior. During the calculation of postbuckling, extreme-value point and forks value point make it difficult to get the result. The FEM analysis method of stiffened composite panels postbuckling can solve these problems successfully.

a) According to the geometry characteristic and loading condition of the box structure, the box structure postbuckling analysis has been simplified into stiffened panel postbuckling analysis.

b) An easy calculation method is used to distinguish extreme-value point and forks value point[5].

c) Considering the progressive damage in inner laminar of panels and stringers when they are in postbuckling deformation, the calculation method of geometry nonlinearity and material progressive damage has been used to ensure the calculation convergence and provide initial damage load and local instable load.

d) The shearing distortion effect is conside-red in the calculation[6].

The postbuckling path FEM analysis increment iterative equation:

$k_T \quad \eta = \quad \lambda F + R$

Here: k_T、F、R are the tangent stiffness matrix, loading vector and imbalance load. η is the displacement increment between the two iterative and Newton-Raphson and arc length method is used to obtain the result.

By using the above calculation method and

self-developed FEM software, the box buckling and postbuckling process is predicted effectively under the bend and twist condition before the test of composite material box. The total postbuckling model of the box panel is given in Figure 2.

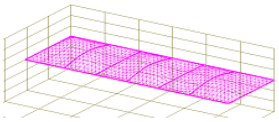

Figure 2. Postbuckling Model of Stiffened Composite Panel

The test of the composite material box

In order to test the static strength, and postbuckling loading ability of composite material box, boxes has been used.

Three condition for static test on composite material box :

a) Bending load static test
b) Twisting load static test
c) Bending-twisting load coupling static test.

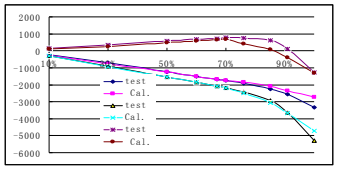

Figure 3. The Damage of The Loading ability Test

After the box static test, the box loading ability test has been finished under the bending-twisting coupling condition. The testing part is damaged when the load comes to 124%. See figure 3.

The test and calculation results show that the panel still has the loading ability when it is applied by bending-twisting coupling load in postbuckling condition. Table 1 shows the comparison between calculation result and testing result.

The Comparison Between Calculation And Testing

strain		30%	60%	67%	76%	100%	122%
0°	test	-713	-1507	-1686	-1899	-3326	-4465
με	Cal.	-754	-1508	-1683	-1836	-2718	-3337
45°	test	-897	-1833	-2100	-2423	-5282	-8560
με	Cal.	-931	-1862	-2079	-2485	-4714	-7210
90°	test	288	684	734	750	-1283	-3806
με	Cal.	362	575	643	411	-1297	-3440

Conclusion: Summarizing the test and analysis above, we can conclude as follows:

a) The composite material box falls into unstable state around 70% load.
b) As the test shows, the box still has 30% postbuckling loading ability after it falls unstable.
c) The model and analysis method introduced in this paper can provide better prediction for the buckling, postbuckling and loading ability of composite material box.

Reference

1. Siugh S B, Kumer A Postbuckling response and failure of symmetyic laminates underin-plane sheer Composites Science and Technology, 58(1998), 1949-1960.
2. Siugh S B, Kumer A. Postbuckling response and strength of laminates under combinedin- planeloads.Compsites Science and Technology, 59(1999), 727-736.
3. Skrna-Jakl I.C., Stiftinger M.A., Rammer storfer F G. Numerical investigations of an imperfect stringer-stiffened composite wing torsion box-an analysis concept. Composites, Part B, 27B(1996),59-69.
4. 航空航天工业部科学技术研究院编. 复合材料设计手册. 北京：航空航天工业出版社（1990），368-371
5. Huang B-Z,Atluri S N. A simple method to follow postbuckling paths in finite element analysis. Computers and Structures, 57(1995),3,477-489.
6. Huang B-Z, Shenoy V B, Atluri S N. A quasi-conforming triangular laminated Composite shell element based on a refined first order theory. Computational Mechanics, 13(1994),4,295-314.