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The Study on Stability of Composite Panel Structure under Axial Compression Load

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1. Introduction

When the composite stiffened panel structure is subjected to axial compression load, buckling instability often occurs and fails. At the same time, the post-buckling behavior is nonlinear, the analysis is complicated and the workload is heavy, so the initial buckling load of the structure has always been taken as the design allowable load in actual engineering design. However, as we all know, the composite stiffened panel structure will not be destroyed immediately after buckling, but will enter the post-buckling stage, at which time the structure still has great bearing capacity. Therefore, it is very necessary to study the post-buckling behavior of composite stiffened panel structure, including finite element analysis method and experimental analysis method, so as to fully explore and utilize the post-buckling bearing capacity of composite stiffened panel structure, not only effectively reduce the structural weight, but also improve the structural design, which has important economic and practical significance for modern engineering structural design.

2. Finite element modeling and analysis

2.1 Organization introduction

A series of composite stiffened panel structure test pieces are manufactured, the overall dimensions of which are all 400mmx500mm, and three T-shaped stringers are uniformly arranged on the flat panel skin.

2.2 Verification of simulation model

The rationality and feasibility of the simulation model can be verified by comparing the finite element strain data and the test strain data and calculating the SAC value of the two.

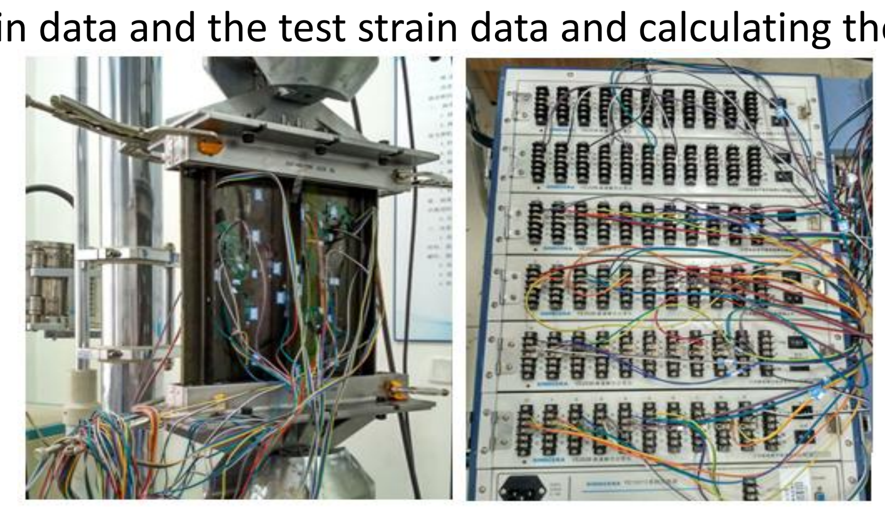

Fig.1 Loading and testing strain value of test piece

As shown in Figure 1, strain gauge is used to extract the stress of stiffened panel structure. The SAC value of variable value, test analysis strain and finite element analysis strain is about 0.95, which is completely larger than the acceptable range of 0.7, which indicates that the finite element simulation model of stiffened panel structure has high credibility.

2.3 Analysis of simulation model

In the finite element analysis, one end of the structure is clamped and restrained, and the axial compressive displacement load of 3mm is applied to the other end of the structure. Based on the finite element analysis software Patran/Nastran, the failure and failure of structural materials are determined by using Hoffman material progressive damage criterion.

Extract the reaction force at the application point of displacement load and make its load-displacement curve, as shown in Figure 2:

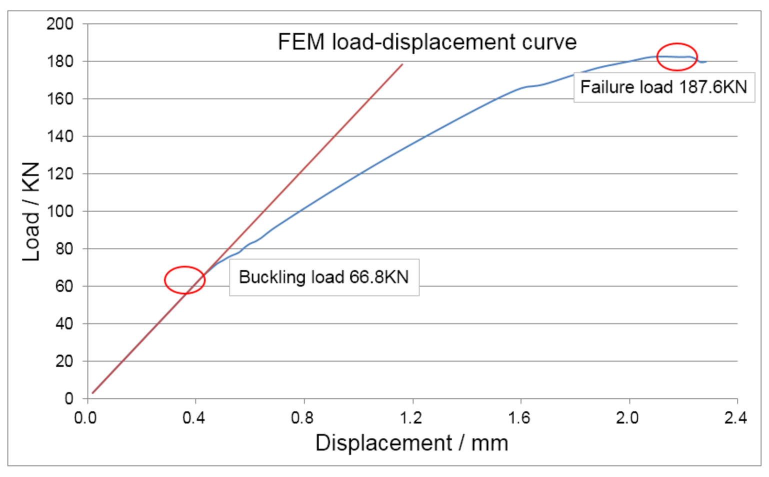

Fig.2 Loading and testing strain value of test piece

It can be seen from Figure 2 that the load and displacement of the structure change linearly in the range of 0~66.8KN; When the load is in the range of 66.8KN ~187.6KN, the structure enters the post-buckling state, and the structure still has great bearing capacity at this time

3. Experimental analysis

3.1 Experiment product preparation

The twister strip is made of 0° carbon fiber prepreg, which is flattened and compacted by a stringer die, then covered with a cover plate and compacted in vacuum. Then, after vacuum compaction for 24 hours, the test piece is sent into hot-pressing irrigation for co-curing, and then taken out of the can and demoulded.

Then carry out nondestructive testing, C-scan the skin part with a machine, and A-scan the stringer web by hand. The test results are compared with the standard block, and the fluctuation within 6dB is qualified; Then, the R area is cut and inspected to ensure that the R area has neither dispersed pores caused by small amount of twisted sliver nor fiber folds and sinks caused by large amount.

3.2 Design of test fixture

According to the form of the Test Machine, the test fixture is as shown in Figure 3:.

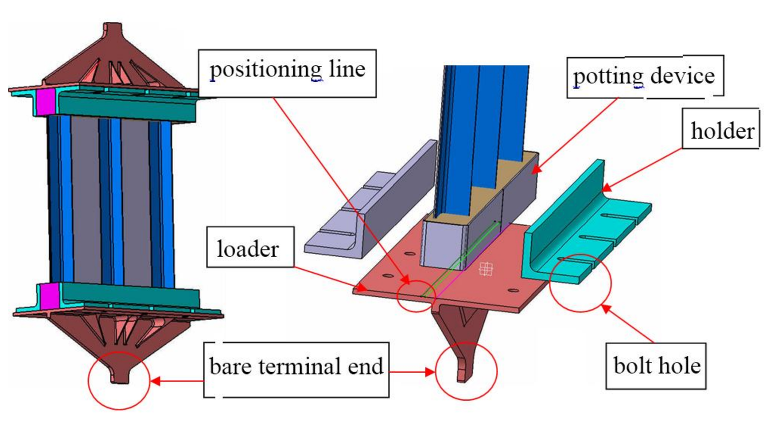

Fig.3 Schematic Diagram of test fixture

3.3 Patch of experiment product

According to the result of finite element analysis of the experiment product, the deformation form of the experiment product is predicted, the dangerous section and position are found out, combining with practical experience, the key inspection position is finally determined, in order to work out the plan of the experiment product, the gage is numbered in combination with the channel sequence of the gage, as shown in Figure 4.

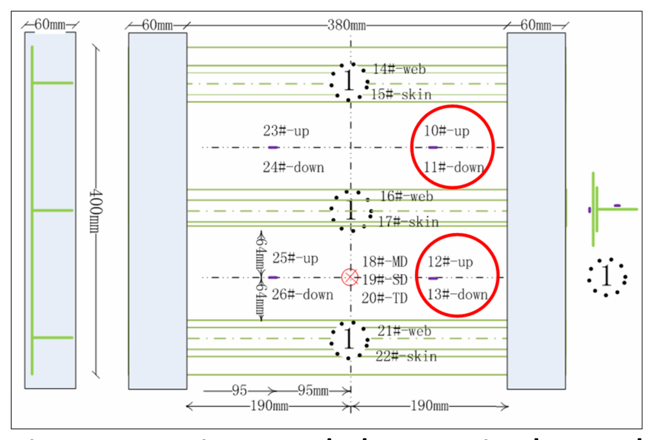

Fig.4 Location and theoretical number of the experiment product

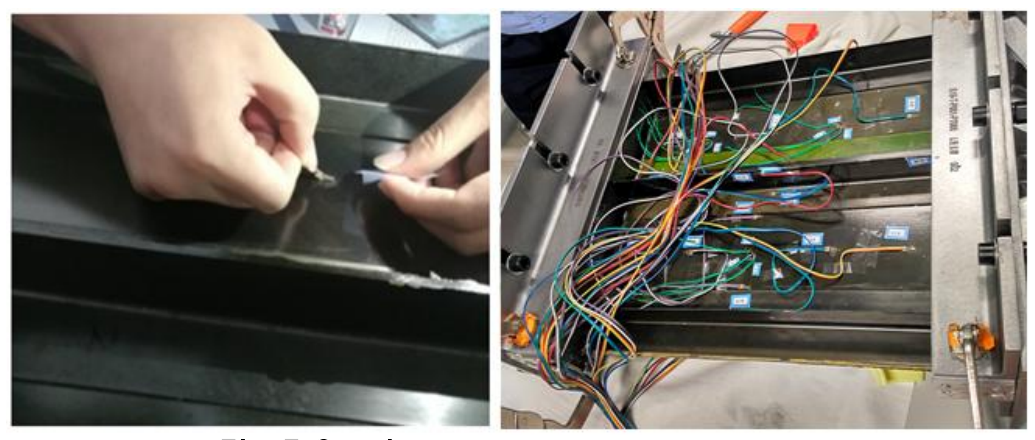

Fig.5 Strain gauge paste map

Using non-welding strain gauge, pasting at room temperature, the strain gauge must be firmly pasted on the tested point to ensure that the strain gauge and the tested object produce deformation together, as shown in Figure 5.

3.3 Axial compression test

The specimen is fixed on the loading machine and preloaded with 50% buckling load, which is 33.4 KN axial compression load, to eliminate the initial torque and bending moment of the specimen. A group of strain gages with symmetrical position are selected to adjust the initial Torque, and a group of strain gages with back-to-back position are selected to adjust the initial moment, it can be seen from Fig. 6.

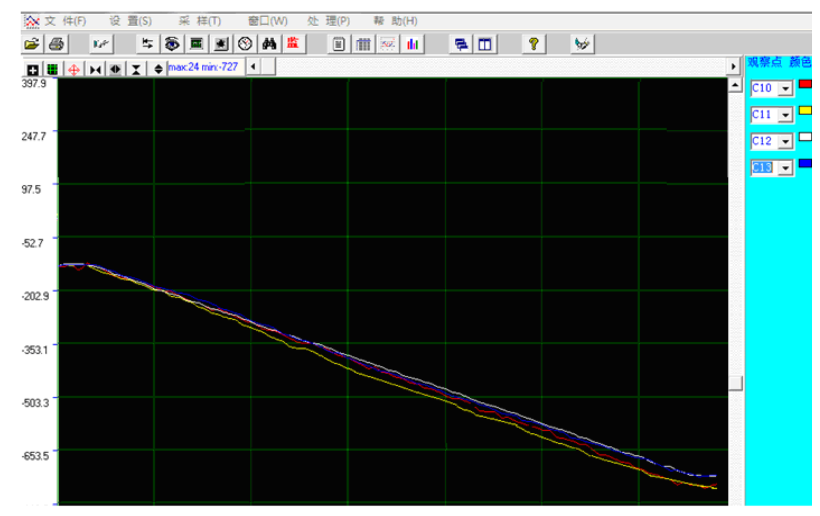

Fig.6 Strain Gauge Diagra

Fig.7 Figure of structural failure

When the load is 64.2 KN, local buckling of the skin takes place, and when the load is 177.1 KN, the specimen is completely destroyed, and the final failure form as shown in Fig. 7, which fits the profile.

4. Comparison of analysis results

According to the test loading data, the load-displacement curve is drawn, as shown in Fig. 8. The buckling load is 64.2 KN and the failure load is 177.1 KN.

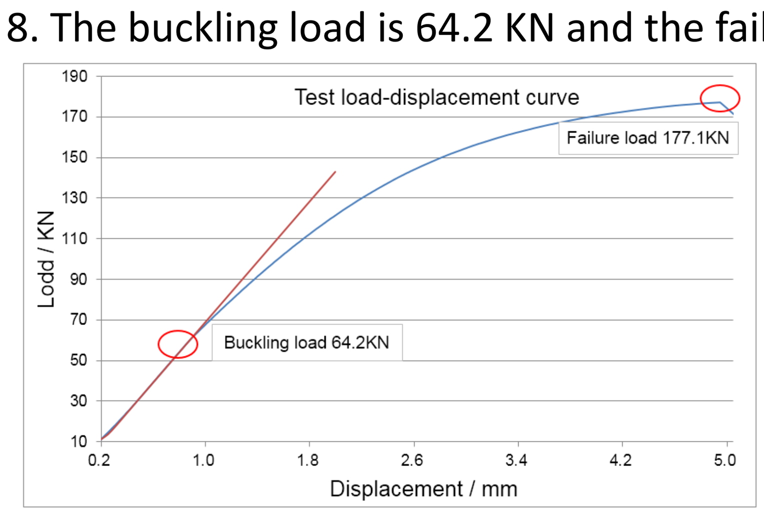

Fig.8 Test analysis-load-displacement curve

Table 1 Results of finite element analysis and test analysis

	Post Buckling Analysis	Test Analysis	Error
Buckling load (KN)	66.8	64.2	4.0%
Failure load (KN)	187.6	177.1	5.9%

It can be clearly seen from table 1 that the error of buckling load and failure load calculated by finite element analysis is very small, which is in good agreement with the test value, that is, the finite element analysis method can truly reflect the stability of composite stiffened panel structure.

5. Conclusion

The general procedure, points for attention and relevant test standards for the study of the stability of composite stiffened panel structures under axial compression are summarized by using finite element method and test analysis method, in particular, the making, preparation, testing, mounting, loading test and data processing of the test pieces have an important role in guiding the study of related issues. At the same time, the failure load of the two analysis methods is about 3 times of the buckling load, which shows that the composite stiffened panel structure still has a great potential. Considering the post-buckling load-carrying capacity in the design of composite structures will give full play to its light weight, high specific strength and high stiffness, which is of great practical significance to promote the use of composite structures.

References:

[1] CHEN Weining. CR929 Strives to be a Model of Cooperation Between China and Russia in High-end Equipment Manufacturing Industry, [J]. Large aircraft ，2017(10)：14-20.

[2] Wang Feifei , Cui Degang , Xiong Qiang , et al. Engineering Analysis of Post-buckling Loading Capability for Composite Stiffened Panels [J]. Journal of Beijing University of Aeronautics and Astronautics , 2013 , 39 (4) ：494-497.

[3] BISAGNI C,DAVILA C G. Experimental Investigation of the Postbuckling Response and Collapse of a Single-stringer Specimen [J]. Composite Structure，2014，108（1）：493-503.

[4] ORIFICI A C，THOMSON R S，DEGENHARDT R，et al. A Finite Element Methodology for Analysing Degradation and Collapse in Postbuckling Composite Aerospace Structure [J]. Journal of Composite Materials，2009，43（26）：3239-3263.