ULTIMATE STRENGTH OF POSTBUCKLING FOR SIMPLY SUPPORTED RECTANGULAR COMPOSITE THIN PLATES UNDER COMPRESSION

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Abstract

It is proved that the ultimate strength of postbuckling for simply supported rectangular composite thin plates under compression is far higher than their buckling stress through the tests of 283 rectangular composite thin laminates in this paper. The ultimate strength of the composite thin plates is studied using large-deflection theory and small-deflection theory of thin plates. According to the failure criterion of the composites ultimate strength is found finally. It is in accordance with the experimental values for the plates having 45 degrees off-axial, and for longitudinal and latitudinal plates, when $\beta < 0.11$, the theoretical values are higher. The coefficient $C$ given in this paper may be referred to in product designing.

Key words compression, failure criterion, composites, postbuckling, ultimate strength

I. Introduction

As is well-known, the postbuckling metal plates can be successively subjected to the load. For some metal plates, the ultimate strength can reach thirty times of the buckling stress. In order to study the bearing capacity of the composite plates through tests and theoretical analysis, failure tests of the 283 specimens of GFRP thin rectangular plates under compression are carried out. It is proved that the GFRP plates in postbuckling still have higher bearing capacity, for the tested specimens showed ultimate strength which is four to twenty-five times that of the buckling stress, and the majority is higher than ten. It can be seen, the composite plates in postbuckling also have greater potential bearing capacity. If the design method of the ultimate strength is adopted, then obviously the weight of the space vehicle and aircraft product can be reduced. In this paper the ultimate strength of the orthotropic composite plates are studied using the large-deflection theory and small-deflection theory, and the theoretical formulae are deduced respectively. The large-deflection theory is combined with the strength theory of the composites, and the theoretical values of the ultimate strength are in agreement with the experimental results for the plates with 45 degrees off-axial. For the longitudinal or latitudinal plates when $\beta < 0.11$, the theoretical values are higher. The result calculated through small-deflection theory is a specific example of the large-deflection theory, and

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approaches to the minimum value. Therefore, they can be used in product designing, and is reliable and safe.

II. Experimental Results of the Ultimate Strength

For the tested specimen the length $a$ is 200mm, the width $b$ are 150, 140, 120, 100, 90, 80 mm and so on, their thicknesses $t$ are 0.6 to 1.4mm. The fixture improved by us is reasonable, to satisfy the assumption of keeping straight longitudinal side and moving freely. The failure forms of the thin plates in compression postbuckling are shown in Fig. 1.

![Fig. 1 Typical failure forms](image)

Fig. 1 Typical failure forms

Fig. 1 (a) and (b) are the failure forms of the unimproved test fixture, so they are reasonable. Fig.1(c) and (d) are the failure forms of the improved fixture. The failure form of (d) is an ideal one. Generally, the process of the failure is that when the load reaches a certain value, the white points (i.e. debonding of the matrix) occurred at cross-points of the longitudinal and latitudinal fiber which are located at the plate corner. After that, the white points are extend along a certain angle. When the load is again increased, the cracks may be seen and the sound be heard. As the cracks are expanded, the sound are enhanced, and the load is reduced. The angle has the following relation with the longitudinal half-wave number $m$ and the dimensions of the plate.

$$\tan \alpha = \frac{a}{mb} \quad (2.1)$$

![Fig. 2 The relation between $C$ in the formula of the ultimate strength and $\beta$ for rectangular thin plate under longitudinal or latitudinal compression](image)

![Fig. 3 The relation between $C$ in the formula of the ultimate strength and $\beta$ for rectangular thin plate under 45 degrees off-axial compression](image)