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NONDESTRUCTIVE TEST METHOD FOR DETERMINING THE CRITICAL PRESSURE ON THE INSIDE PANELS OF A FUSELAGE FUEL TANK

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Abstract

A nondestructive test method is presented for determining critical loads of actual shell structures under external pressure. It is a step-by-step method using the normal deflection of shell structures as a control variable . The nondestructive buckling tests on the inside panels of four fuel tank in an airplane fuselage were carried out by using the method presented by authors. The critical pressures for local buckling and general instability of the shells were exactly determined. The test results show that the nondestructive buckling test method is successful.

Intruduction

Buckling test of structures and structural elements is indispensable for exploring buckling principle of structures , proving and developing the theory of structural stability, and checking actual carrying capacity of structures. Many researchers have carried out a lot of buckling tests of plates and shells. Usually, one specimen is used in buckling test only once. Using the usual experimental method, it is difficult to determine influence of various environmental conditions (For example, boundary conditions and different loading combinations) on buckling behavior of structures, or would be prohibitively expensive because of testing a number of specimens. So, the nondestructive buckling test method has been being craved and sought. Early in this century, Sommerfield (1) tested a clamped-free column using the vibration approach. Since 1970s', the research of the nondestructive buckling test method has been developed. Singer(2) predicted the critical stresses of stiffened shells using vibration approach. Horton(3) predicted the critical loads of cylindrical shells subjected to axial compressive using static-stiffness method. Fan(4) determined the postbuckling behavior of conical shells under overall external pressure using the nondestructive test method controlling instability process of the shells. Besides, it is possible to carry out buckling test time after time on the same specimen made of Mylar meterial. The details of the history development for buckling prediction were presented in ref. 5.

Since several years we have conducted some nondestructive buckling experimental studies on shells under external pressure. First, buckling tests of quasi-structures (the curved panels with circumferential stiffeners) were carried out. Then the critical pressure of inside panels of a fuselage fuel tank was successfully determined by using nondestructive test method(6). In the present paper the nondestructive buckling test method for determining critical pressure of actual shell structures and test results of inside panels of a fuselage fuel tank are presented.

General outline of the tests

1. Specimen

The specimen is the pre-fuselage of an airplane. The test place is the inside panels of 1st to 4th fuel tank on the fuselage. The inside panels of 3rd and 4th tank are cylindrical ones with one circumferentialΩ-stiffener, the others are isotropic curved panels. Sketch of the structure is shown in Fig. 1.

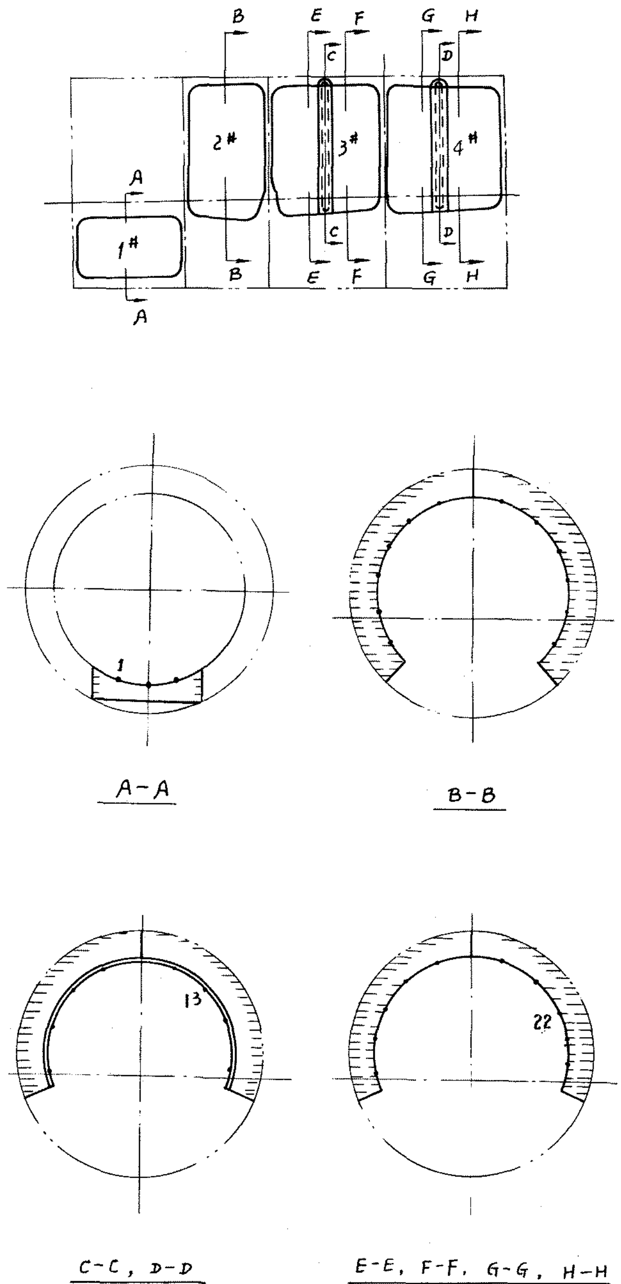

Fig. 1 Sketch of the structure and measuring points of normal deflection

2. Test set-up

Loading system consists of a stationary pressure source, a control board and a soft oil boxes. The system is a closed one. Water is used for pressed medium. The pressure of the oil boxes is measured on pressure manometer. The fuselage is hunged from four posts with the help of jacks in order to test and squceze out air of the oil boxes.

3. Measurement of displacements and strains

A sufficient number of measurement points for displacement and strain are arranged on the panels (See Fig. 1). Strains and normal deflections of the panels were measured respectively with the help of strain gages and the line-displacement transmitter and the digital data recorded facility as well.

The Nondestructive Test Method for Determining Critical Point

Usually, the "snap-through" phenomenon would be exhibited during buckling of shells, and it will result in so large deformation that one specimen is buckled only once, even so in elastic buckling tests. Here we present a nondestructive buckling test method for determining critical pressure of shell structures. It is the step-by-step method by using the normal deflection of shells as a control variable.

1. Control of loading increments

The loading system is a closed one. It consists of a stationary pressure source, a control board and soft oil boxes. Principle of the pressure facility is referred to Ref.7. The stationary pressure source is essential to stationary loading. Water rather than air is used for pressed medium, and everything possible must be done to squeeze off air of the system, so as to be able to make use of the incompressible nature of water sufficiently. It will improve the characters of the pressure set-up, and provide a possibility for controlling deformation close by the critical point.

It must be pointed out that because the structure which consists of aircraft skin and framing panels and connects with the inside panels of the fuselage fuel tank, is an elastomer, it is also deformed during loading process, so that volume change results from the deformation of the inside panels is difficult to be controlle led. So, we use the displacement (the deflection of the inside panels) as a parameter to control loading. During the whole test process, the displacement (refrence to strain) increment result from every step loading Δw_i must be less than or equal to the predetermined displacement value $\Delta \bar{w}$.

2. Choice of the following point of displacements

It is important to choose the following point of displacements because the normal deflections of shell (w) is taken to be the control variable so as to realize "non-destructive buckling".

The measurement results of displacements (or strains) should reflect buckling mode of the specimen, and the measurement points of displacement are arranged on the peaks or ravines of the buckling wave.

Drawing load-displacement curves of every measurement point during test, the point with max. $\Delta w/\Delta p$ (the ratio of displacement increment to load (pressure) increment) is chosen to be the following point controlling loading to approximate to critical point step-by-step.

3. Determination of the critical point

In general, initial geometric imperfection are likely to exist on specimens or actual structures that usually buckle in the limit point instability mode. In this case there is a limit point on the load-displacement curve , and the point is defined as critical one, the corresponding load is termed critical load.

During buckling test, the load-displacement curve of following point is ploted in real time. When the "flat region" is exhibited in the load-displacement curve accompanying "slip" of displacement (or strain) value, it indicates that the critical point is achieved, and the corresponing load is defined as critical load determined from the test.

Test Results

The buckling tests for inside panels of 1st to 4th fuel tank of an airplane fuselage under external pressure were carried out by means of the nondestructive method above mentioned. At the end of these test, a pressure was applied until collapse occurred. The predicted and actual values of the buckling loads of these panels are given in Table 1, where $P_{cr.l}$ and $P_{cr.g}$ are the predicted values of local and general buckling pressure respectively, $P^a_{cr.l}$ and $P^a_{cr.g}$ are the actual ones respectively. The predicted buckling pressure were in good agreement as shown in Table 1. The typical pressure-displacement curves are ploted in Fig. 2 and Fig. 3.

Tank No.	Critical Pressure (kg/cm^2)				Error
	Predicted		Actual		
	$P_{cr.l}$	$P_{cr.g}$	$P^a_{cr.l}$	$P^a_{cr.g}$	
1		2.26		2.28	0.9
2		1.03		1.03	0.0
3	1.745	2.10	1.75	2.12	0.3/0.9
4	1.44	1.44	1.46	1.46	1.4

TABLE 1 TEST RESULTS

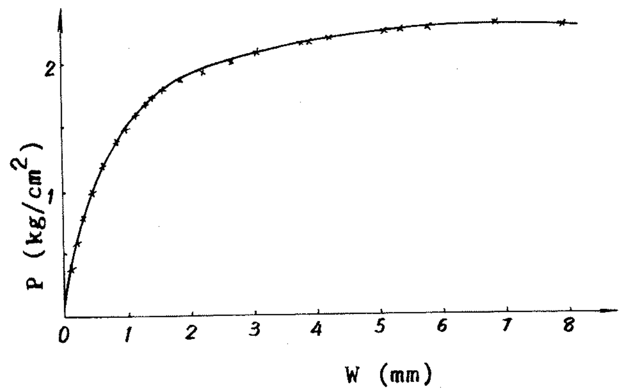

Fig. 2 Pressure-deflection curve
(Tank 1)

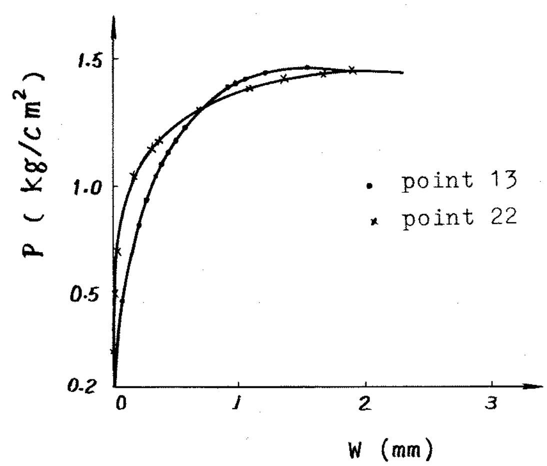

Fig. 3 Pressure-deflection
(Tank 4)

Concluding Remarks

As mentioned above, the results from the tests have proved that the proposed method is successful. Using this method, nondestructive buckling test of shell structures under external pressure can be carried out. For elastic static buckling, it is possible to obtain repeated buckling load combination on the same specimen and thus actual buckling failure never occurred. For unelastic buckling, it will take precautions against too large deformation, and avoid "twice failure" of structures. It appears that the method have wide industrial application for buckling test .

References

1. Sommerfeld, A., Eine Einfache Vorrichtung Zur Veranshaulichung des Knickungsvorqauges, ZVDI,pp 1320-1323, 1905.
2. Singer, J. and Rosen, A., The Influence of Boundary Condition on the Buckling of Stiffened Cylindrical shell, in Buckling of Structures, IUTAM Symposium, Springerverlog Berlin Heidelberg New York, pp 227-250, 1976.
3. Horton, W.H.,Nassar, E.M. and Singhal, M.K., Determination of the Critical Loads of Shells by Nondestructive Methods , Experimental Mechanics, Vol. 17, No.4, pp 154-160, 1977.
4. Fan S.R., Experimental Investigation on thePPostbuckling Behaviour of Conical Shell Subjected to Overall Exeernal pressure, ACTA Mechanica Sinica, No.1,pp 74 -83, 1980.
5. Singer, J., Buckling Experiments on Shells - a Review of Recent Developments , TAE Report 403, Dept. of Aeronoutical Engineering Technion-Israel Institute of Technology Dec. 1980.
6. Chen H.X., Li W.Q., Rong H.Q. and Song M., Nondestructive Experimental Method for Determining Critical Loads of Shell Structures under External Pressure,ACTA Aeronautica et Astronutica Sinica, Vol. 4, No. 3, pp 28-35, 1983.
7. Kaplan, A. and Fung, Y.C., A Nonlinear Theory of Bending and Buckling of Thin Elastic Shallow Spherical Shells, NACA TN 3212, 1954.