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Experimental Buckling Analysis of Thin Cylindrical Aluminium Shells

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Abstract

Buckling is characterized by a sudden failure of a structural member subjected to high compressive stressand it is a structural instability leading to a failure mode. One of the major design criteria of thin shell structures that experience compressive loads is that the buckling load limit. Therefore it is important to know about the Buckling loads. The buckling load of thin shell structures are dominantly affected by the geometrical imperfections present in the cylindrical shell which are very difficult to alleviate during manufacturing process. In this paper, three types of geometrical imperfection patterns are considered for cylindrical shellswith and without dent. Experiments are conducted for all the cases and results are compared with analytical results with ANSYS. .It is found that buckling strength of plain cylindrical shell is different compare to cylindrical shell having dents.

Introduction:

The Aluminium alloy material is selected for thin cylindrical shells due to its Light weight, Strong, High strength to weight ratio, Non magnetic, seamless and Economical.The material properties of aluminium are taken from ASTM standards.

Specimen specifications : Length (L) of work piece =I20 ± 0.01 mm, Outer diameter (OD) = 51mm 0.01 mm .Wall thickness (t) =2 ± 0.01 mm, Young's modulus (E) = 60-80 KN/mm^2, Poisson's ratio (γ) = 0.32-0.36

For a thin shell, its d/t ratio should be greater than 10, the cylindrical tube wall thickness is taken as 2mm, so that the d/t ratio obtained is 23.5which is greater than 10. The thin cylindrical shells are manufactured by extrusion and are cut into pieces of 125mm length.

Formation of dents on test cylindrical shell : Totally, 20 test cylindrical shells were manufactured by extrusion and tested, but out of these only 15 test cylindrical shells for which imperfection measurements taken are presented here. Out of 15 five test plain cylindrical shells without any dents are selected the dimensional details are shown in fig.1(A).Similarly, a longitudinal dent was formed on other five test specimens such that the dent should lie on the surface parallel to the cylindrical axis using a semi cylindrical indenter and a mild steel die groove as shown in The Fig. 1(B).A circumferential dent was formed on five test thin cylindrical specimens at half the height of the specimens using a mild steel indenter and a cylindrical mild steel die having circumferential groove as shown in.Fig.1(C)

Cylindrical Shell Models:

Fig.1 (a). (b) (c) Plain cylindrical shell with longitudinal and circumferential dent

Experimental procedure adopted to predict buckling strength:
A 100 KN UTM (FIE Indian make UTN 40 model) was used to predict the buckling strength of cylindrical shells. Before performing compression test on UTM, the following checking initial settings had been carried out. Before applying load on the test cylindrical shell, the parallelism between top Edge of test specimen and top platen was checked using feeler gauge and it was found to be within the tolerance limit of 30 microns. To ensure extremely slow loading on the cylindrical shell, first, the downward. Movement of the upper ram was controlled at a standard rate . And further, to ensure same loading rate, while testing all the other specimens.

Procedure adoptedto predict buckling strength: First, the test cylindrical shell was kept centrally and vertically on the Bottom plates.The upper platen was moved downward direction nearer to the top edge of the test cylindrical shell rapidly.The uniform displacement load from the top platen was allowed to apply on the specimen, until the cylindrical shell collapses. As soon as the load applied reaches the limit load condition (at which arm of the live dial indicator of the UTM tends to return back on further loading) the limit load value on the dial indicator of the UTM was noted. The experimental values of limit load of all the tested cylindrical shells taken for study are tabulated. Fig.2(B) shows photograph of the test cylindrical shell compressed axially on the UTM machine between platens to determine the buckling strength experimentally.

Fig.2 (A) UTM

Fig.2 (B) Test cylindrical shell compressed axially on UTM

Buckling Analysis forPlain cylindrical shell without dent:SHELL93 is particularly well suited to model curved shells. The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. The deformation shapes are quadratic in both in-plane directions. The element has plasticity, stress stiffening, large deflection, and large strain capabilities

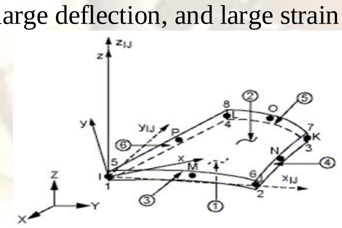


Fig 3 Shell element

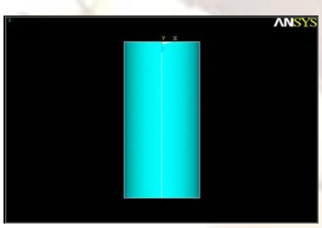


Fig 4.A. Model of Plain cylindrical shell

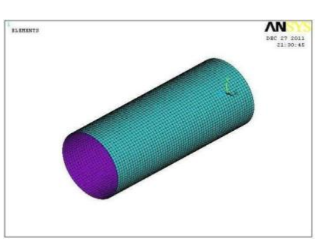


Fig 4.B. Meshed Plain cylindrical shell

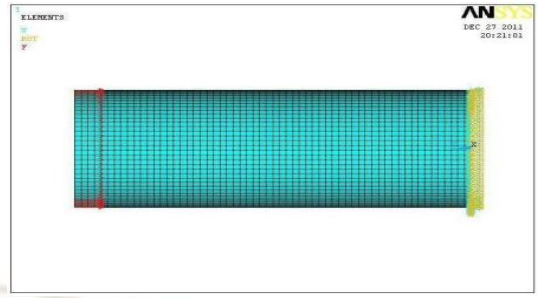


Fig 4.C. Loaded Constrained Plain cylindrical shell

Buckling Analysis for cylindrical shell with a longitudinal dent :

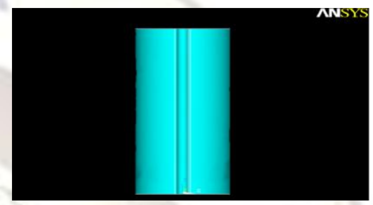


Fig 5a. Model of Cylindrical shell

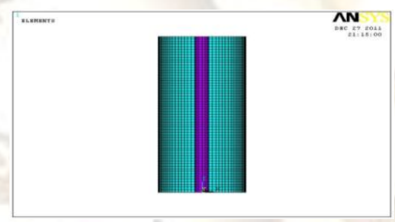


Fig 5.b. Meshed Cylindrical shell with longitudinal dent

Buckling Analysis forcylindrical shell with a circumferential dent:

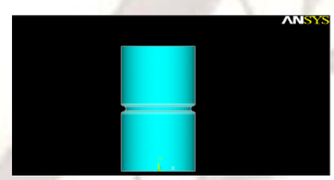


Fig 5.c Model of Cylindrical shell

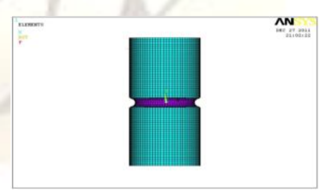
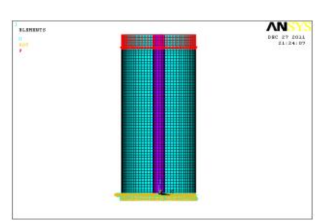


Fig 5.d. Meshed Cylindrical shell with circumferential dent



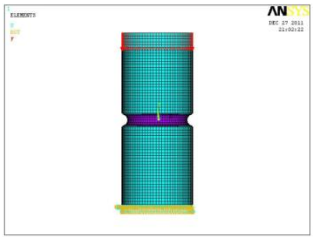


Fig 5.e. Loaded constrained shell with longitudinal and circumferential dent

Results and Discussion:

Analysis of cylindrical shells without dent: (A) Experimental Buckling load:

The test cylindrical shells without dent taken for study failed at the maximum load of 160 kN During this process on reaching the limit load condition the failure of the cylindrical shell was noticed by the formation of partial ring of plastic bulge at the top edge of the cylindrical shell. The Deformed shapes of the test cylindrical shells are shown in Fig6.1.Arespectively.

S.no	Type of cylindrical shell	E Experimental buckling load
01	Plain cylindrical shell	160 KN

Table no: 04 Experimental Buckling load of cylindrical shells without dent

Mode	Buckling factor	Critical load (KN)
01	0.18181E+06	181.81
02	0.18181E+06	181.81
03	0.22594E+06	225.94

The test cylindrical shells without dent taken for study has the critical load 181.81 KN for the two nodes this is due to that deformation along X&Y Direction. The critical load for third mode is 225.94 This is due to that deformation along X,Y&Z Direction. The Deformed shape and Mode shape of the cylindrical shells are shown in Fig 6.1.B &Fig 6.1.Crespectively.

(C) Comparison of Experimental and computational Buckling load

Table 06 Comparison of Experimental and computational Buckling load

S.no	Type of cylindrical shell	Experimental buckling load	Critical Load (KN)	Percentage of increase (%)
01	Plain cylindrical shell	160 KN	181.81	13

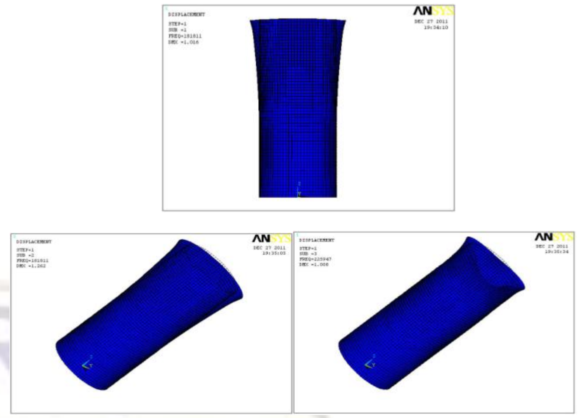


Fig. 6.1.B Deformed shapes of plain cylindrical shell

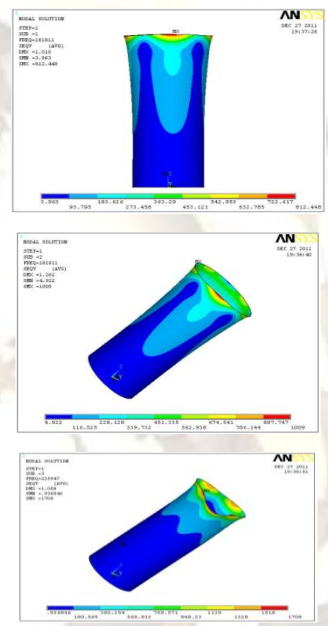


Fig. 6.1.C Mode shapes of plain cylindrical shell

Mode	Buckling factor	Critical load (KN)
01	0.15935E+06	159.35
02	0.19056E+06	190.56
03	0.22159E+06	221.59

Table 07 Buckling factor load results for Cylindrical shell with longitudinal dent

Analysis of cylindrical shells with a longitudinal dent and circumferential dent:

Fig. 6.2.A Deformed shapes--- plain cylindrical shell , with a longitudinal dent and a circumferential dent

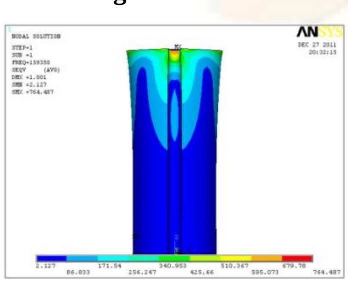
The test cylindrical shell with a longitudinal dent taken for study has the critical load 156.35 KN. For the first mode , 190.56 KN for second mode and 221.59KN for the third mode. Varying load is due to that deformation gradually varying from X,Y&Z Direction. The Deformed shape and Mode shape of the cylindrical shells are shown in Fig 6.2.B &Fig 6.2.Crespectively.

Type of cylindrical shell	Experimental buckling load	Critical load	Percentage of increase (%)
Cylindrical shell with longitudinal dent	142 KN	159.35(KN)	12

Table 08 Computational Buckling load of cylindrical shells with a longitudinal dent

(C) Comparison of Experimental and computational Buckling load:

Fig.6.2.B.Deformed shapes of cylindrical shell with longitudinal dent



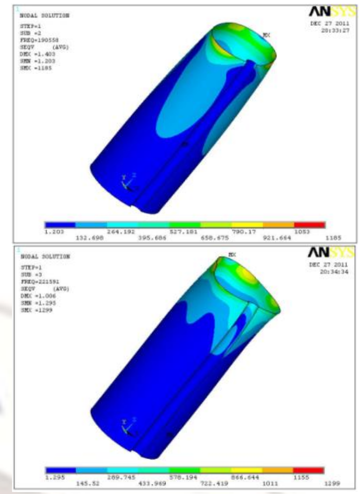


Fig.6.2.C.Mode shapes of cylindrical shell with Longitudinal dent

Buckling factor load results for Cylindrical shell with circumferential dent

Mode	Buckling factor	Critical load (KN)
01	0.10227E+06	102.27
02	0.10233E+06	102.33
03	0.19964E+06	199.64

Table 09 Computational Buckling load of cylindrical shell with a circumferential dent

The test cylindrical shells withcircumferential denttaken for study has the critical load of 102.27 KN. for the two nodes this is due to that deformation along X&Y Direction in dent geometry. The critical load for third mode is 199.64 KN This is due to that deformation along X,Y&Z Direction. The Deformed shape and Mode shape of the cylindrical shells are shown in Fig6.3.B & Fig6.3.Crespectively

(A) Comparison of Experimental and computational Buckling load

Type of cylindrical shell	Experimentalbuckling load	Critical load	Percentage of increase (%)
with circumferential dent	102 KN	102.27 KN	0.3

Table 10Comparison of Experimental and computational Buckling load

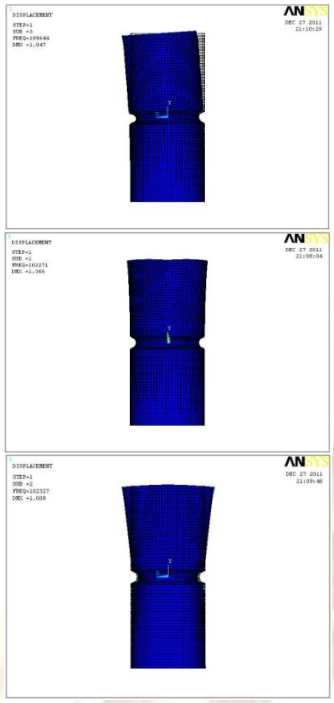


Fig.6.3.B.Deformed shapes of test cylindrical shell with circumferential dent

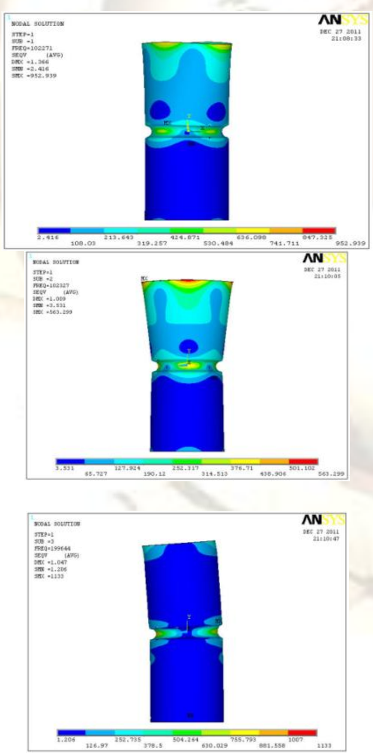


Fig.6.3.C.Mode shapes of test cylindrical shell with circumferential dent

6.4 Comparisons of Results

S.no	Type of cylindrical shell	Experimental buckling load	Computational buckling load	Percentage of increase (%)
01	Plain cylindrical shell	160 KN	181.81 KN	13
02	Cylindrical shell with longitudinal dent	142 KN	159.35 KN	12
03	Cylindrical shell with circumferential dent	102 KN	102.27 KN	0.3

Table 13 comparison of Experimental and computational load results

Conclusions

1. Buckling strength of plane cylindrical shells is higher compare to cylindrical shell with longitudinal dent and circumferential dent.
2. Buckling strength of plane cylindrical shells is 14% more compare to compare to cylindrical shell with longitudinal dent and 77 % more than cylindrical shell with circumferential dent.
3. Buckling strength of cylindrical shells with a longitudinal dent is higher than buckling strength of cylindrical shells with a circumferential dent.
4. Buckling strength of cylindrical shells with a longitudinal dent is 55% higher than buckling strength of cylindrical shells with a circumferential dent.
5. From the analysis it is found that when the maximum amplitude of imperfections is present, the pattern gives out the lowest critical buckling Load when compared to the other imperfection patterns considered. When the amplitude of imperfections is minimum, the pattern gives out the highest critical buckling load when compared to the other imperfection patterns considered.
6. From the analysis it is observed that the displacement, stress and deformation is maximum at top of the shell and minimum at bottom portion of the shell.

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