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BEHAVIOUR OF CYLINDRICAL SHELLS WITH CUT OUTS

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Abstract— In this paper behaviour of thin steel cylindrical shells with circular, square and cylindrical cut outs are studied in detail using finite element program ABAQUS. Shells with cut outs have many applications in civil, mechanical and aerospace engineering. Cut outs lowers significantly the strength of the structures, causes stress concentration and increase the chance of local buckling. Aim of this study is to compare the behaviour of cylindrical shells with various shaped cut out, so that, given a choice to choose we can choose the shape which will give optimum performance. The influence of the cut outs on the behaviour of shells is studied by varying the size as well as area of the cut out. L/D ratio of the shell is considered to be 1. The material used is mild steel. By keeping other parameters constant, size of the cut out was varied from 0.025 to 0.125 of cross sectional diameter of shell. The reduction in strength was found to vary from 0.6% to 5.6%. It has been also noted that shells with elliptical cut out is stronger than those with cylindrical and square cut outs if size of the cut out is the same. Then keeping other parameters and conditions constant, area of the cut out varied from 0.08 to 1.2% of cross sectional area. The reduction in strength is seen to be varying from 0.67% to 5.6 %. It is found that case shells with square cut out is stronger than those with circular and elliptical cut outs. Moreover when the cut outs are too small the effect of shape of the cut out is found to be minimal.

INTRODUCTION

Shells due to their importance as structural elements in many engineering structures, have been receiving great attention by researchers. Shells have several applications in engineering structures and most particularly in civil engineering, mechanical engineering, architecture, aerospace and marine industry. The thin cylindrical shells are prone to a large number of imperfections, due to their manufacturing difficulties. Reliable prediction of strength of these structures is important. Shells with cut outs are used in structures like Storage tanks, Turbine towers, Aircraft parts, Submarine hull, Pipelines, Chimneys, etc.

Miladi & Razzaghi (2014) conducted studies on steel cylindrical shells with circular cut outs. Their finding was that the presence of cut out with any diameter decreases the load tolerance capacity of cylindrical shells about 10 to 35 %. The study also showed that thinner shells are more susceptible to the cut outs compared to thicker ones. Their study also revealed that changing the elevation of cut out from cylindrical shell bottom has no significant effect on the shell buckling capacity.

Stasiewicz (2013) studied the effect of circular cut outs on cylindrical shells made of steel, brass and aluminium alloys. Both analytical and experimental studies were conducted. The study showed that the increase in cut-out size reduces critical stress by 40%. In the models, presence of 5 mm cut out results in reduction in critical stress by 20 % and Presence of 14 mm cut out results in reduction in critical stress by 40%. Analytical formulae derived based on the work of Timoshenk & Bubnov-Galerkin method was used to check the models. Critical stress obtained experimentally were less than that obtained analytically.

Shariati & Rokhi (2010) concentrated on the buckling of steel cylindrical shells with an elliptical cut out. In the models having elliptical cut outs,

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with height constant increase in width caused a reduction in buckling strength by 5 % and with width constant increase in height caused a reduction in buckling strength by 2%. Greater dimension of the cut out if aligned with the longitudinal axis of the shell was found to be having more effect on buckling. Empirical formulae was derived based on the study to predict the buckling load of cylindrical shells with elliptical cut out.Han et al. (2006) conducted numerical and experimental investigations of Aluminium cylinders with circular cut out subject to axial compression. The load bearing capacity was found to decrease by approximately 14, 16 and 20 % for short, intermediate and long cylindrical shells respectively. The load bearing capacity with cut-out located at mid height was found to be the highest, while the capacity is lowest with the cut-out located nearest to the loaded end.

Poursaeidi et al. (2004) studied plastic buckling of cylindrical shells with rectangular and square cut outs. Flexural tests were conducted and bending behaviour was studied. Experimental and theoretical research was conducted. The study showed that if cut out is on tension side limiting buckling moment is more. Also stress concentration factor increases with increasing size of cut outs. Stress value was found to decreases in the area far from hole.

Hilburger et al. (1999) conducted research on response of composite shells with square cut outs to internal pressure and compression loads. Increase in size of the cut out found to cause a significant reduction in buckling load and increase in internal pressure caused an increase in initial buckling load. Another finding was that local buckling response and out of plane deformations occur near the cut out.

Brogan & Almroth (1970) concentrated on buckling of aluminium cylinders with square cut outs. In the models it was found that Presence of cut out resulted in reduction of buckling load by 30%. A comparison was made between theoretical predictions and experimental values.

From the literatures, it can be seen that mostly the researchers concentrated the effect of cut outs on the behaviour of cylindrical shells by varying parameters like cut out size, parameters of the shells like length, thickness, diameter, etc. Their findings tell that the effect of cut outs on the behaviour of cylindrical shells is significant and should be taken care of while design of shell structures. It is also seen that research on comparison among different cut outs are found to be few. The present study aims to compare the effect of square, circular and elliptical cut outs on shell strength.

A. Objectives

This study aims to investigate the behaviour of cylindrical shells with cut outs. The main objectives are

- To find out which type of cut out results in greater reduction in buckling strength for the same maximum lateral dimension.
- To find out which type of cut out results in greater reduction in buckling strength for the same area of cut out.
- To find out the effect of shape of cut out on strength of the shell.

B. Methodology

The analytical investigation process start from fixing the dimension of section up to the final result. The steps involved are as following.

1) Identification of parameters for analysis.
2) Finite element modelling of shells with cut outs.
3) Model validation using available literature.
4) Nonlinear analysis for finding ultimate load.
5) Plotting load-deformation graphs.
6) Comparison and conclusion.

I. GEOMETRIC MODELING

Shell dimensions are given in Table.1. Two studies were done: first one by varying size of cut out and the second one by varying area of cut out. The models with varying size of cut out are denoted by ‘RM’ and with varying area by ‘AM”. Circular (C), square (S) and elliptical cut out (E) are denoted by their first alphabets. All the cut outs are formed at

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mid height of the shell. D_{co} (size of the cut out) was varied from 0.025 to 0.125 of D_{cs} (cross sectional diameter of shell). A_{co} (area of the cut out) was varied from 0.08 to 1.2% of A_{cs} (cross sectional area of the shell).

Table.1. Features of the shell

Diameter	400 mm
Length	400 mm
Thickness	2 mm

A. *Element type and meshing*

Structured meshing was adopted. S8R elements are used for the modelling. S8R elements are 8 noded elements. Mesh size was determined from the mesh convergence study

B. *Boundary conditions*

For the present study the bottom edge of the shell is fixed (U1=U2=U3=0 and UR1=UR2=UR3=0). The boundary condition at top is U1=U2=0, U3≠0 and UR1=UR2=UR3=0.

C. Loading Concentrated load was given at the master node on top of the shell. Load was given as a vector (0, 0, -1). Load can also be applied as shell edge load or can be applied at the node sets/nodes directly.

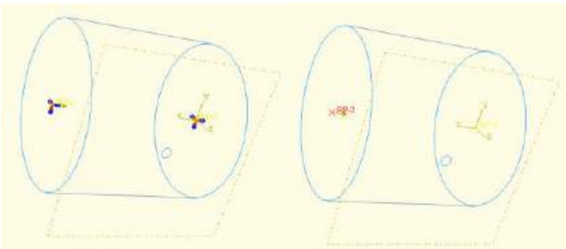

Fig.1. Boundary Conditions and Loading

D. Material properties

Material property values like Poisson's ratio, Young's modulus, etc. which are used for modelling are tabulated below:

Young's modulus (E) = $2*10^5$ N/mm^2

Poisons' ratio (μ) = 0.3

Density = 7860 kg/m^3

Material non linearity is incorporated by giving plastic properties of the steel.

II. RESULTS AND DISCUSSIONS

A. Shells with varying size of cut out

The larger the cut out more will be its effect on the strength of the shell. In this study the cut out size is varied and the comparison was made between square, cylindrical and square cut outs. The load vs deformation graphs were plotted for each size of the cut out and the ultimate load was found. From the obtained graphs it is found that, as the cut out size increases the ultimate load decreases. Comparison between them can be made at the strain level of 0.12% where the shell tends to attain its ultimate strength. The following observations are made. Shells with elliptical cut out are found to be stronger than those with circular and square cut out. When the cut out size is small the difference is negligible.

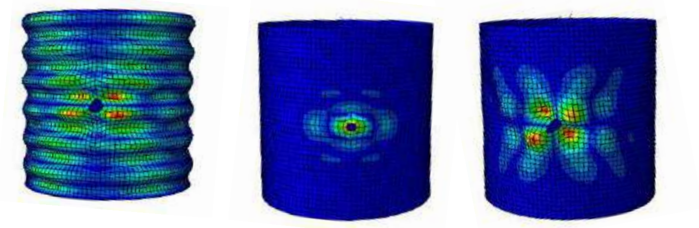

Fig.2. Models showing different mode shapes of shell buckling

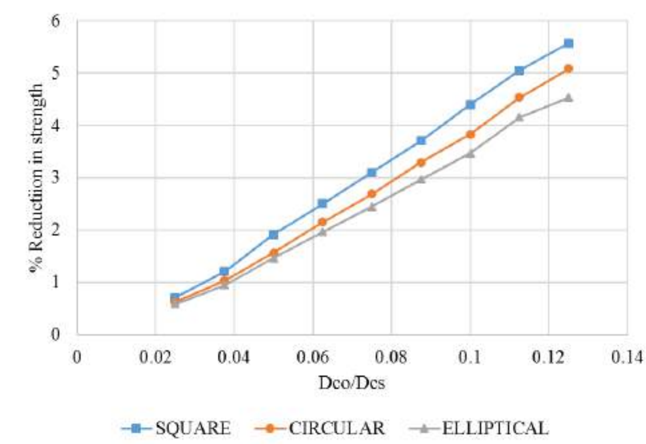

Fig.3. Comparison of reduction in strength of shells having circular, square and elliptical cut out having

same size of cut out.

A. Shells with varying area of cut out

The larger the cut out area more will be its effect on the strength of the shell. In this study the cut out area is varied and the comparison was made between square, cylindrical and square cut outs. The load vs deformation graphs were plotted for each area of the cut out and the ultimate load was found. The following observations are made. Shells with square cut out will be stronger than those with circular and elliptical cut out. When the cut out size is small the difference is negligible.

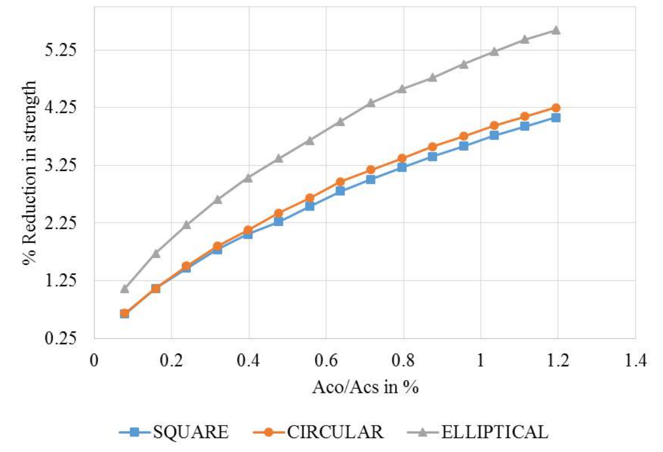

Fig.4. Comparison of reduction in strength of shells having circular, square and elliptical cut out having same area of cut out.

SUMMARY AND CONCLUSIONS

The behaviour of steel shells with cut outs is studied in detail. Comparison was made with cut outs shaped square, circular and elliptical. The study was conducted by varying the size as well as area of the cut out size. Based on the results obtained from the finite element modelling the following conclusions can be made.

1. Varying size of cut out (Dco/Dcs) from 0.025 to 0.125 results in % reduction of shell with L/D ratio 1 as follows

Square :- 0.7% to 5.57%

Circular :- 0.62% to 5.08%

Elliptical :- 0.58% to 4.53%

2. By comparison we can arrange the shells with same size of cut outs according to their strength in the following order : Elliptical > Circular > Square

3. When size of the cut out is too small (Dco/Dcs = 0.025) shape has little effect on strength

4. Dco/Dcs = 0.025 to 0.0625 shells with circular and elliptical cut outs exhibits almost same effect on the strength

5. Varying Area of cut out (Aco/Acs) from 0.08 to 1.2 % results in % reduction of shell with L/D ratio 1 as follows

Square :- 0.67% to 4.08%

Circular :- 0.68% to 4.25%

Elliptical :- 1.11% to 5.59%

6. By comparison we can arrange the shells with same area of cut outs according to their strength in the following order: Square > Circular > Elliptical

7. Shells with square and circular cut outs exhibits almost same effect on the strength of the shell for for Aco/Acs ranging from 0.08 to 0.4 %.

REFERENCES

[1].S. Miladi, M. S. Razzaghi (2014) “A parametric study on inelastic buckling in steel cylindrical shells” International Journal of advanced structural engineering Vol.6 No.1 35-47

[2].Piotr Stasiewicz (2013) “Analytical and experimental studies of cylindrical shells with a

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cut out" Mechanics and Mechanical Engineering Vol. 17 No. 2 (2013) 167-176

[3].Mahmoud Shariati, Masoud Mahizadeh Rokhi (2010) "Buckling of steel cylindrical shells with an elliptical cut out" International Journal of Steel Structures Vol.10 No.2 193-205

[4].Haipeng Han, Jinquan Cheng, Farid Taheri (2006) "Numerical and experimental investigations of Aluminium cylinders with a cut out subject to axial compression" Thin walled structures Vol.44 254–270

[5].E.Poursaeidi, G.H. Rahimi, A.H.Vafai (2004) "Plastic buckling of cylindrical shells with cut out" Asian Journal of Civil Engineering Vol.5 No.3 191-207

[6].Mark W. Hilburger, Anthony M.Waas, James H. Starnes Jr. (1999) "Response of composite shells with cut outs to internal pressure and compression loads" American Institute of aeronautics and astronautics Vol. 37 No. 2 101-110

[7].Frank Brogan, Bo Almroth (1970) "Buckling of cylinders with cut outs" American Institute of aeronautics and astronautics Vol.8 No.2 236-240