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Post-Buckling Behaviour of laminated Cylindrical Panels with/without Cut-Outs

Y.Venkata Narayana, P.M. Pranith Bhargav

Abstract*: Buckling and post-buckling analysis of isotropic and laminated composite cylindrical plates/panels under compressive load has been done by equilibrium path approach (arc-length technique). The impact of cut outs on buckling and post-buckling load of an isotropic and laminated composite cylindrical plates/panels has been assessed by utilizing summed up generalized finite element programming ANSYS. In post-buckling Eigen mode imperfection shape is picked for creating geometric undulations on cylindrical panels with/without circular cut-outs. The impact of the area and size of the cut out and furthermore the composite utilize point on the buckling load of laminated composite cylindrical panel is explored with simply supported boundary conditions. The post-buckling consequences of laminated cylindrical panels have been validated with existing appropriate writing (18) and are additionally stretched out for analysis of sheets/plates with cutouts. It has been seen that the as the curvature of the panel increases load bearing capacity is increasing irrespective of the material and with/without cut out.

Keywords*: buckling, post-buckling, linear analysis, nonlinear analysis, cut-outs, cylindrical panel, buckling load, laminated composite.

I. INTRODUCTION

Thin walled isotropic and laminated cylindrical panels and plates have turned out to be significant basic elements in numerous applications, for example, aviation, mechanical, electrical designing and other general applications. Buckling phenomenon in thin slender member such as plates, shells and panels is viewed as an unexpected geometric collapse of basic elements exposed to high compressive load and it is a geometric unsteadiness prompting collapse mode before material loses its strength. Due to enormous deflections, bifurcations, the buckling analysis of isotropic and anisotropic material thin members requires highly iterative methods suitable for tracing the total load displacement curve of the structures. Their consistent post buckling conduct and their ability to support loads far in abundance of their underlying buckling loads may prompt huge weight reductions, if their post buckling quality is completely utilized and conceivable weakness issues are addressed. In spite of the fact that the genuine reaction is dynamic in nature, a completely static analysis is followed much of the time. In this manner, research on nonlinear steadiness of these structures has been important to researchers. Concentrate on nonlinear conduct of these structures is significant of the down to earth. Also, its load absorbing limit is chosen by its buckling quality which depends firmly on geometrical limitations introduced in it.

The presence of geometric imperfections because of assembling procedures takes overwhelming job in evaluating the real load bearing of the different applications. The use of more advanced materials to the design and implementation in different applications has become standard practice in research. A general weight decrease of these light weight auxiliary structural members requires to quickly examining their dependability qualities and the post-buckling conduct of composite structures has increased more extensive enthusiasm for this respect. This subject is typically examined by methods for the numerical strategies dependent on the finite element (FE) method or by methods for a rough analytical technique.

Post-buckling state [1, 2] of the plates, cylindrical panels is particularly sensitive with loading, boundary conditions, geometry as well mechanical properties of the material, load direction, geometric flaws and its material defects. The load-displacement bend after bifurcation purpose of a dainty walled part gives extremely valuable data on soundness of structure and same can be discovered utilizing enormous deformation analysis which gives the reaction of the structure with reference to beginning geometric blemishes size and shape. The affectability of harmony way was introduced in the accessible writing which depends on either the load-controlled or the displacement-controlled methodologies. Load controlled Newton-Raphson strategy was the soonest technique in such manner yet it flops close to the limit point. To beat the challenges with limit focuses, displacement control procedures were presented. Anyway for auxiliary frameworks showing snap-through or snap-back conduct, these procedures result to blunder. One approach to conquer the issue is by embracing a strategy to change among load and displacement controls [3], by utilizing the fake springs [4] or by relinquishing the harmony emphases in the nearby region of limit point [5]. To get an increasingly broad procedure, the arc-length technique for auxiliary analysis, initially created by Riks [6, 7] and Wempner [8] and later adjusted by a few researchers is ordinarily being utilized. Different types of the arc-length strategy pursued the first work of Riks and Wempner. Li et al. [9] proposed that the nonlinear analysis procedures are useful for following the limit-point-type balance ways.

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* Correspondence Author
Dr. Y.Venkata Narayana*, Professor, Sreenidhi Institute of Science and Technology, Hyderabad.(vnyenugula@gmail.com)
P.M.Pranith Bhargav, M.Tech student, Sreenidhi Institute of Science and Technology, Hyderabad.

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A few enhancements are introduced as displacement irritation strategies just as power annoyance techniques for following the bifurcation-point-type harmony ways. Bisagni and Cordisco [11] assessed the quality limit of composite cylindrical shells in the post buckling area where the underlying geometric defects and the thickness varieties of the external and inward surfaces are filtered before starting the test to evaluate the geometric blemishes. By utilizing the position control mode, these shell/panels are tried to evaluate their post-buckling quality limit.

The buckling tests and numerical analysis which were done on the panels by Mahmoud Shariati et al. [12] showed that: growing the length will barely decline the buckling load. This result is increasingly noteworthy for shorter panels by growing the region edge, and the buckling load will augment about linearly and for impeccable chamber, it variations more. M. Wygoda et al. [13] depicts the estimations of the basic buckling loads for the accompanying buckling modes vary additionally not fundamentally. It could cause the issues with the acquiring the joined arrangement on account of completely non-linear analysis. Hamidreza Allahbakhsh et al. [14] researched the impact of curved cut outs of different sizes in various situations on the buckling load of laminated composite cylindrical panel exposed to axial load. In the planned work, post-buckling conduct of blemished (of Eigen shape), laminated composite cylindrical panels exposed to axial compressive load has been examined by utilizing a equilibrium way method which usages an arc-length technique [15]. Buckling and post-buckling analysis of thin cylindrical shells under axially compression, bending and torsion load was carried out by Yenugula.et al. [19, 20, 21 and 22] with imperfection sensitivities and validated numerically and experimentally.

This present analysis is on comparision of buckling and post-buckling results of both isotropic and laminated composite cylindrical panels and plates with and without cut outs subject to axial compressive loads, and with different curvature angles of the cylindrical panels.

II. FINITE ELEMENT MODELING OF COMPOSITE CYLINDRICAL PANEL

The plate and cylindrical panels with various angle is modeled with finite element programming and divided whole structure in to number of elements. The shell element with six degrees freedom in each node is utilized in buckling and post-buckling analysis. The suitable condition for linear buckling (Eigen value buckling) is as follows:

$$([K]+\lambda_{cr}[K_g]^{ref})\{\delta\}=\{0\} \qquad (1)$$

$[K]$ is the linear stiffness matrix and $[K_g]^{ref}$ reference geometric matrix. λ_{cr} Is an Eigen value and $\{\delta\}$ becomes the eigen-vector defining the buckling mode. An iterative process of solving the nonlinear equations is required and these can be shown as (18)

$$[K_i^T]\{u_i\}=\{f\}^a-\{f_{(i)}\}^{nr} \qquad (2)$$

$$\{u_{i+1}\}=\{u_i\}-\{\Delta u_i\} \qquad (3)$$

$[K_i^T]$ is the tangent stiffness matrix, i representing the current equilibrium iteration and $\{f_i\}^{nr}$ vector of restoring load respective to the element internal loads. The nonlinear analysis is carried out with Newton-Raphson method and post-buckling analysis is carried out with Arc-length method.

A. Procedure -Post-buckling Analysis

(1) Fundamental mode shape is assumed as eigen mode imperfection and is extracted from buckling analysis

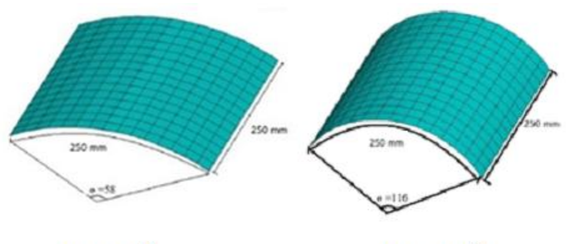
(2) Different Imperfection magnitudes with reference to the thickness of the panel is taken in nonlinear and post-buckling analysis

(3) Nonlinear buckling analysis includes the use of Newton-Raphson method and arc-length method is used for nonlinear and post-buckling analysis respectively.

III. LINEAR BUCKLING ANALYSIS

The isotropic and laminated plate, cylindrical panels are subjected to the axial compressive load Nx (force per unit length) applied at the edges typical to the x bearing. The lengths of the straight edge (a), and the curved edge (b), are both equivalent to 250 mm and $\phi=58^0$ and $\phi=116^0$ angles of the cylindrical panes considered for linear and nonlinear analysis. The 20 mm diameter circular hole (cut-out) is considered in all three panels. The aspect ratio (a/b=1) and thickness (t=2.5mm) of the isotropic and laminated plates and cylindrical panels kept consistent during buckling and post-buckling analysis. The geometry and finite element messed models of plate, cylindrical panels are shown in the Fig 3.1

The nominal material properties for isotropic and laminated plates, panels are taken as shown in table below. The laminated composite material is assumed as the quasi-isotropic and the properties are taken from the literature (18). The mechanical properties of the isotropic panels, laminated cylindrical panels and plates considered for buckling and post buckling are as shown in table.1. Buckling and post-buckling analysis of cylindrical panels and plates has been done with simple supported boundary conditions (SFSF). The linear buckling fundamental (Mode1) mode shapes are shown in below Fig.2.



a) $\Theta = 58^0$ **b)** $\Theta = 116^0$

Fig. I.Cylindrical Panel, a) $\Theta=58^0$, b) panel with $\Theta=116^0$

Table. I: Mechanical property of Isotropic and laminated composite materials (quasi-isotropic).

SNO:	Panel Geometry	Mechanical Properties
1	Isotropic plate and cylindrical panels	$E=200GPa$, $\nu=0.3$

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2	Laminated Composite plate and cylindrical panels	Ex = 270GPa Gyz = 2.7GPa $\gamma_{xy} = 0.25$ $\gamma_{xy} = 0.47$

IV. POST- BUCKLING ANALYSIS

Post-buckling investigation of panels has been carried out to find the limit point buckling load and stability behavior of the cylindrical panel beyond the bifurcation point using the same material properties and geometric parameter like aspect ratio and thickness of the model as the linear buckling analysis employed. Before post-buckling procedure mesh convergence study is carried out with simple supported boundary conditions to find optimum element size i.e element size 20mm and performed post-buckling analysis.

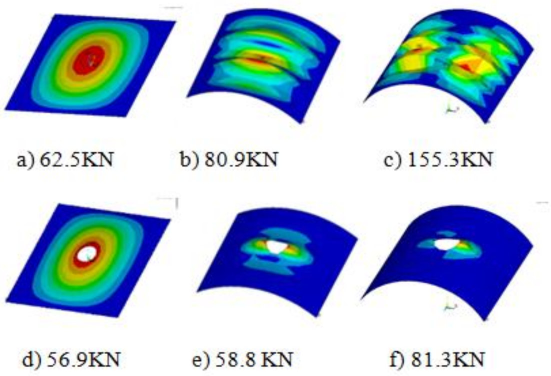

Fig.II Linear buckling mode shapes of Isotropic panel a) plate, b) cylindrical panel with 58⁰, c) cylindrical panel with 116⁰.

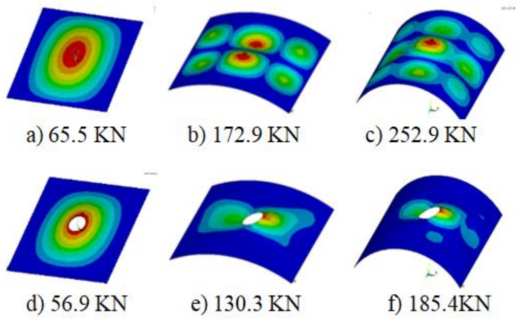

Fig. III Linear buckling mode shapes of Laminated Composite panel a) plate b) cylindrical panel with 580c) cylindrical panel with 1160.

The evaluated post-buckling results with present finite element code are compared with existing literature (18) and found good agreement. The buckling analysis is carried out on laminated cylindrical panels of R/t =100, and R/t =1000 with cross-ply laminate $(0/90)_{5s,}$ and with imperfection magnitude ξ=0.1 of thickness (t), simple supported boundary conditions for validation of the existing results. The validated results depict in the Fig.IV shown. The same analysis is extended further with panels with/without circular cut outs.

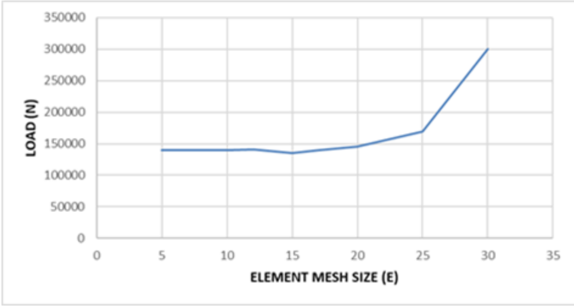

Fig.IV: Convergence study laminated composite cylindrical panel (θ =116^0)

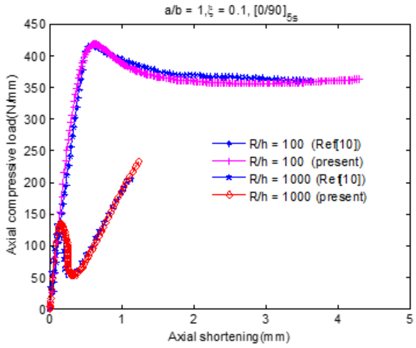

Fig.V Validation of Post-buckling results with existing literature

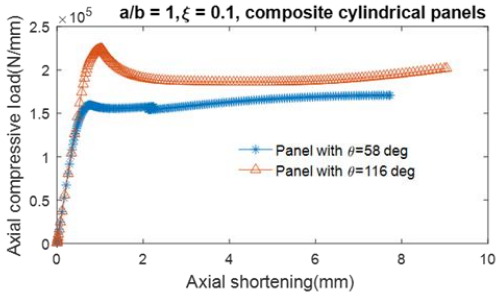

Fig.V Post-Buckling analysis of cylindrical panel with different curvature With out hole.

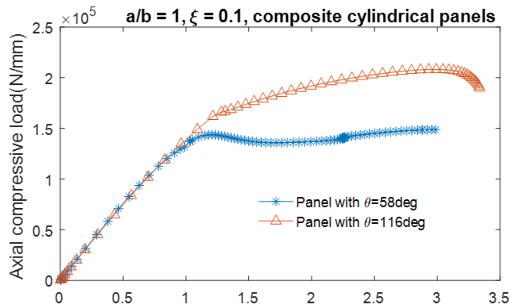

Fig.VI Post-Buckling analysis of Laminated cylindrical panels panel with circular -hole

V. RESULTS AND DISCUSSION

The linear buckling analysis has been carried out on isotropic and quasi isotropic plate, cylindrical panel with different curvature. It has been observed that the linear buckling analysis results increases from plate to cylindrical panels with different curvature for isotropic as well as the laminated composite materials.

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This is evidence in the Fig.II and Fig.III and it also observed that as the radius decrease or increase of the angle of curvature for the same aspect ratio linear buckling load increasing. Post-buckling analysis with arc length method is carried out with and without circular cut out with diameter 20mm. It is also observed that laminated panel without cut out load bearing capacity after post-buckling analysis is increasing and there is a well defined secondary path in post-buckling analysis. The post-buckling analysis with circular cut out (dia. 20mm) shows in Fig.VI and can be observed that the secondary path in there is no well defined path.

VI. CONCLUSION

Buckling and post-buckling analysis of isotropic and laminated composite plate, cylindrical panels with different radius of curvature has been carried out with and without cut outs. It IS observed that as the curvature increases load bearing capacity increases for both isotropic as well as quasi-isotropic panels. Present Finite element code for post-buckling analysis is validated with existing results and found satisfactory. And the same finite element analysis code is used for post-buckling procedure using Arc-length method for analysis of above panels, isotropic as well as laminated cylindrical panels with/without circular cut outs. It is concluded that panels without cut outs observed to be more stable than cylindrical panel with circular cut outs. It is also observed that the cylindrical panels with cut outs there no well defined secondary path and load bearing capacity also decreasing.

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AUTHORS PROFILE

Dr. Y.Venkata Narayana is Professor, Department of Mechanical Engineering at the Sreenidhi Institute of Science and Technology (An Autonomous Institution) Hyderabad. Telangana State in India, which is affiliated by Jawaharlal Technological University Hyderabad . “He carried out research on Investigations on Buckling of Laminated Cylindrical Shells” and awarded Ph.D. degree from Jawaharlal Nehru Technological University, Hyderabad.
Prof. Venkata Narayana’s extensive areas of research include: Buckling and Post-buckling analysis of laminated thin walled structures like plates, cylindrical panels and shells numerically and experimentally, 3D Printing and Design of Experiments using Taguchi Method, Smart material based characterization and design, and Design and Modeling structural Dynamics. He has published 19 national and international journals and around 6 national conferences and one international conference in his area of expertise. He has also published his patent on “Dynamic Speed Limiter Mechanism for Four wheeler for Indian Road Conditions”. Organized several workshops and delivered expert lectures on Finite element Analysis and concurrent Engineering. He has carried out around 14 M.Tech projects and around 40 B.Tech projects in his academic experience.

He has around 6 years rich industrial experience in design and development and he is active team member in development of Continuously Variable Transmission (CVT) to LML trendy. He has also design and development experience in filament wound composite launch tubes and Gun barrels for Bharath Dynamics Limited (BDL) and DRDL. Product Based Ground Mines(PBGM) and Electronics shell for National Scientific Testing Laboratory(NSTL).

Mr.P.M.Pranith Bhargav is pursuing M.Tech (CAD/CAM) in Sreenidhi Institute of Science and Technology (An Autonomous Institution), Hyderabad. (2017-2019) which is affiliated by Jawaharlal Technological University Hyderabad. B.Tech. Mechanical Engineering in Aurora's Technological and Research Institute, Hyderabad (2013-2017). Performed major project on 'Design and Manufacture of a Quad Bike. Attended Project Workshop On "Intermediate, Overhauling Of Coach" in south ccentral rrailways.
Attended Internship program on 'Bus Body Building' at Nagasai Coach Builders IDA jeedimetla, Hyderabad. Attended National seminars and conference by DRDO and Technical workshops, Industrial Expo in my Graduation course of study. Actively participates in several Sports Events. Conducted several Technical and Cultural Events. Won few technical events conducted in my graduation study. Best Student Award in 9th standard by Johnson Grammar School. Winner in volley ball competition in Inter School Championship twice. Won few sports competition at my Graduation level.
He acquired skills in modeling and analysis and post processing software's. He is expert in Parametric modeling software Creo. 2.0., and he carried out several projects based on the finite element software and post processing software's. He published 2 national conference based on finite element analysis of bus body chassis and power transmission. He also a member in Society of Automobile Engineering and ISTE.

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