RESEARCH ARTICLE

RSP Science Hub

International Research Journal on Advanced Science Hub
2582-4376
Vol. 03, Issue 07 July
www.rspsciencehub.com

Check for updates

http://dx.doi.org/10.47392/irjash.2021.191

Nonlinear Bending Analysis of Cylindrical Panel under Thermal Load

Emarti Kumari[1]

[1]*Assistant Professor, Department of Mechanical Engineering, M.B.M. Engineering College, Jai Narain Vyas University, Jodhpur342001, India*

Article History

Received: 28 May 2021
Accepted: 21 July 2021

Keywords:

Nonlinear;
Cylindrical Panel;
Thermal Load;
Laminated Composite

Abstract

In this communication, the nonlinear bending behaviour of laminated cylindrical panels in the presence of thermal load has been studied using the finite element-based simulation package ANSYS. The efficacy of present numerical results is compared with published results. Thereafter, the effect of radius-to-span ratio (R/a) on the nonlinear static response of isotropic and laminated panels under thermal load is studied here. Moreover, the nonlinear bending deflection verses x-axis of cylindrical panels at different thermal loads is presented here that will serve as benchmark for future research.

1. Introduction

Curved panels are widely used in defence, automobile, aerospace, civil and other engineering applications. Thus, the strength and flexural stiffness of these thin-wall structures under the thermal environment is very important for engineers and researchers (Thang, Nguyen, and Lee). The generalized differential quadrature numerical method was employed for the nonlinear analysis with thermo-mechanical loads of moderately thick laminated cylindrical panels and considering the variation of thickness for conical panels (Naidu and Sinha). The linear bending behaviour of skew plates has been studied by employing a shear deformable triangular finite element (Yoosefian, Golmakani, and Sadeghian). They studied the effect of thickness ratio and lamination sequence for skew plates. The geometrically nonlinear bending behaviour of composite plates with analytical approach such as Navier-type and Levy-type techniques has been reviewed by (Madrigal, Navarro, and Chaves). The nonlinear dynamic responses of curved panels have been investigated by employing finite element method with first order shear deformation theory considering Von-Karman's geometric nonlinearity. (Loja, Barbosa, and Scares). The buckling behaviour of isotropic plates under compression and shear has been studied by Qiao, P., & Huo, X. (Qiao and Huo) Analytically investigated the linear buckling of rectangular plates under shear and compression using Rayleigh-Ritz Method (Aghdam and Falahatgar), Kantorovich Method (Yuan and Jin Shufrin, Rabinovitch, and Eisenberger) and numerically by using Finite Strip Method (Smith and Sridharan de Vargas Lisbôa and Marczak). The linear bending results of isotropic plates employing energy method has been by Liew (Saadatpour and Azhari), and investigated the effect of boundary conditions. The static analysis of plates has been performed by using Galerkin Method (Karami, Shahpari, and Malekzadeh Yu and Shen Kumari). Static and Dynamic behaviour of flat panels has been examined by using finite element method with First-Order Shear Deformation Theory (Kumari and Saxena ZHAO, LIU, and LI). The nonlinear bending response of three-dimensional braided laminated cylindrical panels has been investigated using higher-order plate theory with Von-Karman's Geometric Nonlinearity (Moosavi et al.). Nonlinear bending behaviour of functionally graded sandwich panels has been studied by using finite element method with higher-order plate theory (Kumar, Narendar, and Gopalakrishnan Saadatpour, Azhari, and Bradford). It is noticed that nonlinear static analysis of curved panel scarce in literature. Hence, author has been studied the nonlinear bending behaviour of cylindrical panels in the presence of thermal load using commercial finite element software ANSYS.

2. Numerical Procedure

The finite element method-based simulation software ANSYS is used to investigate the nonlinear bending response of cylindrical panels under thermal load. Eight-node shell element 281 is used here to discretize the cylindrical panels.

The governing equation for the nonlinear bending analysis may be written as:

$$[K_L]\{\delta\}+[K_{NL1}(\delta)]\{\delta\}+[K_{NL2}(\delta,\delta)]\{\delta\}=\{F^T\} \quad (1)$$

Here, K_L is the linear, K_{NL1} and K_{NL2} are nonlinear stiffness matrices; $\{d\}$ is the nodal displacement vector represents six degrees of freedom (three displacement u_x, v_y, w_z; and three rotations q_x, q_y, q_z); $\{F^T\}$ is the nodal load vectors due to thermal load.

The Newton-Raphson iterative method has been used to solve equation (1).

Residual Force:

$$\{\Delta F^i\}=\left[K_L+K_{NL1}(\delta^i)+K_{NL2}(\delta^i,\delta^i)\right]\{\delta^i\}-\{F^T\} \quad (2)$$

$$[K_T^i]\{\Delta\delta^{i+1}\}=\{\Delta F^i\} \quad (3)$$

$$\{\delta^{i+1}\}=\{\delta^i\}+\{\Delta\delta^{i+1}\} \quad (4)$$

The iteration process is continued until the difference between and becomes lesser than error tolerance (e = 0.001) [1]. In this study error criteria are considered by:

$$\sqrt{\frac{\sum_{J=1}^{NP}\left|\delta_J^{i+1}-\Delta\delta_J^{i+1}\right|^2}{\sum_{J=1}^{NP}\left|\Delta\delta_J^{i+1}\right|^2}}\le\varepsilon \quad (5)$$

3. Results and Discussion

The Figure 1. presents non-dimensional centre deflection of fully simply supported (SSSS1) anti-symmetric angle-ply [-45/45/-45/45] laminated cylindrical panel subjected to a uniform thermal load (DT) and the present numerical results are validated available published results by Toan Thang, P., Nguyen (Thang, Nguyen, and Lee) and Swamy Naidu, N. v., & Sinha (Naidu and Sinha). In the present study, full cylindrical panel is used with the following geometric and material properties:

a/b = 1, a/h = 200, R/a = 10

E_1 = 138 GPa, E_2 = E_3 = 8.28 GPa, G_{12} = G_{13} = G_{23} = 6.9 GPa, n_{12} = n_{13} = n_{23} = 0.33,

a_1 = 0.18 10^{-6} /C, a_2 = 27 10^{-6} /C

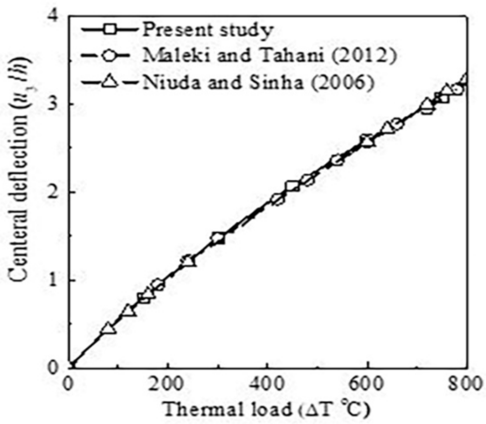

FIGURE 1. Non-dimensional centre deflection of fully simply supported (SSSS1) anti-symmetric angle-ply laminated cylindrical panel subjected to a uniform thermal load (DT).

3.1. Boundary Conditions are:

SSSS1: u_y = u_z = qy = 0; at x = 0, a and

u_x = uz = qx = 0; at y = 0, b

Figure 1. illustrates the non-dimensional centre deflection (u_3/h) of the panel under various uniform thermal loads (ΔT = 0 to 800C) of fully simply supported (SSSS1) anti-symmetric angle-ply centre. The present numerical results are also validated with published FEM results and it is seen that percentage of error is 0.0004% and 0.0005% from previous studies.

Next, studied the effect of radius-to-span ratio on nonlinear bending behaviour of simply supported isotropic cylindrical panel (a/b = 1, a/h = 100). The

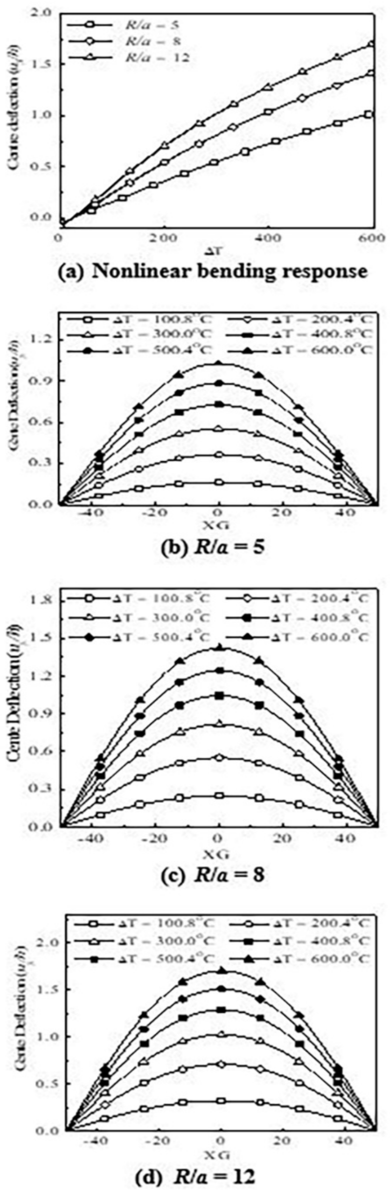

FIGURE 2. **Nonlinear Bending Response (a) and NonlinearBending deflection verses x-axis of simply (b) R/a = 5 (c) R/a= 8 (d) R/a =12**

following material and boundary conditions are considered here:

E = 210 GPa, n = 0.3, r = 7800 kg/m^3,

$\alpha = 2 \times 10^{-6}$ /C

SSSS2: $u_x = u_y = u_z = 0$; at x = 0, a and $u_x = u_y = u_z = 0$; at y = 0, b

It is seen that by increasing the radius-to-span ratio (R/a) from 5 to 12 increases the non-dimensional center deflection (u_3/h) from 1.0 to 1.7 at thermal load ΔT = 600 C. Moreover, the Non-linear Bending Response and Nonlinear Bending deflection verses x-axis of simply (b) R/a = 5, (c) R/b = 8. is presented in Figure. 2 (b-d) for different

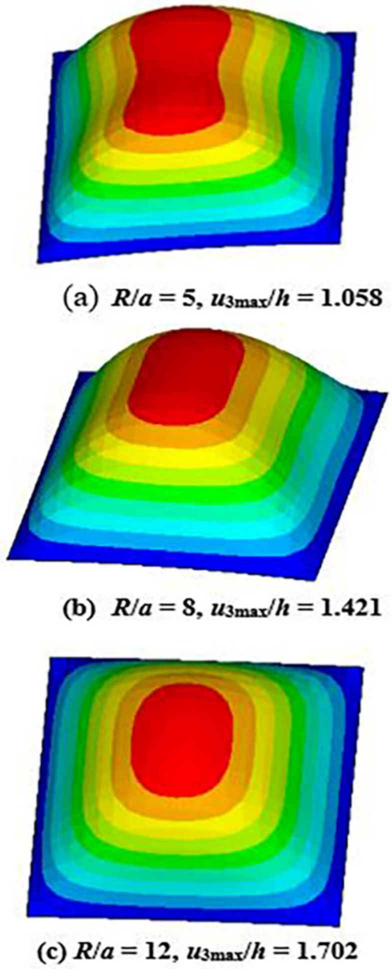

FIGURE 3. **Contour plots ofIsotropic Cylindrical Panel (a/b = 1, a/h = 100) under Thermal Load (a) R/a = 5, u3max/h = 1.058 (b) R/a = 8, u3max/h = 1.421 (c) R/a = 12, u3max/h = 1.702**

radius-to-span ratios (R/a = 5, 8, 12) at various thermal load (ΔT = 100.8 C, 200.4 C, 300.0 C, 400.8C, 500.4 C and 600.0 C). As expected by increasing the thermal load increases the non-dimensional central deflection (u_3/h) of cylindrical panel.

The Contour plots of Isotropic Cylindrical Panel (a/b = 1, a/h = 100) under thermal load (ΔT = 600.0 C) for different radius-to-span ratios is shown in Figure. 3. It is observed that snap-through thermal buckling occurs in deep cylindrical panels.

Now, studied the effect of radius-to-span ratio on nonlinear bending behaviour of simply supported angle-ply [45/-45/45/-45/45] cylindrical panel (a/b = 1, a/h = 100) under thermal load (ΔT = 50.4 C, 100.8 C, 200.4 C, 300.0 C). The following material and boundary conditions are considered here:

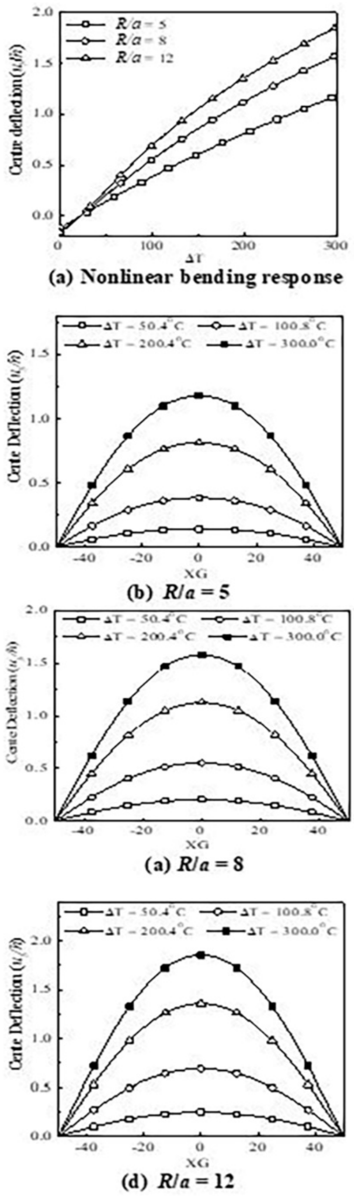

FIGURE 4. (a) Nonlinear bending response of simply supported laminated cylindrical panel (a/b = 1, a/h = 100) (b) R/a = 5 (c) R/a = 8 (d) R/a = 12

E_{11} = 130 GPa, E_{22} = E_{33} = 10.3 Gpa, G_{12} = G_{13} = G_{23} = 6.0 Gpa,

n_{12} = n_{13} = n_{23} = 0.32, r = 1600 kg/m^3

$\alpha_1 = 0.2 \times 10^{-6}$ /C, $\alpha_2 = 40 \times 10^{-6}$/C

SSSS2**:** $u_x = u_y = u_z = 0$; at x = 0, a and y = 0, b

It is observed that nonlinear bending behavior of laminated composite cylindrical panel is qualitatively similar to the isotropic cylindrical panels.

4. Conclusion

The nonlinear bending behaviour of isotropic and laminated composite cylindrical panels under thermal load has been studied in this communication using the finite element method based commercial software ANSYS. To model cylindrical panel 8 node 281 shell element is used with 441 elements. Firstly, validation study was performed with available literature in the thermal environment. Thereafter, the effect of radius-to-span ratios is studied here on the nonlinear static response of cylindrical panels. It is noticed that by reducing the deepness of cylindrical panels reduces the load carrying capacity and increases the non-dimensional central deflection of these panels.

ORCID iDs

Emarti Kumari https://orcid.org/0000-0002-3339-8153

References

Aghdam, M. M. and S. R. Falahatgar. “Bending analysis of thick laminated plates using extended Kantorovich method”. *Composite Structures* 62.3-4 (2003): 279–283. 10 . 1016 / j . compstruct . 2003 . 09 . 026 ; %20https : / / dx . doi . org/10.1016/j.compstruct.2003.09.026.

De Vargas Lisbôa, Tales and Rogério José Marczak. “A recursive methodology for the solution of semi-analytical rectangular anisotropic thin plates in linear bending”. *Applied Mathematical Modelling* 48 (2017): 711–730. 10.1016/j.apm.2017.04.020;%20https://dx.doi.org/10.1016/j.apm.2017.04.020.

Karami, G., S. Ali Shahpari, and P. Malekzadeh. “DQM analysis of skewed and trapezoidal laminated plates”. *Composite Structures* 59.3 (2003): 393–402. 10 . 1016 / s0263 - 8223(02) 00188 - 5 ; %20https://dx.doi.org/10.1016/s0263-8223(02)00188-5.

Kumar, T. J. Prasanna, S. Narendar, and S. Gopalakrishnan. “Thermal vibration analysis of monolayer graphene embedded in elastic medium based on nonlocal continuum mechanics”. *Composite Structures* 100 (2013): 332–342. 10.1016/j.compstruct.2012.12.039;%20https://dx.doi.org/10.1016/j.compstruct.2012.12.039.

Kumari, E. “Free vibration analysis of rotating laminated composite plate type blades with variable thickness”. *Materials Today: Proceedings* 43 (2021): 1762–1773.

Kumari, Emarti and Deepika Saxena. “Buckling analysis of folded structures”. *Materials Today: Proceedings* 43 (2021): 1421–1430. 10.1016/j.matpr.2020.09.179;%20https://dx.doi.org/10.1016/j.matpr.2020.09.179.

Loja, M. A. Ramos, J. Infante Barbosa, and C. M. Mota Scares. “Buckling behaviour of laminated beam structures using a higher-order discrete model”. *Composite Structures* 38.1-4 (1997): 119–131. 10 . 1016 / s0263 - 8223(98) 80011-1;%20https://dx.doi.org/10.1016/s0263-8223(98)80011-1.

Madrigal, C., A. Navarro, and V. Chaves. “A simplified plasticity model for multiaxial non-proportional cyclic loading”. *Theoretical and Applied Fracture Mechanics* 103 (2019): 102247–102247. 10 . 1016 / j . tafmec . 2019 . 102247 ; %20https://dx.doi.org/10.1016/j.tafmec.2019.102247.

Naidu, N.V. Swamy and P. K. Sinha. “Nonlinear transient analysis of laminated composite shells in hygrothermal environments”. *Composite Structures* 72.3 (2006): 280–288. 10.1016/j.compstruct.2004.12.001;%20https://dx.doi.org/10.1016/j.compstruct.2004.12.001.

Qiao, Pizhong and Xuping Huo. “Explicit local buckling analysis of rotationally-restrained orthotropic plates under uniform shear”. *Composite Structures* 93.11 (2011): 2785–2794. 10.1016/j.compstruct.2011.05.026;%20https://dx.doi.org/10.1016/j.compstruct.2011.05.026.

Saadatpour, M. M. and M. Azhari. “The Galerkin method for static analysis of simply supported plates of general shape”. *Computers & Structures* 69.1 (1998): 1–9. 10 . 1016 / s0045 - 7949(98) 00073-x;%20https://dx.doi.org/10.1016/s0045-7949(98)00073-x.

Shufrin, I., O. Rabinovitch, and M. Eisenberger. “Buckling of symmetrically laminated rectangular plates with general boundary conditions – A semi analytical approach”. *Composite Structures* 82.4 (2008): 521–531. 10 . 1016 / j . compstruct . 2007 . 02 . 003 ; %20https : / / dx . doi . org / 10 . 1016 / j.compstruct.2007.02.003.

Smith, T. R. Graves and S. Sridharan. “A finite strip method for the buckling of plate structures under arbitrary loading”. *International Journal of Mechanical Sciences* 20.10 (1978): 685–693. 10.1016/0020-7403(78)90055-3;%20https://dx.doi.org/10.1016/0020-7403(78)90055-3.

Thang, Pham Toan, Tan-Tien Nguyen, and Jaehong Lee. “Nonlinear static analysis of thin curved panels with FG coatings under combined axial compression and external pressure”. *Thin-Walled Structures* 107 (2016): 405–414. 10.1016/j.tws.2016.06.007;%20https://dx.doi.org/10.1016/j.tws.2016.06.007.

Yoosefian, A. R., M. E. Golmakani, and M. Sadeghian. "Nonlinear bending of functionally graded sandwich plates under mechanical and thermal load". *Communications in Nonlinear Science and Numerical Simulation* 84 (2020): 105161–105161. 10.1016/j.cnsns.2019.105161;%20https://dx.doi.org/10.1016/j.cnsns.2019.105161.

Yu, Yin and Hui-Shen Shen. "A comparison of nonlinear vibration and bending of hybrid CNTRC/metal laminated plates with positive and negative Poisson's ratios". *International Journal of Mechanical Sciences* 183 (2020): 105790–105790. 10.1016/j.ijmecsci.2020.105790;%20https://dx.doi.org/10.1016/j.ijmecsci.2020.105790.

Yuan, S. and Y. Jin. "Computation of elastic buckling loads of rectangular thin plates using the extended Kantorovich method". *Computers & Structures* 66.6 (1998): 861–867. 10.1016/s0045-7949(97)00111-9;%20https://dx.doi.org/10.1016/s0045-7949(97)00111-9.

ZHAO, Yi-Xi, Tao LIU, and Zhi-Min LI. "Nonlinear bending analysis of a 3D braided composite cylindrical panel subjected to transverse loads in thermal environments". *Chinese Journal of Aeronautics* 31.8 (2018): 1716–1727. 10.1016/j.cja.2018.03.022;%20https://dx.doi.org/10.1016/j.cja.2018.03.022.

Embargo period: The article has no embargo period.

To cite this Article: Kumari, Emarti, " **Nonlinear Bending Analysis of Cylindrical Panel under Thermal Load**." International Research Journal on Advanced Science Hub 03.07 July (2021): 145–150. http://dx.doi.org/10.47392/irjash.2021.191